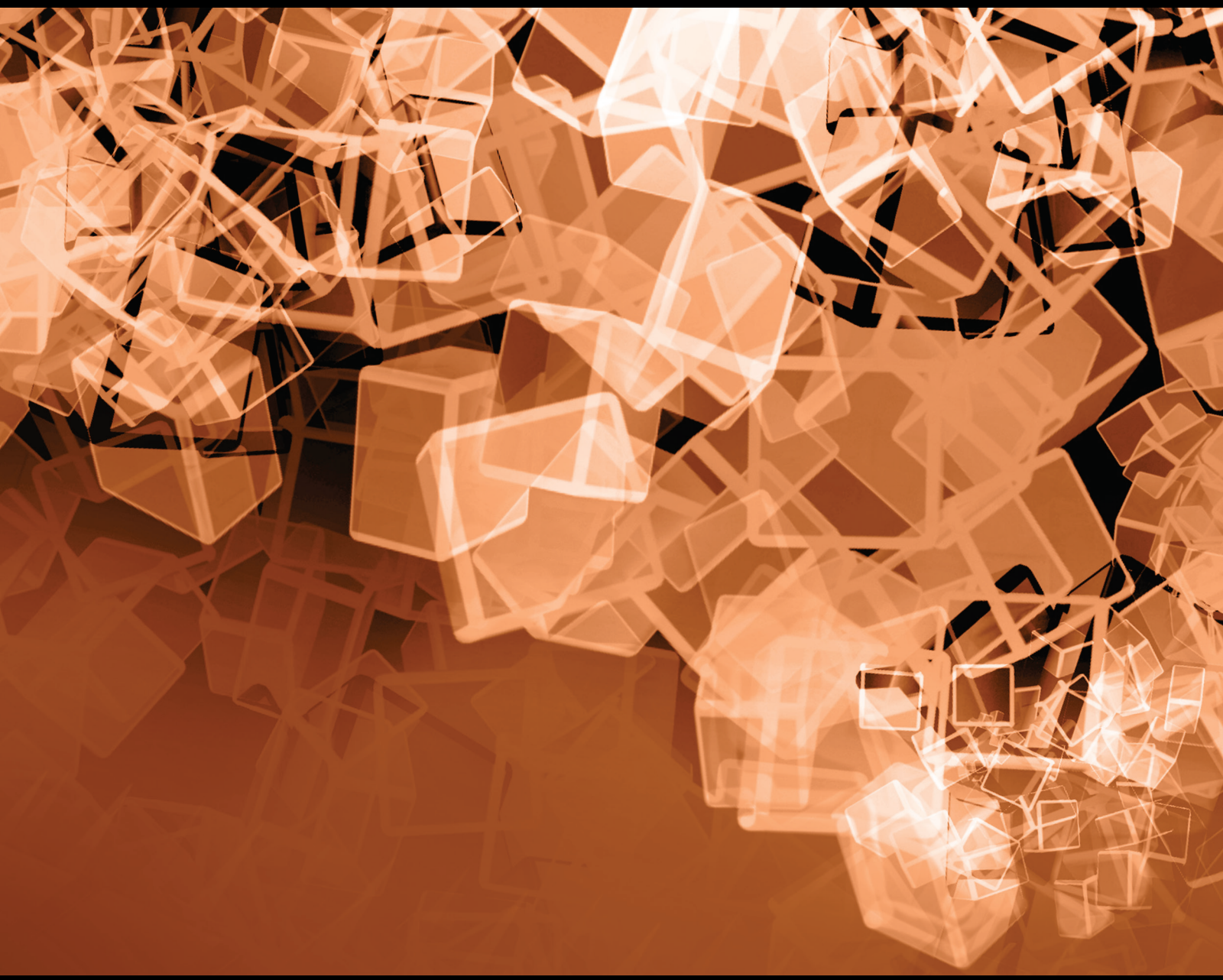
Discrete Dynamics in Nature and Society

Model Optimization System Analysis of Business Operation Performance

Lead Guest Editor: Wen-Tsao Pan
Guest Editors: Chi Keung Lau, Giray Gozgor, and Liang Gao



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Retraction

Retracted: Population Economic Transfer Function Model Based on Genetic Tabu Search Algorithm

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope

(2) Discrepancies in the description of the research reported

(3) Discrepancies between the availability of data and the research described

(4) Inappropriate citations

(5) Incoherent, meaningless and/or irrelevant content included in the article

(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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Research Article

Node Location Method of Ecological Environment Monitoring Network Based on Zigbee

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In view of the poor initialization performance of ecological environment monitoring network node location, a method of ecological environment monitoring network node location based on Zigbee is proposed. The node data collection model of ecological environment monitoring network is built based on Zigbee, and the performance is stable, which is more suitable for the node location of the ecological environment monitoring network; it is hoped that this study can provide reliable value reference and help for the future ecological studies. Through the installation of different types of sensors, the data of the ecological environment monitoring network nodes are automatically collected and sent to the server. The static weight coefficient of the collected data of the ecological environment monitoring network nodes is modified. According to the modified results, the ecological environment monitoring network is modified by DV-HOP positioning algorithm. The nodes of the ecological environment monitoring network are located by the three-way positioning method. The experimental results show that the initialization performance of this method is better, the accuracy is about 98%, and it is stable. It is more suitable for the node location of ecological environment monitoring network, which mainly includes ZigBee wireless sensor network module, embedded ARM, and Linux.

1. Introduction

Since the 1980 s, the global greenhouse effect has been obvious, and the climate is in the trend of drought. As a result, ecological problems such as glacial retreat, snow line decline, lake area change, water system change, land desertification, and grassland degradation are becoming increasingly serious, leading to the serious weakening of the water saving and purification ability of the ecological environment itself and the ability to resist erosion [1]. At present, the ecological environment is facing problems such as the crisis of water resources change, the intensification of land desertification, water and soil loss, wetland shrinkage, frequent geological disasters, and rapid and disorderly population growth. Under the influence of global warming and human activities, the wetland presents a shrinking trend, leading to the decline of lake water level, the reduction of river water supply, grassland degradation, and even frequent local climate change, which will lead to serious soil erosion and frequent occurrence of geological disasters such as collapse, landslide, and debris flow and pose a serious threat to agricultural production, traffic construction, and people's life and property safety in these areas. Since the 1980s, the greenhouse effect has increased the side effects of human production activities (especially industrial activities) on the ecosystem. The contradiction between the rapid and disorderly growth of population and the carrying capacity of environment and resources has become increasingly obvious [2]. Monitoring the ecological environment through the ecological environment monitoring network can improve the precision and real-time degree of ecological environment monitoring, reduce the tedious degree of artificial participation, and form a multi-level, multi-parameter, real-time, and fine ecological environment monitoring process. Many

scholars have studied the network node localization methods. Wang et al. [3] proposed a real-time positioning and monitoring method of network node data under the data standard. Wang and Dai [4] proposed a node localization algorithm based on Gauss–Newton iterative estimation for wireless sensor networks. Gaussian filtering algorithm is used to optimize the received signal strength to reduce the ranging error. The result of traditional trilateral positioning is used as the initial position of the sampling point, and the Gauss–Newton iteration is repeated to estimate the optimal position. Zhang and Zhao [5] proposed an improved weighted centroid algorithm node positioning method, which uses the reciprocal of the error obtained by substituting the normal equation into the coordinates as the weight and uses the weight difference to process different positioning results with different positioning errors. The reciprocal of the smaller error corresponds to the larger weight, and the reciprocal of the larger error corresponds to the smaller weight, so as to improve the positioning accuracy. Through MATLAB simulation of the traditional centroid algorithm and the improved weighted centroid algorithm, the position coordinates of the positioning nodes are estimated. Song and Huang [6] proposed a DV-Hop location algorithm based on wolf colony optimization. Firstly, the DV-Hop distance estimation algorithm is optimized, and then for the unknown node whose hop number is 1 from the anchor node, the RSSI method is used to directly calculate the distance between it and the anchor node, so as to reduce the error of the estimated distance. Secondly, since the wolf swarm algorithm is easy to fall into local optimization, the optimized wolf swarm algorithm (IWCA) is proposed [7, 8]. When the K iterations of wolf detection do not change the position, it is allowed to walk in the direction of poor effect with a certain probability. The walking mode is chaotic mapping. Finally, the IWCA algorithm is applied to the node location calculation stage to reduce the error caused by DV-Hop range estimation algorithm when calculating the node location [9–11].

Although the above methods can achieve network node positioning, the accuracy is still low. Therefore, in order to make better use of the ecological environment monitoring network, a node location method of ecological environment monitoring network based on Zigbee is proposed.

2. Realization of Node Location in Ecological Environment Monitoring Network

2.1. Construction of Node Data Acquisition Model. Based on Zigbee, the node data collection model of ecological environment monitoring network is constructed, and the node data of ecological environment monitoring network are automatically collected by installing different types of sensors and sent to the server. The structure of Zigbee protocol is shown in Figure 1.

The node data collection model of the ecological environment monitoring network can be divided into four modules in terms of function, namely, Zigbee wireless sensor network module based on star topology, embedded module based on ARM and Linux, breakpoint continuous transmission processing module, and information management module based on web [12, 13]. Zigbee wireless sensor network module adopts a star topology structure, which can collect and summarize various data of ecological environment monitoring network to the main node in a wide range; embedded module based on ARM and Linux is deployed on the main node, which is mainly responsible for processing and packaging the collected data, which are sent to the server by 3G router after AD conversion; breakpoint continuous transmission processing module is enough to send the lagging data to the server to ensure the integrity of the collected data; the web-based information management module is deployed on the web server to realize the functions of receiving data, querying, and downloading data [14]. The framework of the node data collection model of the ecological environment monitoring network is shown in Figure 2.

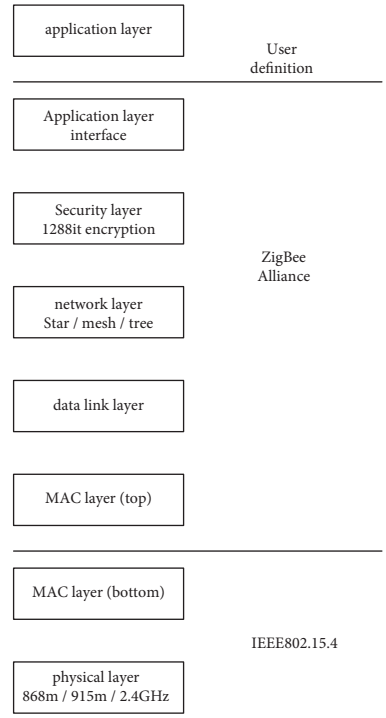

Figure 1: Structure and division of labor of Zigbee protocol.

2.1.1. Design of Zigbee Wireless Sensor Network Module. In Zigbee wireless sensor network module based on star topology, the slave node communicates with the master node directly. The slave node is mainly used in the network distribution scene with short distance and more monitoring positions [15]. The specific structure of Zigbee wireless sensor network is shown in Figure 3.

The master node plays the coordination function in Zigbee wireless sensor network. The main node is the convergence node of the network, and the physical device used is the full-function device FFD, which can communicate with other devices in the network through software design [16–18]. In Zigbee wireless sensor network, the slave node uses the simplified function device RFD, which can

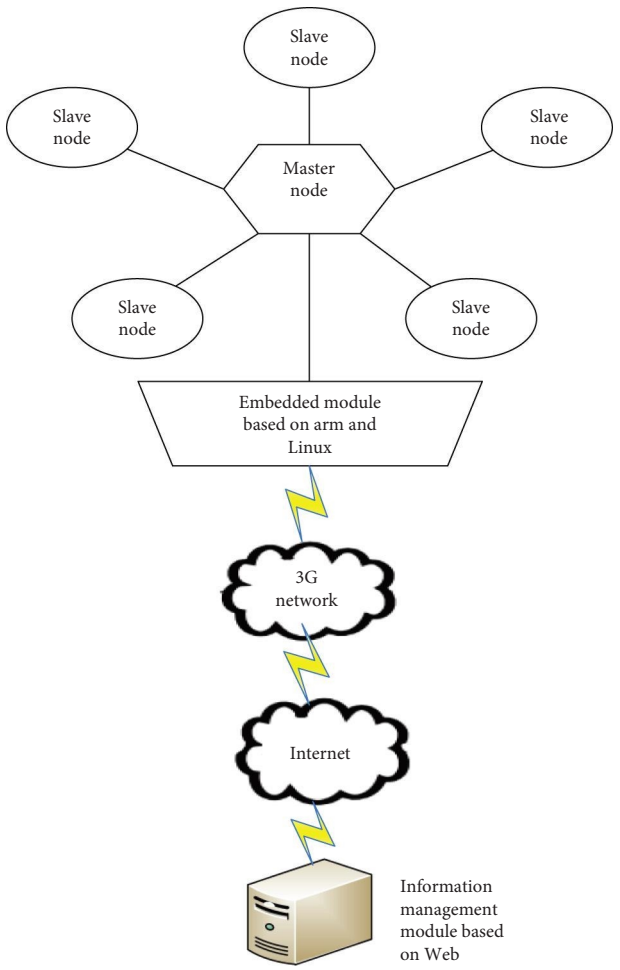

Figure 2: Framework of node data collection model of ecological environment monitoring network.

complete the communication function with the master node. JN5139 chip is used in sensor network nodes. JN5139 chip is a low-power, low-cost wireless microcontroller, which is suitable for Zigbee applications. JN5139 chip integrates 32-bit RISC reduced instruction set processor, fully compatible with 2.4 GHz IEEE802.15.4 wireless transceiver, 96 kb RAM, 192 kb ROM, and a variety of mixed analog and digital external devices. The ROM and RAM architecture of JN5139 chip supports the storage system software, including protocol stack, routing table, application code and data, and so on. On the other hand, based on the special Jennic development tools, Zigbee network platform can be built conveniently and quickly and can be easily integrated into the product, so as to help developers develop stable programs in a short time, shorten the product development cycle, and reduce the development difficulty and cost [19]. The specific block diagram of JN5139 is shown in Figure 4.

Zigbee wireless sensor network module is equipped with RS-485 interface and RS-232 interface, which can form a system with RS485, Ethernet, RS232, and GPRS according to specific application. The communication between RFD and FFD adopts the special development tool Jennic suite, and the programming language of Zigbee wireless sensor network module is C language. In Zigbee wireless sensor network, each master device can communicate with 2–4 slave devices, and each slave device can connect up to 16 sensors, which can meet the actual application requirements of data collection of ecological environment monitoring network. The slave device first collects the data of the ecological environment monitoring network and then transmits the collected data to the master device. After receiving the data from the device, the master device first summarizes the data and then sends the summarized data to the arm board [20, 21]. After receiving the data, the arm board converts the data into binary format and sends it to the web information management module on the server [22]. The transmission data flow of the main equipment is shown in Figure 5.

2.1.2. Design of Embedded Module Based on Arm and Linux. The embedded module based on arm and Linux is the lower computer of the node data collection model of the ecological environment monitoring network [23, 24]. The arm data acquisition board consists of a core board and an expansion board connected by a connector. The core board is a 6-layer board, mainly including the core circuit of arm system such as the main controller, memory SDRAM, power and clock circuit, and flash of stored program. The expansion board is equipped with a memory controller and various interfaces that can communicate with external devices. Its memory controller includes 32 MB SDRAM, 64 MB NandFlash, and 4 MB NorFlash memory modules; It has two USB2.0 interfaces, a debugging port, and two data serial ports, as well as a 10/100 M adaptive Ethernet port and multiple GPIO ports. The expansion board is also equipped with RTC clock, power supply, and other auxiliary circuits. Among them, the 10/100 M self-adaptive Ethernet port is used for network transmission of data, the USB interface is used for local data storage and connecting the USB interface micro-camera, the serial port is mainly used to connect the Zigbee main node, and the multi-channel GPIO interface is mainly used to output control instructions and control the auxiliary equipment. The control panel of the arm board is shown in Figure 6.

The Linux operating system is a cross platform system, which can adapt to a variety of CPUs and hardware platforms, support multi-user, multi-task, multi-thread, and multi-CPU, and support 32-bit and 64-bit hardware [25].

2.1.3. Design of Breakpoint Continuous Transmission Processing Module

The overall design of the breakpoint continuous transmission processing module is as follows:

(1) Start the main thread and initialize global variables.

(2) The main thread starts the data collection thread, data sending thread, receiving confirmation thread, and breakpoint renewal thread.

(3) The main thread establishes a network communication socket with the web information management module on the server.

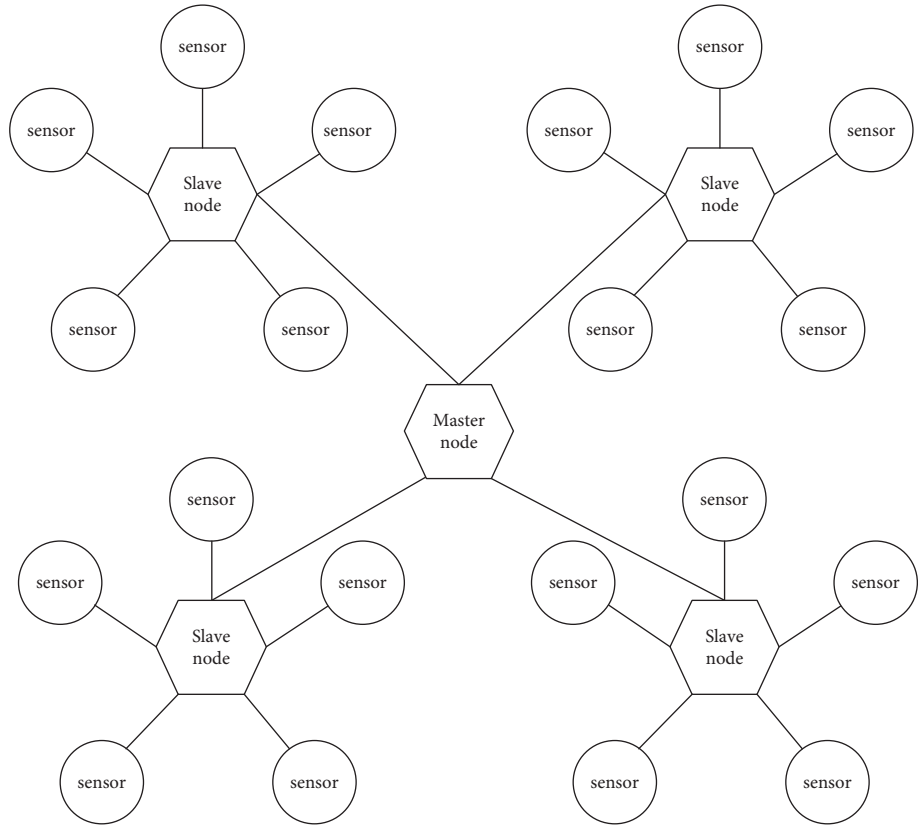

Figure 3: Specific structure of Zigbee wireless sensor network.

(4) After the network communication socket is established, the web information management module on the server will send the last received collection data timestamp through the network communication socket.

(5) The receiving confirmation thread receives the time stamp sent by the web information management module and compares the time stamp with the collected data saved in the local file. If the time stamp of some collected data is greater than the time stamp sent by the web information management module, the collected data will not be sent to the server directly, but will be sent to the server by the breakpoint update thread notified by the receiving confirmation thread.

(6) The data acquisition thread collects the value of each channel sensor of each Zigbee node and forms the data message according to the format of the collected data. The header of the message includes the time stamp of month, day, hour, and minute.

(7) The data collection thread writes the data message into the memory for the data sending thread to send and also stores the data message in the local file. When the file is full of 100 pieces of collection, close the file, create a new local file, and start to save the collection data. The file name is named by the time stamp corresponding to the first record.

(8) The data sending thread obtains the data message put in by the data collection thread from the memory and then sends it to the web information management module on the server through the socket communication connection.

(9) After the web information management module receives 100 collection data messages, it sends a receiving confirmation message through the network communication socket. After receiving the confirmation message, the receiving confirmation thread informs the data collection thread to delete the local files corresponding to the 100 collection data, so as to avoid the local storage space being filled up after too many files [26].

2.1.4. Design of Information Management Module Based on Web. The web-based information management module is deployed on the server, which mainly realizes the following functions: communicating with the lower computer based on arm and Linux, receiving the collected ecological environment monitoring network data, and storing the data in the database; interacting with the user, providing the functions of browsing, and downloading the collected data [27–29]. The information management module based on web is realized by ASP.NET and C# programming language [30, 31]. Microsoft SQL Server 2005 database is used to store information, and MVC mode is used to design the

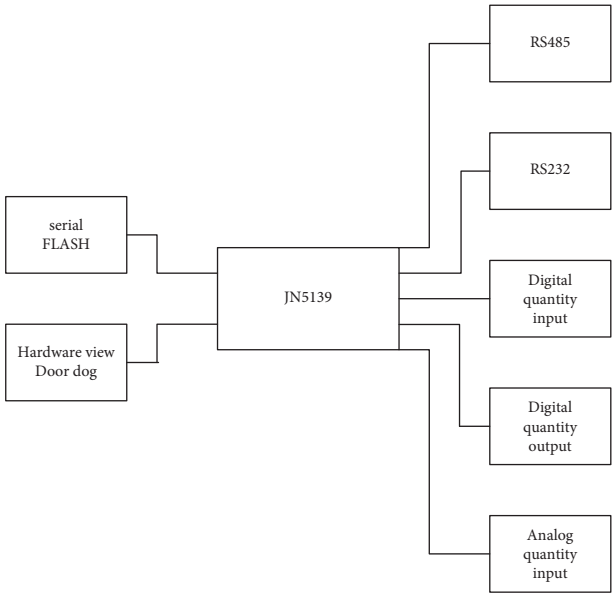

Figure 4: Specific block diagram of JN5139 chip.

architecture of the whole web module. ASP.NET includes all kinds of services necessary for generating enterprise level web applications with as little code as possible. It has the characteristics of excellent upgrade, stability, faster development, easier management, brand-new language, and network services. Microsoft SQL Server 2005 is a comprehensive database platform, which uses integrated business intelligence tools to realize enterprise level data management, provides more secure and reliable storage functions for relational data and structured data, and has functions such as analysis, report, integration, and knowledge [32–34].

The information management module based on web adopts the design pattern of MVC and clearly divides each level of web module. Specifically, the model layer is responsible for the realization of the business logic function of the module [35, 36]. The view layer includes an interface that provides user access. The control level is mainly responsible for the control of the process. MVC pattern has many advantages, such as low coupling, high reusability, applicability, low life cycle cost, rapid deployment, and maintainability [37, 38]. The MVC mode is shown in Figure 7.

The collected ecological environment monitoring network data is converted through the ad embedded module in the arm and Linux software, and sent to the web server through the 3G router. The collected data are received and saved by the information management module deployed on the web server. The information management module deployed on the web server receives and saves the collected data.

2.2. Correction of Data Static Weight Correction Coefficient

2.2.1. Correction under the Change of Location Area Size. The static weight correction coefficient is used to modify the collected ecological environment monitoring network node

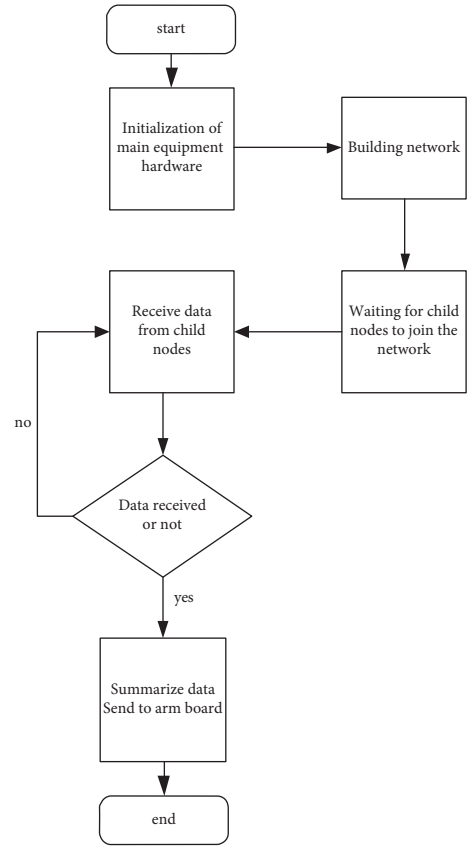

Figure 5: Transmission data flow of main equipment.

data. The optimal weight correction coefficient is generally obtained between $(0, 4)$, which has an important impact on the quality of node positioning. Under the same location conditions, when the size of the location area, the number of reference nodes, the intensity of air interference and the number of obstacles change, it is necessary to modify the static weight value correction coefficient. Firstly, the change of the size of the location area is corrected. In the MATLAB simulation environment, 10 reference nodes and 2 unknown nodes are randomly deployed in the location area [39]. For the Gaussian white noise with the mean increase of signal strength of 0 and the variance of 1, the weight correction coefficient increases in steps of 0.1 within $(0, 4)$ and gradually traverses the interval value. The size of the location area is $10\,\text{m} \times 10\,\text{m}$, $20\,\text{m} \times 20\,\text{m}$, and $30\,\text{m} \times 30\,\text{m}$, respectively, and the simulation results are shown in Figure 8.

According to the simulation results of the influence of the change of the size of the positioning area on the static weight correction coefficient, the static weight correction coefficient is corrected, and the correction results are shown in Table 1.

It can be seen from Table 1 that when the size of positioning area changes, because the number of reference nodes is determined, the larger the positioning area is, the smaller the distribution density of reference nodes is, and the less the number of reference nodes selected by unknown nodes is, the greater the positioning error is, and the larger the positioning error is, the larger the static weight

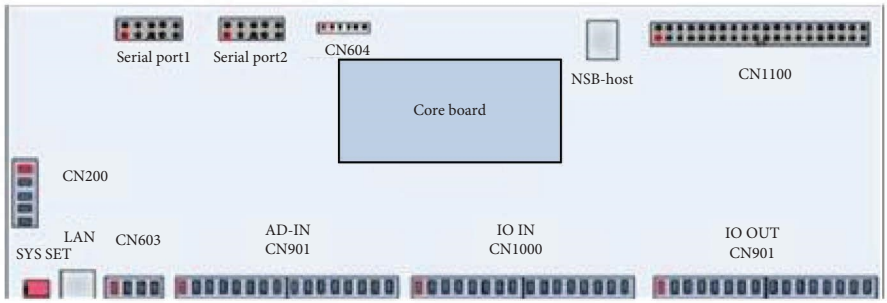

Figure 6: Control panel of arm board.

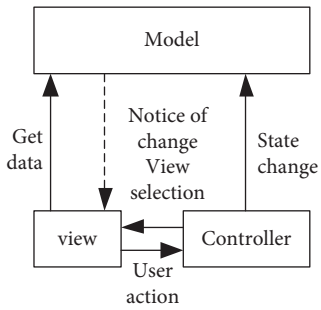

Figure 7: MVC mode.

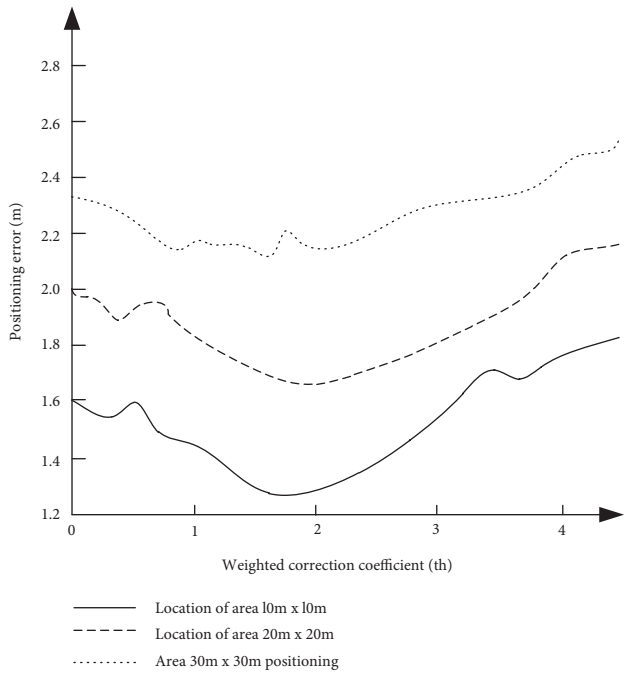

Figure 8: Impact diagram of location area size.

correction coefficient is. On the contrary, the smaller the location area, the smaller the static weight correction coefficient, and the smaller the location error.

2.2.2. Correction under the Influence of Obstacles. In the MATLAB simulation environment, 10 reference nodes and 2 unknown nodes are randomly deployed in the location area. In the location area of $10\,\text{m} \times 10\,\text{m}$, for the Gaussian white noise with the mean value of signal strength increase of 0 and variance of 1, the weight correction coefficient increases in steps of 0.1 within $(0, 4)$, and gradually values are traversed [40]. At the same time, the number of people in the location area increases from 1, 2, and 3, and the obstacles are randomly determined; the simulation results are shown in Figure 9.

As shown in Table 2, when the number of obstacles changes, the wireless signal will reflect when encountering obstacles, which will result in the error of the signal strength received by the receiving node, thus affecting the positioning results. The more the number of obstacles, the larger the static weight correction coefficient, which shows that under the influence of the number of obstacles, the correction direction of the static weight correction coefficient is that the smaller the static weight correction coefficient is, the smaller the positioning error is.

2.2.3. Correction under the Influence of Air Interference Intensity. In the MATLAB simulation environment, 10 reference nodes and 2 unknown nodes are randomly deployed in the location area, and the size of the location area is within the range of $l0\,\text{m} \times l0\,\text{m}$. For the Gaussian white noise with the mean value of signal strength increase of 0 and the variance increasing from 1, 2, 3, 4, and 5, respectively, the weight correction coefficient is 0.1 in step within $(0, 4)$, and it is gradually traversed from the value within the interval. The simulation results are shown in Figure 10.

The simulation results of the influence of the variance of Gaussian distribution on the static weight correction coefficient are sorted out, as shown in Table 3.

It can be seen from Table 3 that when the variance of Gaussian white noise changes, as the interference intensity received by the sensor node increases, the interference generated by the signal intensity value received by the receiving node also increases, and the positioning accuracy of the unknown node will produce errors. When the variance of Gaussian white noise is larger, the static weight correction coefficient is larger, which shows that under the influence of air interference intensity, the correction direction of static

Table 1: Static weight correction coefficient correction results of positioning area size.

Location area (m^2)	Error range	Optimal weight correction coefficient
10×10	1.31–1.71	1.9
20×20	1.67–2.12	2.0
30×30	2.05–2.59	2.1

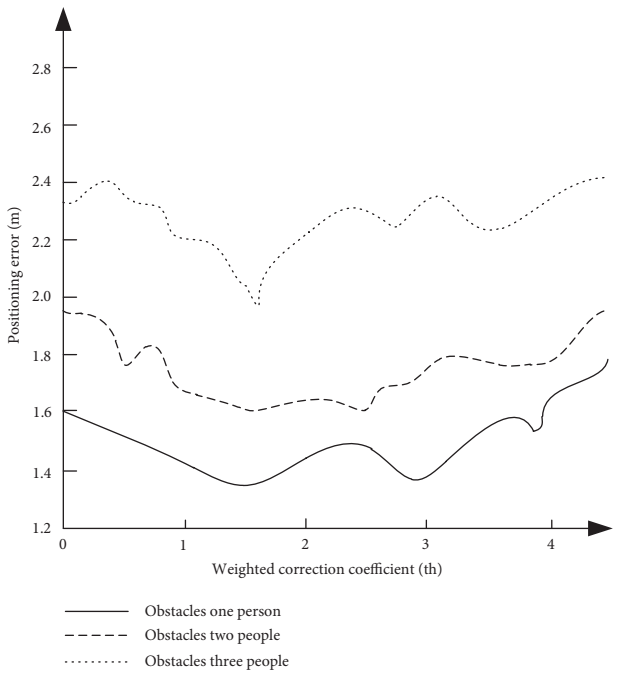

Figure 9: Obstacle impact diagram.

weight correction coefficient is that the smaller the static weight correction coefficient is, the smaller the positioning error is.

2.2.4. Correction under the Influence of the Number of Reference Nodes. In the MATLAB simulation environment, the size of the positioning area is within the range of $10\,\text{m} \times 10\,\text{m}$. For the Gaussian white noise with the mean value of signal strength increase of 0 and the variance of 1, the number of reference nodes increases gradually from 10, 15, 20, 25, and 30, and the weight correction coefficient traverses in steps of 0.1 within $(0, 4)$. The simulation results are shown in Figure 11.

The simulation results of the influence of the number of different reference nodes on the static weight correction coefficient are sorted out, as shown in Table 4.

It can be seen from Table 4 that when the number of reference nodes changes, the number of reference nodes increases due to the constant location area, that is, the density of reference nodes in unit area increases, and the number of unknown reference nodes increases, so the more accurate the signal strength value received by the unknown nodes, the more accurate the positioning accuracy. When the signal strength value received by the unknown node is more accurate, the static weight correction coefficient is smaller, which shows that under the influence of the number of reference nodes, the correction direction of the static weight correction coefficient is that the smaller the static weight correction coefficient is, the smaller the positioning error is.

2.3. Realizing Node Positioning

2.3.1. Node Linear Distance Ranging. According to the results of the static weight correction coefficient, the distance between the nodes of the ecological environment monitoring network is measured by DV-HOP algorithm, which includes two stages [41–43].

In the first stage, using the wireless sensor network architecture, through the typical distance vector exchange protocol, each reference node in the ecological environment monitoring network broadcasts its own location information group to the neighbor node, so that other reference nodes in the ecological environment monitoring network can obtain the minimum hop information of the reference node [44–47]. The architecture of wireless sensor network is shown in Figure 12.

$L1$, $L2$, and $L3$ represent three reference nodes with known positions, the rest are unknown nodes, and unknown node A is located by three reference nodes.

In the second stage, each reference node uses the location information of other reference nodes and the minimum number of route hops to calculate the average distance of each hop. For unknown node a, its distance to reference nodes $L1$, $L2$, and $L3$ is obtained by multiplying the average minimum number of hops by the average distance of each hop. The specific formula is as follows:

$$\begin{cases} \widehat{d}_1 = 3 \times HS_1^D, \\ \widehat{d}_2 = 2 \times HS_2^D, \\ \widehat{d}_3 = 3 \times HS_3^D, \end{cases} \tag{1}$$

where $\widehat{d}_1$ represents the distance from unknown node A to reference node Ll; $\widehat{d}_2$ represents the distance from unknown node A to reference node $L2$; $\widehat{d}_3$ represents the distance from unknown node A to reference node $L3$; HS_1^D represents the average per hop distance calculated based on reference node Ll; HS_2^D represents the average per hop distance calculated based on reference node $L2$; and HS_3^D represents the flat distance calculated based on reference node $L3$. Every jump distance represents the average per hop distance calculated based on reference node L3.

After calculating the average per hop distance of communication between the reference nodes in this range, it is broadcast to the unknown nodes in the network. The unknown node is used to locate itself after receiving these data [48, 49]. The unknown node will receive the average per hop distance from all the reference nodes. The average per hop distance from each reference node can reflect the node density of the reference node. Because the average hop distance calculated by each reference node is different, the DV-HOP algorithm is improved by using weighted average to reduce the overall error range [50–52]. Through the

Table 2: Correction results of static weight correction coefficient under the change of the number of obstacles.

Number of obstacles	Error range	Optimal weight correction coefficient
1	1.42–1.75	1.9
2	1.71–2.92	2.0
3	2.01–2.39	2.1

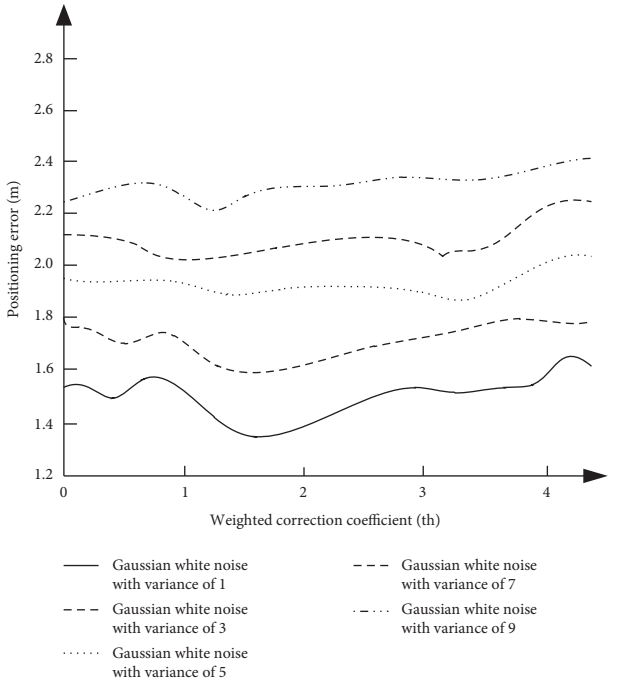

Figure 10: Interference intensity influence diagram.

weighted process, the average hop distance of unknown nodes can be reflected from the average hop distance of multiple beacon nodes. The weighted average hop distance is closer to the actual average hop distance of the network [53–57].

2.3.2. Node Location of Ecological Environment Monitoring Network. Based on the obtained results, the nodes of the ecological environment monitoring network are located by the trilateral positioning method. The principle of trilateral positioning method is shown in Figure 13.

Equation (2) can be listed according to the distance formula between two points:

$$\begin{cases} (x_a - x)^2 + (y_a - y)^2 = d_a^2, \\ (x_b - x)^2 + (y_b - y)^2 = d_b^2, \\ (x_c - x)^2 + (y_c - y)^2 = d_c^2. \end{cases} \quad (2)$$

Among them, x_a and y_a represent the left and right coordinates of reference node A; x_b and y_b represent the left and right coordinates of reference node B; x_c and y_c represent the left and right coordinates of reference node C; x and y represent the left and right coordinates of unknown node D; and d_a, d_b, and d_c are the distances from D to three reference nodes A, B, and C obtained by the same ranging algorithm.

By solving the equation, the coordinates of the unknown nodes can be obtained, and the nodes of the ecological environment monitoring network can be located.

Table 3: Correction results of static weight correction coefficient under the influence of air interference intensity.

Variance (σ^2)	Error range	Optimal weight correction coefficient
1	1.36–1.74	1.9
3	1.59–1.92	2.0
5	1.83–2.12	2.1
7	2.10–2.28	2.2
9	2.21–2.49	2.3

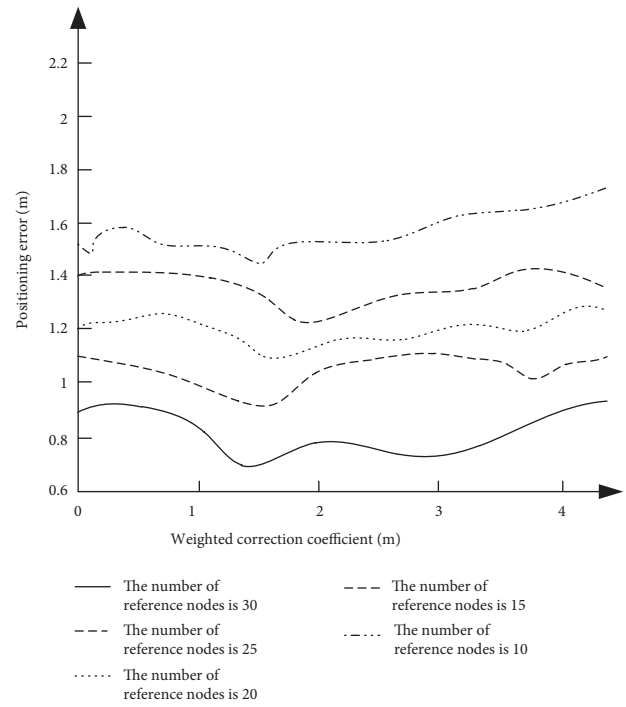

Figure 11: Reference node number influence chart.

3. Experimental Studies

3.1. Experimental Preparation. Firstly, the experimental test platform is built to realize the construction of Zigbee network and its connection with Wi-Fi network and then realize two-way communication, as shown in Figure 14.

The specific control protocol of the experimental test platform is shown in Table 5.

The experimental node distribution is shown in Figure 15.

3.2. Experiment and Result Analysis. In order to ensure the reliability of the experimental results, the real-time location and monitoring method of network node data under the metadata standard in literature [3] is taken as the traditional

Table 4: Correction results of static weight correction coefficient under the influence of number of reference nodes.

Number of reference nodes	Error range	Optimal weight correction coefficient
10	1.36–1.69	2.1
15	1.23–1.50	2.1
20	1.08–1.23	2.0
25	0.91–1.15	2.0
30	0.77–0.96	1.9

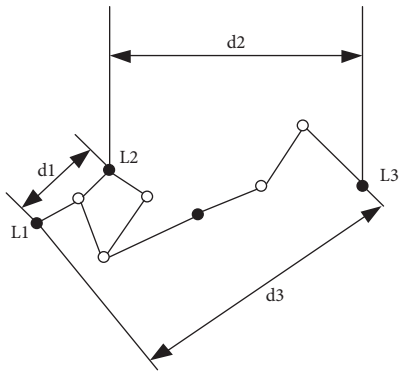

Figure 12: Wireless sensor network architecture.

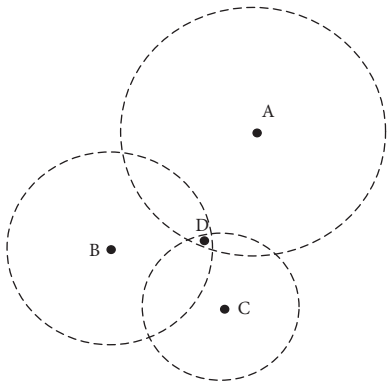

Figure 13: Principle of trilateral positioning method.

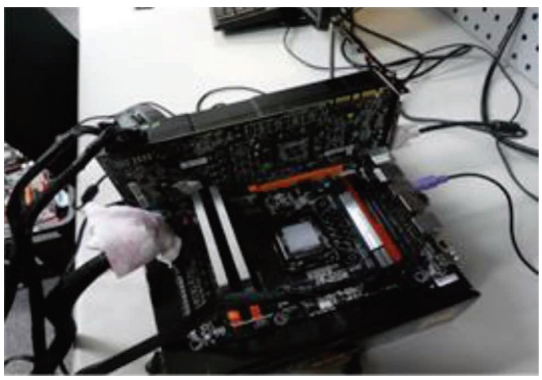

Figure 14: Experimental test platform.

method, and the wireless network node location algorithm based on Gauss–Newton iterative estimation in literature [4] is taken as the comparison method. The comparison is made with the Zigbee-based ecological environment monitoring node location method designed in this paper. First, the node

Table 5: Specific control protocol of experimental test platform.

Hexadecimal	Decimal system	Control object	State
01H	01	LED1	On/off
02H	02	LED2	On/off
03H	03	LED3	On/off
04H	04	LED4	On/off
05H	05	LED5	On/off
06H	06	LED6	On/off
07H	07	LED7	On/off
08H	08	LED8	On/off
09H	09	LED1/3/5/7	Full open
OAH	10	LED1/3/5/7	Full open
OBH	11	LED2/4/6/8	Full open
OCH	12	LED1/3/5/7	All pass
ODH	13	All LED	Full open
OEH	14	All LED	All pass
OFH	15	On/off	Open/close

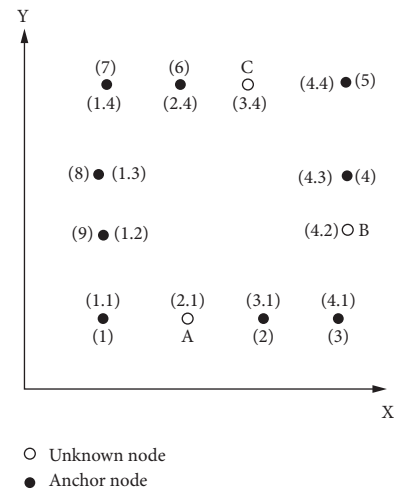

Figure 15: Node distribution of experiment.

initialization performance is compared. The judgment of node initialization performance is based on the density of the node initialization distribution map. The denser the node initialization distribution is, the more the nodes are proved and the better the initialization performance is.

The experimental results of node initialization performance of traditional ecological environment monitoring network node positioning method are shown in Figure 16.

The experimental results of node initialization performance of the comparison method are shown in Figure 17.

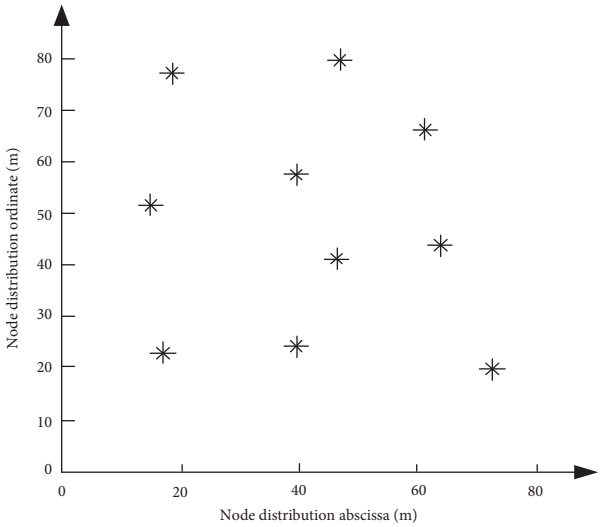

Figure 16: Experimental results of node initialization performance of traditional methods.

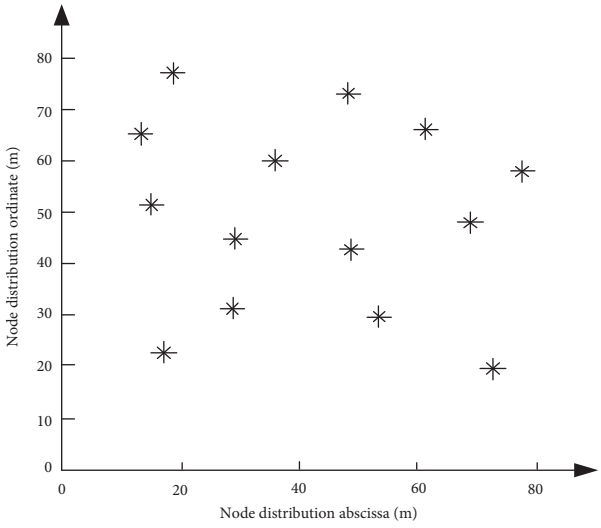

Figure 17: Experimental results of node initialization performance of the comparison method.

The experimental results of node initialization performance of Zigbee-based ecological environment monitoring network node positioning method are shown in Figure 18.

According to the experimental results of the node initialization performance in Figures 16–18, the density of the node initialization distribution map of the traditional method and the comparison method is relatively scattered, while the density of the node initialization distribution map of the Zigbee-based ecological environment monitoring network node positioning method is very dense, which indicates that the node initialization performance of the proposed method is better than the first two methods.

In order to further verify the accuracy of the proposed method, the positioning accuracy performance of the proposed method is compared with that of the traditional

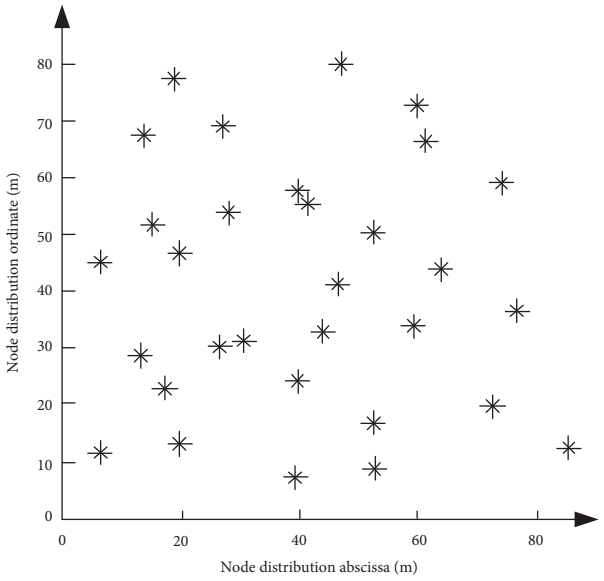

Figure 18: Experimental results of node initialization performance of this method.

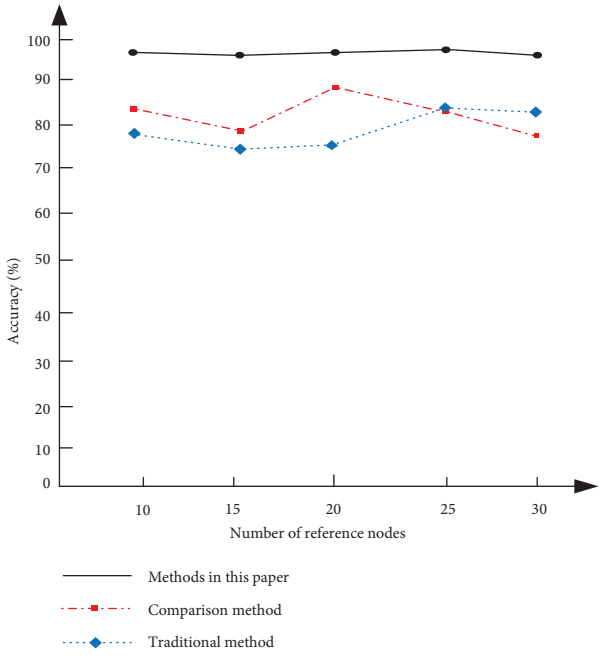

Figure 19: Positioning accuracy comparison results.

method and the comparison method. The results are shown in Figure 19.

According to the experimental results of node positioning accuracy in Figure 19, it can be seen that the measurement results of node positioning accuracy of the traditional method and the comparative method are unstable, high, and low, and the accuracy results are between 75% and 89%. The accuracy of the proposed method is about 98%, and the measurement results are stable, which indicates that the proposed method has high node positioning accuracy and stable results.

4. Conclusions

Due to the poor initialization performance of the ecological environment monitoring network node positioning method, a Zigbee-based ecological environment monitoring network node positioning method is proposed to improve the accuracy of node positioning. Based on Zigbee, the node data collection model of the ecological environment monitoring network is constructed, and the nodes of the ecological environment monitoring network are located by the trilateral positioning method. The results show that the initialization performance of this method is better, the accuracy is about 98%, and it is stable. It is more suitable for the node location of ecological environment monitoring network. The improvement of node initialization performance is of great significance to the development of ecological environment monitoring network. It can improve the precision and real-time degree of ecological environment monitoring, reduce the tedious degree of human participation, and form a multi-level, multi-parameter, real-time, and fine ecological environment monitoring process.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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Research Article

Application of Big Data Analysis in Cost Control of Marine Fishery Breeding

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In order to improve the stability of the cost control of marine fishery culture, a method of controlling the cost of marine fishery culture based on big data analysis algorithm was proposed. We establish the cost analysis model of marine fishery, use the big data correlation analysis method to conduct distributed mining on the cost characteristics of marine fishery, deeply grasp the relevance of data characteristics, use the information fusion method to build the constraint parameter analysis model of aquaculture cost operation, limit the amount of calculation, and use the adaptive neural network weighted training method to adaptively optimize the cost control to avoid falling into local optimization. The objective model of aquaculture cost control is established, and the cost constraint is carried out by the parameter optimization method. The statistical feature quantity of marine fishery cost control is obtained, and the cost control of marine fishery is realized by the feature recombination method. The simulation results show that this method is more stable in the cost control of marine fishery culture and improves the adaptability of the cost control of marine fishery culture.

1. Introduction

With the continuous improvement of marine fishery culture management, it is necessary to construct a dynamic cost analysis model of marine fishery culture, analyze the dynamic cost distribution characteristics of marine fishery culture, adopt fuzzy information fusion method, carry out dynamic cost analysis of marine fishery culture, improve the dynamic cost operation and control management ability of marine fishery culture, and study the dynamic cost control method of marine fishery culture [1, 2]. It has great significance in optimizing the dynamic cost prediction and control of marine fishery culture. In the traditional method, the dynamic cost control of marine fishery culture is based on the cost parameter analysis [3–6], combined with the quantitative equilibrium analysis method, the dynamic cost control of marine fishery culture is carried out, and the cost analysis model of marine fishery culture based on adaptive game equilibrium model is proposed in reference [7, 8]. The cost control method of marine fishery culture based on the principal component analysis method is proposed by Oken and Essington [9, 10]. However, in the cost analysis, there are some problems, such as over dispersion and easy to fall into local optimization, which lead to low reliability of the results.

Big data analysis can quickly collect information data related to marine fishery aquaculture costs, analyze the correlation between data, classify and mine data, obtain data characteristics, and obtain more accurate centralized processing results. In view of the abovementioned problems, this paper proposes a cost control method for marine fishery culture based on big data analysis. The analysis model of marine fishery culture cost is established, the big data correlation analysis method is used to carry out the characteristic distributed mining of marine fishery culture cost, the fuzzy constraint parameter identification model of marine fishery culture cost control is established, and the characteristic distributed reorganization method is adopted to realize the marine fishery culture cost control [11–14]. Finally, the simulation analysis shows the superior performance of this method in improving the cost control ability of marine fishery culture.

2. Materials and Methods

We use the HBase method to store big data of aquaculture, and according to this data to study the parameters and objectives of cost control of the marine fishery. In aquaculture data, the daily increment of single remote sensing monitoring data is increased by geometric order of magnitude [15–17]. In order to reduce the processing pressure and improve the efficiency of big data storage, the system chooses HDFS distributed storage. In order to read the database in real-time, the column-oriented distributed database HBase is used.

The HBase datastore is in region, and there are multiple stores inside the region, and the store has the corresponding column clusters [18]. The specific data are stored in each file as <key, value>, and the file is encapsulated by the store file. HBase composition is shown in Figure 1.

2.1. Restraining Parameters and Object Model of Marine Fishery Culture Cost Control

2.1.1. Control Parameters of Marine Fishery Aquaculture Cost. In order to realize the cost control of marine fishery culture based on big data analysis, the constraint parameters and object model of marine fishery culture cost control are first constructed, and the marine fishery culture scenario is shown in Figure 2.

Using fuzzy information analysis method, the panel data distribution relation of marine fishery culture cost control is as follows:

$$\begin{aligned} 2\xi^T(t)W\left[x(t-d_1(t))-x(t-h_1)-\int_{t-h_1}^{t-\mathrm{d}_1(t)}\dot{x}(t)\mathrm{d}t\right]&=0,\\ 2\xi^T(t)K\left[x(t)-x(t-d_1(t))-\int_{t-\mathrm{d}_1(t)}^{t}\dot{x}(t)\mathrm{d}t\right]&=0,\\ 2\xi^T(t)M\left[x(t-d_1(t))-x(t-d(t))-\int_{t-\mathrm{d}(t)}^{t-\mathrm{d}_1(t))}\dot{x}(t)\mathrm{d}t\right]&=0,\\ 2\xi^T(t)L\left[x(t-d(t))-x(t-h)-\int_{t-h}^{t-\mathrm{d}(t)}\dot{x}(t)\mathrm{d}t\right]&=0, \end{aligned} \tag{1}$$

where in $\xi^T(t)$ means the deterministic component of marine fishery culture cost control, K means the artificial cost of marine fishery culture cost control, $d_1(t)$ means the quality distribution set of marine fishery culture cost control, and adopts dynamic optimization method to control the marine fishery culture cost [19, 20]; Combined with the discrete control variable analysis method, the characteristic equations of marine fishery culture cost control are as follows:

$$\begin{cases} b_{20}(t;\lambda)=\dfrac{1}{2}(1-\lambda t)(1-t)^3,\\ b_{21}(t;\lambda)=\dfrac{1}{2}\left[1+(\lambda+3)t-3(\lambda+1)t^2+4\lambda t^3-2\lambda t^4\right],\\ b_{22}(t;\lambda)=\dfrac{1}{2}(1-\lambda+\lambda t)t^3. \end{cases} \tag{2}$$

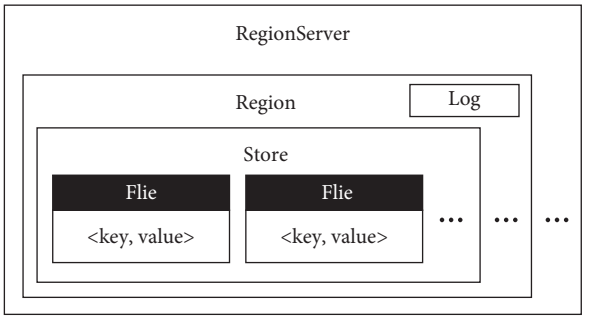

Figure 1: The composition of HBase.

Figure 2: Marine fisheries culture scenario.

In minimizing the cost constraint method, establishing the marine fishery culture cost control function, combining with the descriptive statistical analysis method [21, 22], establishing the correlation characteristic distribution set of marine fishery culture cost control is as follows:

$$\begin{aligned} \text{Subject.to.}&Q_i\ge Q_{th},\\ &E_i\ge E_{th},\\ &C_i\le C_{th},\\ &Q_{jk}\ge 0, E_{jk}\ge 0, C_{jk}\ge 0,\\ &\sum_{j=1}^{Nj}x_{jk}=1,\quad \forall i, 1\le k\le M,\ 1\le j\le N_j. \end{aligned} \tag{3}$$

This paper constructs a fuzzy evaluation decision model for marine fishery aquaculture cost control and dynamic optimization to improve the stability of marine fishery aquaculture cost control [23].

2.1.2. Object Model of Marine Fisheries Cost Control. Combined with the game equilibrium method, the net cash flow distribution of marine fishery culture cost control is expressed as

$$f(k)=\begin{cases} f(k-1)-\dfrac{1}{n}, & 1\le k<n,\\ 1, & k=n. \end{cases} \tag{4}$$

Based on the lever benchmark virtual variable analysis method, the cost control of marine fishery culture is carried out, and the statistical cost function of marine fishery culture cost control is obtained by using the sensitivity constraint method as follows:

$$i = \max_{j}\left\{\frac{P\left(Y|\lambda_j\right)}{P\left(Y|\lambda_j\right) > P\left(Y|\lambda_T\right)}\right\} \quad (j = 1, 2, 3, \ldots, C). \tag{5}$$

Based on the relation of fixed assets ratio and cash ratio of marine fishery culture cost, the cost function of marine fishery culture cost control is obtained by using the spatial statistical analysis method:

$$\mathrm{EST}_1\left(v_i, p_q\right) = \max_{v_j \in \mathrm{prnt}\left(v_i\right)}\left\{\begin{array}{c} p_\mathrm{available}\,(q), \\ \mathrm{EFT}\left(v_j, p_m\right) + k \cdot C\left(v_j, v_i\right) \end{array}\right\}. \tag{6}$$

According to the abovementioned cost function, the adaptive equilibrium game is used to quantitatively analyze the cost control of marine fishery culture [24], and the constraint function of marine fishery culture is as follows:

$$''Z_1 = B\sum_{w\in W} q^w - \sum_{a\in A} x_a\left[t_a\left(x_a\right) + \beta v_a\right], \quad \forall v_{\min} \le v_a \le v_{\max}. \tag{7}$$

The nonlinear index sequence $y'(n)$ is used to represent the fuzzy evaluation characteristic of marine fishery culture, and the mathematical modeling of marine fishery culture control is as follows:

$$\int_{t-\sigma}^{t}\begin{bmatrix} y(s) \\ f(y(s)) \end{bmatrix}^T\begin{bmatrix} R_1 & E \\ E^T & R_2 \end{bmatrix}\begin{bmatrix} y(s) \\ f(y(s)) \end{bmatrix}\mathrm{d}s. \tag{8}$$

Using the adaptive neural network weighted training method, the fuzziness function of marine fishery culture control is established:

$$\int_{t-\sigma}^{t}\left[y^T(s)R_1 y(s) + f^T(y(s))R_2 f(y(s))\right]\mathrm{d}s. \tag{9}$$

Using the principal component analysis method, the optimization model of marine fishery breeding is expressed as follows:

$$x_i(k+1) = x_i(k) + s\left(\frac{x_j(k) - x_i(k)}{\left\|x_j(k) - x_i(k)\right\|}\right), \tag{10}$$

where $\|\vec{x}\|$ denotes the norm of $\vec{x}$. In summary, the model of marine fishery culture control object is established, combined with the parameter optimization method to carry out marine fishery culture restraint and cost control [25].

2.2. Optimization of Marine Fisheries Cost Control. After investigating and understanding the actual situation of each marine fishery aquaculture by using big data technology, it is found that the main causes of the disease are as follows:

2.2.1. Cost Management Thinking Is Limited. At present, the cost management concept of most breeding bases is deficient, which is mainly manifested in the absence of a strategic cost management idea and the lack of an overall concept of cost management. The cost management mode that the enterprise implements at present are simpler, mainly saving costs [26]. The current cost concept of enterprises believes that cost management is cost saving and reduction, mainly relying on cost saving and cost reduction. For example, strict control of staff reimbursement, procurement of raw materials, and other controls are also very strict and strive to minimize expenditure and control business-related costs [27]. But this kind of single link saving has not brought the enterprise overall cost reduction. The current concept of cost control is more limited, only unilateral cost reduction, and not with the development of the enterprise strategy. At the same time, the key point of cost control is to reduce the cost of direct cultivation and to reduce the expenditure on feed and medicine as far as possible [28].

2.2.2. Unreasonable Control of Cost Occurrence. The unreasonable cost is mainly embodied in three aspects, first is the increase in seedling, feed, and medicine costs, second is the waste of feed and medicine, and third is the excessive amount of fishery insurance. The high cost of seedlings, feed, and medicine is caused by the improper control of the enterprise. In the selection of seedlings and medicines, enterprises do not pay attention to establishing strategic alliances with suppliers of seedlings and medicines, which causes changes in the quality and price of raw materials. In the selection of feed, there is no attention to the nearby call feed, which will cause an increase in the amount of freight [29, 30]. Secondly, the feeding process did not pay attention to the feed ratio, which also increased the cost. Due to the lack of a systematic cost control system, the calculation of the insured amount of fishery lacks data basis, which may lead to inaccurate calculation and loss of enterprises.

2.2.3. An Unsystematic Cost Control System. Enterprises lack of systematic cost control system. The cost control of enterprises' aquaculture is mainly embodied in the following two aspects: Firstly, the management system is not sound; with the continuous increase of the scale of marine fishery enterprises and the gradual increase of business volume, the problem of lack of a systematic cost control system is more prominent. The current cost control is mainly carried out separately, and a set of cost control systems for fishery aquaculture that meet the actual conditions of enterprises has not been formed. Second, the management mode is backward, marine fishery enterprises still use the traditional cost control mode, the traditional cost management mode has many shortcomings, and cannot adapt to the development of modern enterprise cost management.

2.2.4. Imperfect Management and Restraint Mechanism. The restraint mechanism of marine fishery aquaculture for salesmen and breeding households is imperfect, and there is information asymmetry between the company and breeding households. On the one hand, because the wages of salesmen are included in labor costs, and because wages are calculated

on the basis of stocking volume, there is a possibility that salesmen make false reports about taking medicines and materials. At the same time, they will deceive the company with the farmers on the survival rate of breeding, and the company will not know. On the other hand, the oil subsidies of the staff are reimbursed by the company according to the number of kilometers of the staff, which is very false, these are the reasons for the increase in direct labor costs so that the company's breeding costs exist inflated and wasted. In terms of the payment and management of customer subsidies, special subsidies are granted to farmers according to the memorandum brought back by the salesman. Although the general manager has signed the special subsidies, the authenticity of the contents remains to be examined. The MOU is the basis for the salesman to record all the circumstances of the aquaculture farmers that need subsidies in the process of aquaculture and the company to make subsidies. However, when the salesman fills out a memorandum, the bonus the salesman will be deducted accordingly, and the company can only make subsidies to the aquaculture farmers by relying on the memorandum.

2.2.5. Inadequate Level of Human Resources Management. The company's management has always focused on the company's profits, because more branches, complex business, management, and personnel are imperfect. Because the seedlings are raised by the farmers, so the company will give all the work to the salesman to deal with, too dependent on the salesman, leading to a lot of serious information asymmetry between the company and the farmers. At the same time, due to the dispersed management of farmers, the company has difficulties in management, and the company does not have a complete set of human resources management programs, or a sound cost management team, but the company's manager and the financial department are responsible. Finally, causes the company costs to increase year by year, and the company profit suffers the loss.

Therefore, based on the abovementioned analysis, the optimal design of the cost control of aquaculture is carried out.

2.2.6. Cost Control of Marine Fisheries. Taking the abovementioned shortcomings of cost control as a reference, different cost control indicators are selected from four aspects to form the independent variables of cost control, which are uniformly expressed by $sp_{i,j}(t)$. To construct the relevant statistical analysis model of marine fishery culture cost [31], the characteristic quantity of marine fishery culture cost association rule is expressed as follows:

$$S_{i,j}(t) = \frac{p_{i,j}(t) - sp_{i,j}(t)}{p_{i,j}(t)}. \tag{11}$$

The $T_{i,j}(t)$ represents the operating characteristic set of the cost of marine fisheries culture:

$$T_{i,j}(t) = \frac{\left|p_{i,j}(t) - \Delta p(t)\right|}{p_{i,j}(t)}. \tag{12}$$

Using the multivariate regression analysis method, the dynamic mining of marine fishery culture cost is carried out, and the quantitative characteristic distribution function of marine fishery culture cost is obtained as follows:

$$U_{i,j}(t) = \exp\left[-b\left[z_i(t) - z_j(t)\right]^2\right], \tag{13}$$

wherein $p_{i,j}(t)$ is the cross-correlation characteristic of marine fishery culture cost prediction; $sp_{i,j}(t)$ is the independent variable of marine fishery culture cost control; $\Delta p(t)$ is the gain coefficient; And $z_i(t)$, $z_j(t)$ are expressed as the fuzziness function of marine fishery culture cost [32].

2.2.7. Fuzzy Clustering Function of Marine Fishery Cost Control. Using the big data information fusion method to carry on the marine fishery culture cost operation management and the statistical forecast, obtains the operation dynamic cost control training function $s_i = \{x_j\colon d(x_j, y_i) \le d(x_j, y_l)\}$, under the fuzzy information guidance, obtains the marine fishery culture cost control fuzzy degree characteristic quantity:

$$\begin{aligned} \mathrm{Min}WH &= \min\{w(cc), h(cc)\}, \\ \mathrm{Area_Ratio} &= \frac{\mathrm{Area}(cc)}{\mathrm{Area}(\mathrm{pic})}. \end{aligned} \tag{14}$$

Using RBF neural network learning, the weighted vector of marine fishery culture cost control is obtained:

$$U = \{\mu_{ik} | i = 1, 2, \ldots, c, k = 1, 2, \ldots, n\}. \tag{15}$$

Under the guidance of association rules, using global statistical information to extract the characteristics of marine fishery culture cost [33], the optimized objective function is as follows:

$$J_m(U, V) = \sum_{k=1}^{n} \sum_{i=1}^{c} \mu_{ik}^m (d_{ik})^2. \tag{16}$$

Based on the differential grouping model [34], the fuzzy clustering function is obtained as follows:

$$\begin{aligned} \mu_{ik} &= \frac{1}{\sum_{j=1}^{c} \left(d_{ik}/d_{jk}\right)^{2/m-1}}, \\ V_i &= \frac{\sum_{k=1}^{m} (\mu_{ik})^m x_k}{\sum_{k=1}^{n} (\mu_{ik})^m}. \end{aligned} \tag{17}$$

In the formula, m is the embedded dimension of the dynamic control of marine fishery culture cost and $(d_{ik})^2$ is the measured distance between the sample x_k and the characteristic distribution set V_i. According to the abovementioned analysis, the cost control model of marine fishery culture is established to improve the cost control ability of marine fishery culture [35].

3. Results

3.1. Experimental Environment and Conditions. In order to verify the application performance of this method in the cost prediction and control of marine fishery aquaculture, the

simulation experimental analysis is carried out. The experiment was carried out in a recycling aquaculture enterprise located in Binhai New Area, Tianjin. Circulating water aquaculture workshop construction area 45000 m^2, net aquaculture water 25000 m^2. The wastewater discharged from the aquaculture pool is returned to the aquaculture pool for reuse after physical filtration, biological filtration, degassing, pure oxygen addition, and ultraviolet disinfection. The system changes about 20% of the new water every day. In the heating season of each year, that is, from October of the current year to April of the next year, using geothermal water and aquaculture wastewater source heat pump heating system, the temperature of the added water can be adjusted to 30°C–32°C to maintain the water temperature of the aquaculture system above 25°C, so that grouper can be in the best growth water temperature in the whole year. Breeding wastewater is discharged after purification. The system has successfully bred varieties such as the *Epinephelus coioides* and the *Plectropomus leopardus*, all of which have achieved balanced growth throughout the year. The experiment was carried out in a recycling aquaculture enterprise located in Binhai New Area, Tianjin. Circulating water aquaculture workshop construction area 45000 m^2, net aquaculture water 25000 m^2. The wastewater discharged from the aquaculture pool is returned to the aquaculture pool for reuse after physical filtration, biological filtration, degassing, pure oxygen addition and ultraviolet disinfection. The system changes about 20% of the new water every day. In the heating season of each year, that is, in October of the current year to April of the next year, using geothermal water and aquaculture waste water source heat pump heating system, the temperature of the added water can be adjusted to 30°C–32°C to maintain the water temperature of the aquaculture system above 25°C, so that grouper can be in the best growth water temperature in the whole year. Breeding wastewater is discharged after purification. The system has successfully bred varieties such as the *Epinephelus coioides*, the *Epinephelus fuscoguttatus,* and the *Plectropomus leopardus*, all of which have achieved balanced growth throughout the year.

Grouper culture cost mainly consists of seedling, feed, artificial, water and electricity, depreciation, management, epidemic prevention, liquid oxygen, and so on. Under the condition of full load operation, the expenses for labor, water and electricity, depreciation, management, epidemic prevention, and liquid oxygen are basically fixed expenses for the whole year, which shall be calculated according to the actual expenses. Based on the cultured data of *Epinephelus* gentianus, the cultured cost was estimated [36]. Unit grouper costs are calculated by dividing the actual costs incurred under a single heading by the total yield estimated for the cultured unit yield.

Seedling cost calculation:

$$C_{\mathrm{FRY}} = \frac{C_s}{\left(S_r/100 \times W\right)}. \tag{18}$$

In the formula, C_{FRY} is unit grouper seed cost, yuan/kg; C_s is price of single-tailed grouper, yuan; S_r is survival rate of grouper culture, %; and W is listing quality of single-tailed fish, kg.

Calculation of feed cost:

$$C_{\mathrm{feed}} = \left(1 \times F_{CR} + F_{\mathrm{dead}}\right) \times P. \tag{19}$$

In the formula, C_{feed} is feed cost per grouper, yuan/kg; C_{feed} is feed coefficient of grouper culture; F_{dead} is fodder quality of dead grouper shared by listed grouper; and P price of unit fodder, yuan/kg.

3.2. Data Analysis of Breeding Cost. The circulating water aquaculture system shall operate normally. During the coldest winter, the temperature of the system aquaculture shall be above 25°C, the daily water exchange volume shall be 20% of the aquaculture water body, the ammonia nitrogen and nitrite nitrogen in the water shall be kept below 0.2 mg/L and 0.02 mg/L, respectively, the average aquaculture cycle from dissolved oxygen 6–8 mg/L, and the culturing of pearl gentian macula to the market specification (0.8 kg) shall be one year, the culturing density of finished fish shall be 30–40 kg/m^2, and the survival rate of each batch shall be 60%–80%.

3.2.1. Seedling Cost. Based on the estimation of cultured pearl gentian stone spot varieties, the average marketed specifications are 0.8 kg (one-tail quality), the survival rate is 60%–80%, and the one-tail price of the seedling is CNY6. When the survival rate is 60%, 70% and 80%, the cost of the seedling is CNY12 5/kg, CNY10 72/kg, and CNY9 38/kg, respectively.

3.2.2. Feed Cost. The feed coefficient (FCR) is 1.1 in the process of culturing the stone spot of pearl gentian, the feed price is 12 yuan/kg, and the feed cost is calculated when the yield per unit is 30 kg/m^2, 40 kg/m^2 and the survival rate is 60%, 70%, and 80%, respectively. The cost of feed will change with the change in survival rate, mainly the feed consumed by the dead grouper should be taken into account in the feed cost of the adult fish. The death of grouper occurred mainly at the seedling stage of 10–15 cm in length. According to the empirical data, the average consumption of feed for grouper was 20 g/tail. At a yield of 30 kg/m^2 per unit area, 937500 groupers, totalling 750000 kg, need to be produced on the basis of the effective area of 25000 m^2. When the survival rate is 60%, 70%, and 80%, respectively, the tail number of the dead grouper is 625000, 401786, and 234375, respectively, and the consumed feed is 12500 kg, 8036 kg, and 4688 kg, respectively, which are apportioned to 0.0168 kg, 0.0108 kg, and 0.0062 kg for each kg of cultured fish, and the cultured 1 kg of Gentian grouper consumes 1.1168 kg, 1.1108 kg, and 1.106 kg of feed, respectively, and the corresponding feed cost is 13.40 yuan, 13.33 yuan, and 13.27 yuan, respectively. Similarly, at 40 kg/m^2, 1250000 groupers would have to be produced, totalling 1000 kg. When the survival rate is 60%, 70%, and 80%, respectively, 1.1167 kg, 1.1107 kg, and 1.1063 kg are consumed for culturing 1 kg Gentian grouper,

Table 1: Production cost (yuan/kg) and its percentage accounting for the total cost under different survival rates.

Project	60% survival rate				70% survival rate				80% survival rate			
	30 kg/m^2		40 kg/m^2		30 kg/m^2		40 kg/m^2		30 kg/m^2		40 kg/m^2	
	Prime cost	Proportion	Prime cost	Proportion	Prime cost	Proportion	Prime cost	Proportion	Prime cost	Proportion	Prime cost	Proportion
Offspring seed	12.50	22.4	12.50	25.9	10.72	19.9	10.72	23.1	9.38	17.8	9.38	20.8
Forage	13.40	24.0	13.40	27.7	13.33	24.7	13.33	28.7	13.27	25.3	13.27	29.4
Man-made	7.80	14.0	5.86	12.1	7.80	14.5	5.86	12.6	7.80	14.8	5.86	13.0
Hydroelectricity	7.80	14.0	5.86	12.1	7.80	14.5	5.86	12.6	7.80	14.8	5.86	13.0
Depreciation	7.80	14.0	5.86	12.1	7.80	14.5	5.86	12.6	7.80	14.8	5.86	13.0
Manage	1.56	2.8	1.18	2.4	1.56	2.9	1.18	2.5	1.56	3.0	1.18	2.6
Epidemic prevention	1.30	2.3	0.98	2.0	1.30	2.4	0.98	2.1	1.30	2.5	0.98	2.2
Liquid oxygen	3.64	6.5	2.74	5.7	3.64	6.7	2.74	5.9	3.64	6.9	2.74	6.1
Total	55.80	100.0	48.34	100.0	53.95	100.0	46.47	100.0	52.55	100.0	45.07	100.0

Table 2: Descriptive statistical analysis of marine fisheries culture control.

5Statistical period	Marine fisheries control rate	Cost control level	Capital holdings	Cost ratio
First quarter	0.367	0.678	0.465	0.433
Second quarter	0.655	0.665***	0.656	0.345**
Third quarter	0.467	0.535	0.654***	0.434
Fourth quarter	0.545***	0.456	0.345	0.454**
Full sample	0.567	0.656	0.456	0.432

Note. The symbols *, **, and *** represent significant levels of 1%, 5%, and 10%, respectively.

and the corresponding feed costs are 13.40 yuan, 13.33 yuan, and 13.28 yuan, respectively.

3.2.3. Apportioned Cost. The apportioned expenses for artificial, hydroelectric, and other expenses are relatively fixed each year, and the values are the same under different survival rates for the same unit output. At the yield of 30 kg/m^2, the expenses for artificial, hydroelectric, depreciation, management, epidemic prevention, and liquid oxygen of grouper kg are CNY7.8, CNY7.8, CNY1.56, CNY1.3, and CNY3.64, respectively. At the yield of 40 kg/m^2, the cost per unit was 5.86 yuan, 5.86 yuan, 5.86 yuan, 1.18 yuan, 0.98 yuan, and 2.74 yuan, respectively.

3.2.4. Total Breeding Cost and Proportion of Each Cost. The proportion of total culture cost and each unit culture cost is shown in Table 1. Breeding cost, as high as 30 kg/m^2, 55.80 yuan/kg at 60% survival rate, as low as 40 kg/m^2, and 45.07 yuan/kg at 80% survival rate. Feed, seedling, labor, water and electricity, and depreciation constitute the main cost of grouper culture, accounting for 88%–90% of the total cost. Under different yields and survival rates, each single cost accounts for 18%–26%, 24%–29%, 12%–15%, 12%–15%, 12%–15%, and 12%–15%. The survival rate of grouper larvae was 22%, 20%, and 18% of the total cost when the yield was 30 kg/m^2, and 26%, 23%, and 21% when the yield was 40 kg/m^2. The cost of depreciation, manpower and hydropower at 40 kg/m^2 is reduced by 2% and liquid oxygen by 1%, respectively, compared with that at 30 kg/m^2.

3.3. Data Statistics Results. The abovementioned cost-related data are counted, and the descriptive statistical analysis method is adopted to obtain the descriptive statistical results of marine fishery aquaculture cost control as shown in Table 2. It can be seen from Table 2 that except for the first quarter, the cost control items in other quarters show a significant correlation, which indicates that the application of this method has a significant effect on cost control. However, due to the characteristics of fishery aquaculture, the first quarter is the low input period of aquaculture cost, so the cost control effect is not obvious, which is not relevant to a certain extent, but based on the characteristics of the industry, it can be ignored.

According to the result of marine fishery culture cost control, the logarithmic relation between the cost deviation coefficient and the total assets is shown in Figure 3.

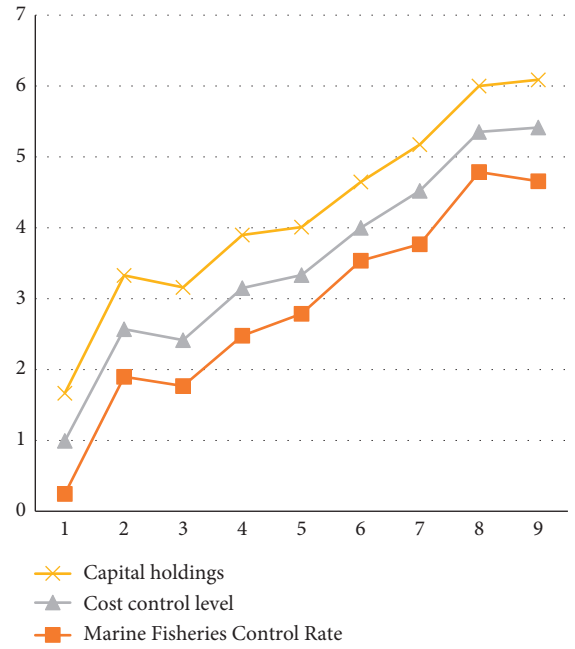

Figure 3: Relation between the cost bias coefficient and total assets.

The analysis of Figure 3 shows that the general trend of capital holding, cost control level and marine fishery control rate is basically the same, which indicates that the method in this paper can effectively calculate the cost and effectively control the costs of various items under the analysis of capital input, thus realizing the control of marine fishery breeding cost and improving the asset control level and the dynamic control index distribution of test cost is tested, and the results are shown in Figure 4.

The analysis of Figure 4 shows that under the control of this model, the indicators of cost ratio, capital holding, cost control level and marine fishery control rate in different quarters can all show relatively stable control effects, and the fluctuation trend of all indicators is consistent, which indicates that this model carries out dynamic control of marine fishery culture cost, improves the cost dynamic control ability and improves the profit level of the enterprise.

4. Discussion

Cost control, as its name implies, is to control and manage the construction cost of marine fishery aquaculture, so as to reduce the cost of marine fishery aquaculture, and finally, realize the improvement of economic profit of marine fishery aquaculture. For any enterprise, cost control is the

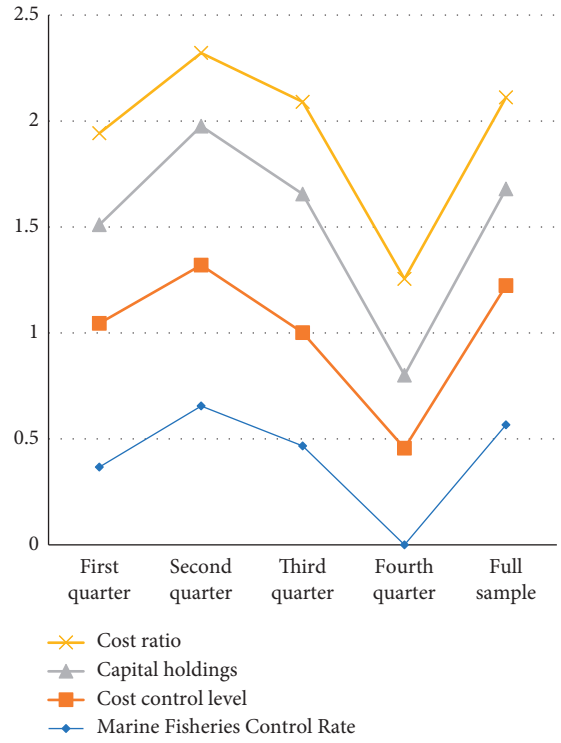

Figure 4: Cost dynamic control index distribution.

core part of its work, so it can be seen that cost control is important to every enterprise. Marine fishery aquaculture construction is a periodic work, in its work process, to involve a lot of content and process, and in each link and process, will involve the cost management problem, if there is one link of the cost management work is not done in place, will lead to the overall failure of cost management [37, 38]. In practical work, cost control can be divided into three stages, namely, early, medium, and late, while in each stage, cost control is divided into two components, one is personnel cost control, and the other is material and economic cost control, in addition to many indirect costs, we can use the sentence to summarize the cost control, which is the sum of the various kinds of expenses needed for the marine fishery aquaculture project as a whole:

(1) Culture of grouper in circulating water

The death of *Epinephelus gentianus* in aquaculture was mainly caused by putrefactive skin disease when the body length was 10–15 cm. After the occurrence of putrescence, grouper culture rarely occurred a major disease. At present, there is no effective treatment for epinephelus putrescens in grouper culture, which can only be achieved by improving the water environment and enhancing the autoimmunity of grouper fry. Controlling the occurrence of grouper putrescence is the key to improve the survival rate. The total survival rate of the grouper was 80.11%, the average feed coefficient was 1.03 and the density was 102 kg/m^3 in the circulating water test system with pH, pure oxygen, and ozone. In the large-scale circulating aquaculture system, the yield per unit area can exceed 30 kg/m^3, and the survival rate is over 90%. Systematic water circulation is one of the key factors in aquaculture. Large water circulation can remove the stool and bait in the fish pond in time and provide sufficient dissolved oxygen for aquaculture. Because of the different construction time, the design circulation quantity of the circulating water workshop in this experiment is different, and the growth rate and survival rate of one cycle per hour is obviously higher than that of one cycle per hour. The yield per unit area of different workshops is 30–40 kg/m^2, and the survival rate is 60–80%. There should be a lot of room for improvement in the survival rate, mainly from the prevention of grouper disease. One advantage of factory-farmed groupers in the North over groupers shipped to the North from the South is that, because of the short transport distance, grouper have longer shelves, better shelf-life, and longer shelf-life in fish stalls and temporary tanks in restaurants, which can be used to build market brands and achieve good quality at good prices.

(2) Breeding costs

The method of big data analysis is used to study the culture cost. The total unit production cost of Scophthalmus maximus is 44.64 yuan per kg and that of running water culture is 52.46 yuan/kg. The fixed unit production cost of the former is higher than that of the latter, and the variable unit production cost is lower than that of the latter. Under the combined effect of the two, the total unit production cost of circulating water culture is lower than that of running water culture. In this study, 30 kg/m^2 of cultured *Epinephelus gentianus* at 60% survival rate was 55.80 yuan/kg, and 40 kg/m^2 at 80% survival rate was 45.07 yuan/kg. According to the selling price of grouper in the northern market at present, it has certain market competitiveness. From the composition of culture cost, seedling, feed, artificial, water and electricity, depreciation constitute the main cost of grouper culture, accounting for 88% to 90% of the total cost. Among them, artificial, seedling, feed costs accounted for 58% to 65% of the total cost of breeding. The cost of feed, artificial and fry accounts for about 95% of the total cost of culturing large yellow croaker in cage. From this data, recycling aquaculture does have higher hydropower and depreciation costs, but its stability, resistance to typhoons and other natural disasters and environmental protection is cage culture cannot be compared. The survival rate was increased from 60% to 80%, and the cost of seedling was reduced from 12.5 yuan/kg to 9.385 yuan/kg. The cost of seedling decreased by 2% when the survival rate was increased by 10%. Increasing unit output can reduce labor, water and electricity costs, unit output from 30 kg/m^2 to 40 kg/m^2, the total cost from 29.9 yuan/kg to 22.48 yuan/kg. Therefore, the circulating aquaculture

system needs to support the higher carrying capacity when it is designed. The labor cost can be reduced through the realization of breeding grading, automatic feeding, reducing the number of operating workers and so on. The cost of liquid oxygen is 2.7–3.64 yuan/kg, accounting for 6%–7%, which is related to the low efficiency of adding inflatable liquid oxygen in enterprises.

(3) In order to improve the level of the cost control management of the marine fishery aquaculture project, it is necessary to implement a sound and complete budget quota control process, ensure the flexibility of the conversion, set up an effective management plan, maintain the effectiveness of the management objectives and management results, and reduce the budget error of the cost control of the marine fishery aquaculture project to a certain extent, and create a good platform for the subsequent improvement of the effectiveness of the overall work process. It is worth mentioning that in the process of budget quota analysis and implementation, the relevant departments should actively integrate the management elements and control standards, consolidate the management foundation, and maintain the comprehensive value of the management mode according to the corresponding management control mode. In addition, we should pay more attention to the cost control work, and apply the whole process management mechanism to effectively take cost control as the management standard. Relevant personnel should complete the management system of marine fishery breeding funds in the project decision-making period on the basis of clear specific behavior, and provide a guarantee for the implementation of cost supervision work.

Marine fishery aquaculture construction is a relatively large use of funds comprehensive project, in the process of marine fishery aquaculture construction, there are different needs for funds in different links, which requires in the process of marine fishery aquaculture construction, we must actively adopt dynamic, scientific, and systematic cost management methods, combined with the consumption of funds in different links, and implement scientific and comprehensive cost management methods, so as to optimize the construction cost of marine fishery aquaculture as a whole, and promote the intensive and efficient development of marine fishery aquaculture industry in an all-round way.

5. Conclusion

This paper presents a method of controlling the cost of marine fishery aquaculture based on big data analysis. According to the characteristics of marine fishery culture, the cost of marine fishery culture is deeply analyzed. With the advantages of the comprehensive and strong correlation of big data analysis methods, the data features are deeply mined. On the basis of building the cost analysis model, the adaptive neural network is introduced to optimize parameter identification, and the feature distribution is reorganized to realize cost control. During the experiment, the culture condition of grouper was mainly analyzed. *Epinephelus*is a good breed in industrial culture in North China. Seedling, feed, artificial, hydropower, depreciation, management, epidemic prevention, and liquid oxygen constitute the cost of industrialized recirculating water culture of grouper, of which seedling, feed, artificial, hydropower, and depreciation constitute the main cost of grouper culture, accounting for 88%–90% of the total cost. The results showed that the key to reduce the cost of recirculating aquaculture was to increase the yield per unit and the survival rate in the process of aquaculture. How to improve survival rate by immunization, how to increase yield per unit area and reduce cost, how to realize automation and reduce labor cost, how to increase efficiency of adding liquid oxygen and reduce cost of liquid oxygen are the problems that industrial grouper culture enterprises need to face in the future. The analysis shows that the method has high stability of marine fishery culture cost control, improves the adaptability of marine fishery culture cost control, and improves the profit level of enterprises. In the application of the method, it is found that the fusion effect of big data and cost control is not very ideal, which affects the development of cost management under the big data environment. Therefore, in the future research, we will focus on the work of data fusion.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

The Game and Impetus Analysis of Ecological Enrichment of Corporate Citizens

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Ecological enrichment is not the growth of the economic value of a business entity and the use of surplus to fund deficits, but the coordinated growth of corporate citizens' ecological value and economic value, which is conducive to the positive evolution of ecological beauty and economic vitalization. Through the game model, this paper makes a game analysis of various possibilities of the game of ecological enrichment and further gives a balanced solution to the impetus of ecological enrichment. Positive-sum return, return equilibrium, and dynamic equilibrium are all the necessary conditions for the positive selection of repeated games for corporate citizens' ecological enrichment and play a decisive role in the impetus of ecological enrichment.

1. Introduction

Ecological enrichment corresponds to a beauty economy, that is, a beautiful ecological environment and high flow and wealth stock. Ecological enrichment is high-quality development and a distinctive feature of a double carbon economy and harmonious economy in the new era. Ecological enrichment guided by ecological value in post rich areas (coincrease of ecological value and economic value) is conducive to giving full play to the ecological value advantage of post rich areas, solving the reverse evolution of economic value and ecological environment and promoting the positive evolution of beauty and economy, to achieve the dual long-term goals of beautiful China (double carbon) and rural vitalization (common prosperity).

2. Ecological Enrichment and Its Impetus

2.1. Ecological Enrichment and Its Superiority. Compared with the goal of double carbon and common prosperity, low-quality development has two limitations: firstly, the process of economic value growth in post rich areas is a process of pollution transfer. The economic value and the ecological environment evolve in an opposite direction, causing the post rich areas to fall into the trap of environmental pollution with an upturn in the economy and sacrifice ecological beauty for economic growth, in which the cost of pollution transfer goes against the original intention of development; secondly, the process to fund deficits with the surplus of economic value in post rich areas is a process of value transfer. The use of surplus to fund deficits, regardless of transfer payment of wealth or preferential allocation of resources, belongs to wealth granting and does not create any wealth by itself. And the longer the principal-agent chain, the higher the dissipative value of wealth in funding deficits with a surplus, and the lower the effectiveness. [1].

To achieve the goal of double carbon and common prosperity, it is necessary to reconstruct the evolutionary relationship between GDP (economic vitalization, which corresponds to low-quality development) and GEP (gross ecosystem product, which corresponds to ecological enrichment). Ecological Enrichment, also known as ecological value-oriented vitalization, refers to giving full play to the ecological value advantages of the post rich areas, transforming the role of business entity to the corporate citizen, realizing the positioning of the ecological industry chain and ecological value chain, and realizing the coordinated growth

of ecological value and economic value, to achieve the win-win goal of ecological beauty and wealth creation teaching. [2].

The two advantages of ecological enrichment make up for the two limitations of low-quality development well: firstly, on the basis of preserving ecological enrichment and giving full play to the ecological value advantages of the post rich areas, material civilization and ecological civilization of the post rich areas evolve in the same direction, avoiding the transfer of pollution; secondly, ecological enrichment does not mean using the surplus of economic value to fund deficits; instead, it realizes the positive correlation and evolution between economic value and ecological value, while teaching how to get rich, with the positioning of ecological industry chain and ecological value chain. In addition, ecological enrichment is conducive to the realization of the long-term goal of harmony between man and man and harmony between man and nature of a community of shared future for mankind. So, ecological enrichment of ecological value-oriented is equal to the ecological revitalization of environmental value-oriented + rural revitalization of economic value-oriented, which has more economic value than ecological revitalization and more environmental value than rural revitalization.

2.2. Impetus of Ecological Enrichment. The subject of environmental enrichment is enterprises, which, by dichotomy, are divided into the business entity and corporate citizens. From the perspective of the human nature hypothesis, business entity refers to the economic man taking economic value as guidance to pursue the goal of maximizing economic value (prioritizing profit rate and taking into account the amount of profit) of self-worth; corporate citizens refer to the self-actualizing man and social man taking ecological value as guidance to pursue the goal of maximizing ecological value (prioritizing economic value and taking into account the environmental value) of stakeholders. Corporate citizens are the first business entity, which has positive externalities. At the same time, corporate citizens are social men and should avoid negative externalities [3].

2.3. Impetus Theory of Ecological Enrichment. Contract Theory analyzes the impetus of ecological enrichment from the perspective of written contracts and psychological contracts. The written contract corresponds to the rigid impetus of ecological enrichment, while the psychological contract corresponds to the flexible impetus of ecological enrichment. Utilitarianism analyzes the impetus of ecological enrichment from the perspective of pursuing "the greatest happiness" and holds that the impetus of ecological enrichment depends on whether the choice of environmental enrichment can bring corporate value, namely, whether the marginal benefit is greater than marginal cost. The theory of human nature assumption includes four human nature hypothesis such as economic man, self-actualizing man, social man, and complex man hypothesis, which analyzes the impetus of ecological enrichment from different human nature assumptions. For example, the economic man assumption implies that human nature is evil, which corresponds to the impetus of a business entity. Self-actualizing man assumption implies that human nature is good, and social man assumption implies that human nature is group identity, corresponding to the mission impetus of corporate citizens. Stakeholder theory studies the impetus of ecological enrichment from the diversified enterprise goals and holds that enterprises, customers, employees, government, and other stakeholders pursue different interest goals, such as enterprise value maximization, customer value maximization, employee value maximization, ecological value maximization, and so on. The multiple goals of stakeholders jointly determine the combined impetus of corporate citizens' ecological enrichment [4]. Generally, the theory of human nature hypothesis is the theory that best determines the impetus of ecological enrichment.

2.4. Definition of Impetus of Ecological Enrichment. The impetus of ecological enrichment comes from corporate niche, the more favorable the chosen ecological enrichment is to the material or spiritual niche of an enterprise, the greater the impetus of ecological enrichment. The physical niche corresponds to an explicit written contract and determines the rigid impetus of ecological enrichment, and the spiritual niche corresponds to an implicit psychological contract and determines the flexible impetus of ecological enrichment. At the same time, the corporate niche is influenced by both the external public among the stakeholders and the internal public, so the impetus of environmental enrichment can be divided into external impetus and internal impetus. As a result, ecological enrichment has four impetuses, that is, an external rigid impetus (third-party coercive impetus), an external flexible impetus (third-party ethical impetus), an internal rigid impetus (economic impetus of business entity), and an internal flexible impetus (mission impetus of corporate citizens) [5].

3. Game Analysis of Ecological Enrichment

3.1. Ecological Industry Chain and Ecological Value Chain. From the perspective of positioning among businesses, enterprises achieve ecological enrichment mainly by positioning the ecological industry chain. The analyses on environments (macro environment, industrial environment, and competitive environment), missions (corporate citizens' ecological value mission and business entities' economic value mission), and strengths (corporate resources and corporate value chain) jointly determine the positioning of the corporate ecological industry chain. In the practice of positioning among businesses, there are two game strategies, positioning the economic industry chain of business entities and positioning the ecological industry chain of corporate citizens [6].

From the perspective of positioning internal business, enterprises achieve ecological enrichment mainly by positioning the ecological value chain. The four links, including green research and development (dark green technology and light green technology), green production (clean production

and virtual production), green marketing (green logistics and network direct marketing), and green brand (low-carbon certification and ecological brand), jointly constitute the ecological value chain positioning of enterprises. In the practice of positioning internal business, there are two game strategies, positioning the economic value chain of business entities and positioning the ecological value chain of corporate citizens [7–9].

In the practice of ecological enrichment game, the choice of ecological enrichment not only depends on the expected return of individuals, but also depends on the influence of the expected return of individuals from other enterprises choosing or not choosing ecological enrichment in post-rich areas. In the theory of ecological enrichment game, the game and impetus of ecological enrichment of corporate citizens are the cooperation-competition game and impetus positioning of ecological industry chain and ecological value chain.

3.2. Game Model Hypothesis and Element Definition. In order to construct the game model, the following four assumptions are made:

(1) The total number of players in the post rich areas who choose or do not choose ecological enrichment is N.

(2) Player choosing ecological enrichment strategy means corporate citizens in the post rich areas implement the positioning of the ecological industry chain and ecological value chain, and the player not choosing ecological enrichment strategy means business entities in the post rich areas implement the positioning of the economic industry chain and economic value chain.

(3) With the increase of the number M of the players in the post rich areas who choose ecological enrichment, namely, positive selection, the expected return of corporate citizens shows an increasing trend, and the positive selection return curve PS inclines upward to the right.

(4) With the increase of the number N-M of the players who do not choose ecological enrichment, namely, adverse selection, the expected return of business entities shows a decreasing trend, and the adverse selection return curve AS inclines downward to the left.

Based on such assumptions, "PARTS," the five elements of ecological enrichment game are defined as follows: Player refers to the rational decision-making subject that takes its own value maximization as the criterion, that is, all the enterprises in the post rich areas that choose or do not choose ecological enrichment. Added values refer to the economic or ecological value added by the game choice, that is, the achievement of the dual goals of maximum corporate value and maximum ecological value by the player by choosing ecological enrichment. Rules refer to the game decision procedure and value allocation agreement, that is, the distribution of benefits or risks corresponding to added value by players according to written contracts and psychological contracts. Tactics means the specific decision method game choice, that is, the players establish a common vision and choose ecological enrichment, or they do not trust each other and do not choose ecological enrichment. Scope refers to the quantitative boundary of each element of the game, that is, the industry chain scope, game time, game times, and other conditions of the players in ecological enrichment game.

3.3. Game Model Analysis. Among the five elements of an ecological enrichment game, the change of any element may lead to different strategies for the players. The following is an analysis of various game possibilities of ecological enrichment in post rich areas.

3.3.1. Smooth Slope Model. Figure 1 is a smooth slope model. N is the number of players in the post rich areas, M is the number of players making a positive selection, N-M is the number of players making an adverse selection, and the vertical axis represents the expected return of positive or adverse selection. Positive selection return curve PS inclining upward to the right and adverse selection return curve AS inclining downward to the left cannot make the players in the ecological enrichment game be motivated by positive selection or tempted by adverse selection. When the expected return of the players' adverse selection exceeds that of their positive selection, the curve PS is located below the curve AS, and at this time, the players may collectively make an adverse selection to obtain higher returns.

In the game practice of ecological enrichment in post rich areas, many situations will lead to smooth slopes. For example, due to the change in the macro environment and industry environment, the dual goal of maximizing enterprise value and ecological value (added value change) cannot be achieved by choosing ecological enrichment; there are many disputes about the expected return and risk distribution of environmental enrichment in the written contract or psychological contract, or the information of positive and adverse selections is asymmetric (rules misleading); the players use each other rather than trusting each other and have different views on the expected return and the prospect of choosing ecological enrichment (tactical loopholes); in the process of choosing ecological enrichment, the variables such as the industry chain scope, game time, and game times of players change (scope variables). Because the return of point F is higher than that of point B, curve AS is the rational choice of players, and the collective adverse selection of players eventually leads players to slide down the smooth slope to point E of curve AS [10]. In the smooth slope model of ecological enrichment, the players can obtain a higher expected return from adverse selection than that from positive selection, and the number of players who choose ecological enrichment declines along the smooth slope, ultimately causing ecological enrichment only with slogans and lacking motivation.

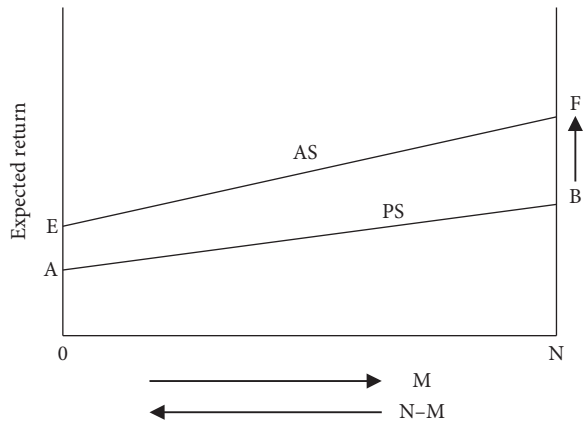

Figure 1: Smooth slope model.

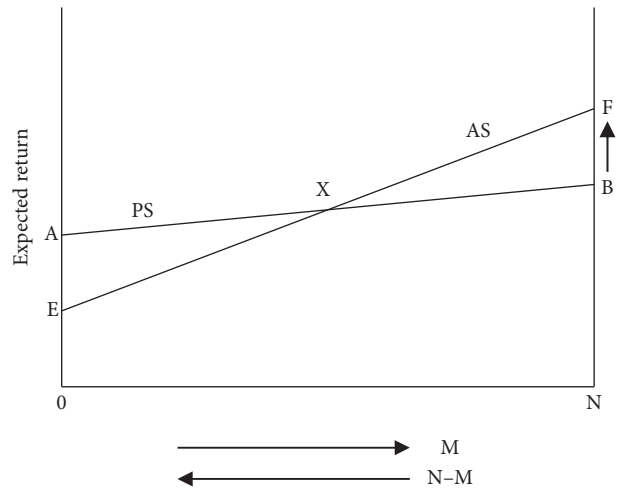

Figure 2: Self-resistance slope model.

3.3.2. Self-Resistance Slope Model. Figure 2 is a self-resistance slope model. The differences from Figure 1 are that the expected return of adverse selection decreases and adverse selection return curve AS moves down, intersecting with the positive selection return curve PS at point *X*; the lowest point A of curve PS is higher than the lowest point *E* of curve AS, and the highest point B of curve PS is lower than the highest point F of curve AS. On the right side of point *X*, the return of point F is higher than that of point B, indicating that adverse selection is the best policy for the players; on the left side of point *X*, the return of point A is higher than that of point *E*, indicating positive selection is the best policy for the players. In the self-resistance slope model of ecological enrichment, the written contract and psychological contract of ecological enrichment cannot effectively restrain every player, and point *X* instead of point B (the optimal scale boundary) becomes the scaled boundary of the number of players making the positive selection.

In the game practice of ecological enrichment, compared with oligopoly industries with a small number of players, monopolistic competitive industries with a large number of players face more uncertainties of the returns from choosing ecological enrichment with the increase in the number of players, and some players may make an adverse selection to reach the critical scale boundary at point X. The self-resistance slope can be set by "PARTS" to change the expected return of choosing ecological enrichment and that of not choosing ecological enrichment, so that the number of players not choosing ecological enrichment will be blocked at a certain number, instead of falling completely or even bringing the strategy of choosing ecological enrichment to collapse [11–13]. When curve AS slides down to point *X*, the choice of ecological enrichment will become favorable, and the dominant strategy of the players will change to choosing ecological enrichment from not choosing ecological enrichment. In the self-resistance slope game, when an adverse selection strategy occurs at point *X*, the initiator of ecological enrichment can strengthen the external negative reinforcement of adverse selection through the setting of the five elements of the ecological enrichment game, so as to prevent the probability of adverse selection by the players and move point *X* to the right. In the Internet + era, external positive reinforcement or negative reinforcement can be made to rectify deviations, prevent the self-resistance slope from becoming a smooth slope, and increase the rightward displacement scale of point *X* of the self-resistance slope model and thus increase the number of corporate citizens who choose ecological enrichment in post rich areas.

3.3.3. Viscous Slope Model. Figure 3 is a viscous slope model. The differences from Figure 2 are that the positive selection return curve PS and adverse selection return curve AS exchange their places. The best collective policy of the players is at point B of curve PS. On the left side of *X*, the expected return of choosing ecological enrichment is less than that of not choosing ecological enrichment, and players show a trend of the smooth slope. On the right side of point *X*, the expected return of choosing ecological enrichment is greater than that of not choosing ecological enrichment, and at point B, players are motivated to collectively make a positive selection, avoiding the vicious slope from becoming a smooth slope.

In the game practice of ecological enrichment, if a certain number of players choose ecological enrichment in post rich areas, ecological enrichment will enter a virtuous cycle and the expected return of players from choosing ecological enrichment will be greater than that from not choosing ecological enrichment; however, if the certain number is not reached, the ecosystem of ecological enrichment will not enter a virtuous cycle and the expected return of players from not choosing ecological enrichment will be greater than that from choosing ecological enrichment.

By "PARTS" setting, the initiator of ecological enrichment can make the return from positive selection greater than that from adverse selection and correct adverse selection motivation. When players collectively strive for point B, ecological enrichment becomes a rational solution. However, before the rational expectation of choosing

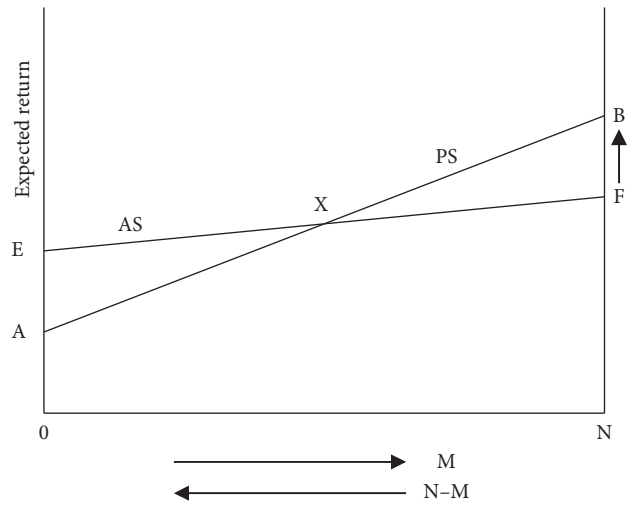

Figure 3: Viscous slope model.

ecological enrichment is established, if the ecological value chain has nothing to do with enterprise income or the positive selection suffers a loss, players will be tempted to abandon the income at point A and choose the income at point *E*, and finally all players make an adverse selection. In the vicious slope model, the turning point of the game is the critical number of players choosing ecological enrichment; when it is less than the critical number, players will pursue the range of not choosing ecological enrichment at the left side of point *X*; when it is larger than the critical number, players will pursue the range of choosing ecological enrichment at the right side of point *X* [14–16].

3.3.4. Cycle-Step Model. Figure 4 is a cycle-step model. From point A, the expected return from choosing ecological enrichment is greater than that from not choosing ecological enrichment, to choose ecological enrichment is a dominant strategy taken by players, and positive selection return curve PS controls adverse selection return curve AS. When reaching point B where curve AS and curve PS intersect, the expected return from choosing ecological enrichment changes in direction, and the return of curve AS is greater than that of curve ps (curve ps and curve PS have opposite expected returns). At point B, curve AS becomes a smooth slope and players slide down to point A. The cycle step starts from point A and the expected return from the positive selection is solid line PS; if the cycle step starts from point B, the expected return will become dotted line ps. In the cycle-step game model, the apex of positive selection is the beginning of adverse selection when the expected return from choosing ecological enrichment changes in direction [17].

In an ecological enrichment game, players are always rational and believe that the other parties are rational too. Under the conditions of repeated games and failure of external correction, if a player makes an adverse selection before ending the last cooperative game, the strategy of "Like for Like" fails, at least for this game. The group game logic of players is the same as that of the individual game: each game is subject to reverse reasoning, the best strategy taken by players in the group game

		Enterprise B	
		Not choose	Choose
Enterprise A	Not choose	0, 0	$0, -I_0\lambda_2$
	Choose	$-I_0\lambda_1, 0$	$£¨P_0 - I_0£\lambda_1©, £¨P_0 - I_0£\lambda_2©$

Figure 4: Static game return matrix of ecological enrichment.

is to make an adverse selection from the first game and players may be trapped in the cycle steps if they choose ecological enrichment. Therefore, in order to prevent the opposite party's adverse selection in the last round of the ecological enrichment game, each player may cause the positive selection to fall short. In the practice of ecological enrichment, the policies of economic vitalization and ecological enrichment alternate with each other, and ecological enrichment is often trapped in cycle steps in case of regional transfer and protection of polluting enterprises. The initiator of ecological enrichment should adjust the group expectation when the expected return of environmental enrichment is likely to reverse (at point B), so as to avoid the failure of positive selection.

4. Impetus Analysis on Ecological Enrichment

According to the game analysis on ecological enrichment, the initiator of ecological enrichment should adjust the five-game elements. Only when the expected return of game parties from the positive selection is greater than that from adverse selection, will the parties be motivated to make ecological enrichment, and then the strategy of ecological enrichment will enter a virtuous circle. So that the relationship between the game analysis and impetus analysis of environmental enrichment is that before there is the impetus of ecological enrichment, there will be the revenue increment by the rational game analysis of ecological enrichment. All parties in the ecological enrichment game seek to maximize their returns, which include not only short-term return and absolute financial income but also long-term income and relative competitiveness. Especially when game parties of ecological enrichment are in a competitive or potential competitive relationship, knowing each other under repeated games that the positive feedback and negative feedback laws will lead to the increase and decrease of the returns and the competitiveness. Therefore, game players of ecological enrichment not only pay attention to the absolute returns of ecological enrichment but also pay more attention to its relative returns [18]. The following is a balanced solution to the impetus of ecological enrichment from the perspective of the absolute return of static game and the relative return of dynamic game, respectively.

4.1. Static Impetus of Ecological Enrichment

4.1.1. Static Game Assumption. In order to construct a static game return matrix of ecological enrichment, the following two assumptions are made:

(1) There are only two enterprises, A and B, in post rich areas, which play a game or repeated games under the condition of constant relative competitiveness

(2) When these two enterprises obtain positive-sum total returns from ecological enrichment (namely $1 + 1 > 2$), they distribute the returns according to the proportion of resources invested in ecological enrichment

4.2. Static Impetus Equilibrium. Figure 5 is the static game return matrix of players' ecological enrichment. In a static game, the players' return function has nothing to do with the relative return gap. I_0 is the total investment in ecological enrichment; P_0 is the total returns of enterprises A and B from ecological enrichment; λ_1 and λ_2 are, respectively, the proportion of the agreed investment (distribution) of enterprises A and B in ecological enrichment to the total investment (total return), $\lambda_1 + \lambda_2 = 1$, and suppose $\lambda_1 \neq \lambda_2$. Among the two pure-strategy Nash equilibriums of the static return matrix, the lower right corner of Figure 5 where they both choose ecological enrichment is the positive-sum total return, which is the only pure-strategy Nash equilibrium [19]. In ecological enrichment practice, the greater the absolute return in the lower right corner of the return matrix, the more motivated players are to choose ecological enrichment.

4.3. Dynamic Impetus of Ecological Enrichment. Figure 5 is the dynamic game return matrix of players' ecological enrichment. In a dynamic game, the players' return function is related to the relative return gap. Industry correlation coefficient of players is δ ($\delta \in [0,1]$); P_1 and P_2 are, respectively, the returns of Enterprise A and B from ecological enrichment: $P_1 = P_0\lambda_1 + (\lambda_1\text{-}\lambda_2)\, P_0\delta\text{-}I_0\lambda_1$ and $P_2 = P_0\lambda_2 + (\lambda_2 - \lambda_1)\, P_0\delta - I_0\lambda_2$. In the dynamic return matrix, there are two pure-strategy Nash equilibriums too, and the lower right corner where they both choose ecological enrichment is a deterministic solution. Because the conditions of the deterministic Nash equilibriums where they both choose ecological enrichment are $P_1 \geq 0$ and $P_2 \geq 0$, the conditions under which the investment allocation ratio meets ecological enrichment demand are worked out, namely,

$$\lambda_2 \geq \frac{P_0\delta}{P_0 - I_0 + 2P_0\delta}. \quad (1)$$

By setting the return on investment in ecological enrichment as α, $P_0 = I_0(1 + \alpha)$, equation (1) can be further simplified, namely,

$$\lambda_2 \geq \frac{\delta}{\alpha/1 + \alpha + 2\delta}. \quad (2)$$

Four deductions can be drawn from equation (2): (1) when the industry correlation coefficient δ is constant, players can adjust the investment (distribution) ratios λ_1 and λ_2 through contract or external correction, so as to establish the condition equation of environmental enrichment and motivate all players to make ecological enrichment; (2) when

Enterprise A \ Enterprise B	Not choose	Choose
Not choose	0, 0	$0, -I_0\lambda_2$
Choose	$-I_0\lambda_1, 0$	P_1, P_2

Figure 5: Dynamic game return matrix of ecological.

δ is constant, the greater the return on investment α, the higher the positive-sum returns of group game, and the greater the incentive for players to make ecological enrichment; (3) when δ and α are both constant, the larger the investment (distribution) ratio of an enterprise λ, the greater the incentive for an enterprise to make ecological enrichment; and (4) when δ, α,and λ are all constant, the bigger the relative return gap of an enterprise which is beneficial to itself, the greater the incentive for an enterprise to make ecological enrichment.

The same is true for repeated game analysis of ecological enrichment by multiple enterprises. In order to motivate the enterprises in the same or different industries and areas rich after foreign aid (wealth creation teaching) to make ecological enrichment in the process of dynamic repeated games, we should not only consider the equilibrium of absolute return distribution among players but also consider the adverse impact of the relative return gap on the impetus of ecological enrichment. The impetuses of ecological enrichment include static and dynamic impetus. The static impetus corresponds to positive-sum return and returns equilibrium, is the game source impetus, and is the single game impetus of ecological enrichment. The dynamic impetus corresponds to dynamic equilibrium, which is the repeated game impetus of ecological enrichment [20].

5. Conclusions

(1) Ecological enrichment is not the growth of economic value or the use of surplus to fund deficits, but the positioning of the ecological industry chain and ecological value chain and the dual achievement of ecological value and economic value. Contract, stakeholder, human nature hypothesis, and other theories should be jointly taken into account in defining the four impetuses of ecological enrichment: internal, external, voluntary, and compulsory. Generally, the four composite impetuses are the impetus for the ecological enrichment of corporate citizens.

(2) From the perspective of an ecological enrichment game, it is necessary to meet two conditions, including corporate citizens' positive-sum return (return condition) and return equilibrium (contract conditions), only under which can enterprises make a positive selection (choosing ecological enrichment), rather than an adverse selection (not choosing ecological enrichment).

(3) From the perspective of ecological enrichment impetus, it is necessary to meet two conditions, including the growth of corporate citizens' absolute return (static impetus equilibrium) and favorable relative returns (dynamic impetus equilibrium), only under which can enterprises be motivated to make ecological enrichment.

(4) Based on the above two perspectives, three conditions are needed in enhancing the impetus of ecological enrichment: positive-sum return, return equilibrium, and dynamic equilibrium. Positive-sum return is the game source impetus of ecological enrichment of corporate citizens, return equilibrium is the single game impetus of ecological enrichment of corporate citizens, and dynamic equilibrium is the repeated game impetus of ecological enrichment of corporate citizens.

The impetus of environmental enrichment is a complicated system. By establishing the model of the solution and describing the current situation of the solution with an axiomatic approach, the optimal solution of the impetus game of ecological enrichment players can be obtained. As a whole, positive-sum return, return equilibrium, and dynamic equilibrium are all the necessary conditions for the positive selection in the repeated games of environmental enrichment and play a decisive role in the impetus of ecological enrichment. Government citizens and society citizens can rectify the impetus for corporate citizens to make ecological enrichment through external positive reinforcement (ecological subsidies, ecological honor roll, and so on) and negative reinforcement (ecological taxes, ecological blacklists, and so on).

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

The Role of Organizational Learning in Mediating the Relationship between Business Model Design and Innovation Performance

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Innovation in the business model (BM) may be irreversible and therefore entails more significant risk and ambiguity compared to product, service, or process innovation. This paper focused on exploring the role of organizational learning in mediating the relationship between business model design and innovation performance using hierarchical hybridized linear regression analysis (HHLRA). Furthermore, this paper shows that organizational learning is based on variables that mediate the relationship between training and performance and improve performance through its positive effect on organizational learning. Furthermore, the study examines the multi-dimensional and contingent progressive impact on the corporate performance of organizational training through innovative conjunctive roles. However, this study determines that both organizational learning capabilities (OLC) and organization innovativeness (OI) have a positive effect on organizational performance (OP). Besides, organizational innovativeness mediates the relationship between OLC and OI. Finally, the findings suggest that managers should improve organizational learning capabilities and improve innovation performance to enhance positive entrepreneurial orientation performance connections.

1. Introduction

The modern business environment has required enterprises to implement advanced business models to continue competitively in an uncertain and volatile market. In a competitive environment, organizations must modify themselves to meet the demands of the external and internal environment [1]. Business model design is central to the development of entrepreneurship and strategic business research [2]. Innovations can be preserved as drivers of profit, as drivers of growth, and as drivers of market value when considered. From the knowledge point of view, organizational learning is the progression of enhanced organizational behavior via the acquisition, exchange, and use of information [3]. Organizational learning, therefore, plays a significant role in the innovation of the business model. At the center of the innovation business model is the ability to offer customers valuable and innovative products or services that involve the redesign of operations, business processes, and value creation and transmission [4]. The key to the successful execution of these activities is organizational capacity [5]. Excellent integration capacity has considered an essential factor for companies to implement the innovation of their business model [6, 7].

Organizational learning improves product and process innovation by developing new abilities and unlearning old skills [8]. Change depends on the human capital of the organization. The creativity of employees contributes to the modernization of the company [9, 10]. When an organization offers its employees flexibility and opportunity, creativity is promoted. In this framework [11], human resource systems and practices play a crucial role through the provision of desired skills and the creativity of employees that is more innovative. Organizational learning offers a support system in which human resource management practices allow creative behavior [12–14]. The social and

psychological experiences [15] of members of an organization produce multiple learning activities and ultimately lead to organizational change in performance [16]. That is, how new knowledge flows from the individual to the organizational level [17] and how existing knowledge flows [15] from the organization to the individual performance [18, 19]. Figure 1 shows the corporate learning and business model design.

In this paper, the hierarchical hybridized linear regression analysis (HHLRA) has been proposed to determine the role of organizational learning in mediating the relationship between business model design and innovation performance. This study, therefore, seeks to explore the mechanism for the functioning of resource integration in the field of organizational learning link between business model design. First, the proposed model considers mediating and moderating effects to illustrate how managers can guarantee that the BMI offers firms more benefits in terms of performance. Secondly, it helps practitioners align their BMI efforts with business strategy and day-to-day operations by providing a larger, more realistic view of what is happening in the company [20, 21].

The main contributions of the paper are as follows:

(i) To propose hierarchical hybridized linear regression analysis (HHLRA) to explore the role of organizational learning in mediating the relationship between business model design and innovation performance.

(ii) Designing the business model and questionnaire survey model to enhance organizational learning and innovation performance.

(iii) The experimental results demonstrate the positive effects on the business model and innovation performance.

The remainder of the paper is discussed as follows: section 1 and section 2 discussed the introduction of business model design and existing methods. In section 3, hierarchical hybridized linear regression analysis (HHLRA) has been proposed to determine organizational learning in mediating the relationship between BM design and innovation performance. In section 4, the numerical results have been illustrated. Finally, section 5 concludes the research article.

2. Conventional Survey and Its Impact

Zhu et al. [22] suggested structural equation modeling (SEM) for analyzing the supply chain integration value creation via handling interorganizational learning. Their findings verify the relationship between the integration of the supply chain and firm focal performance between organisationally based learning.

Zhu et al. [23] proposed the high-performance work system (HPWS) to determine the impacts of organizational learning and entrepreneurial orientation. The experimental outcomes show that, when organizational learning is stronger, the relationship between high-performance work systems and a firm's performance is positive.

Lafuente et al. [24] introduced the sequential deductive triangulation analysis (SDTA) for discovering the role of organizational learning ability in knowledge-intensive business services companies. The findings show that organizational learning capacity has a positive effect on the performance of innovation.

Kafetzopoulos et al. [25] initialized the exploratory factor analysis monitored by confirmatory factor analysis and structural equation modeling (EFA-CFA-SEM) for analyzing the relationship between European foundation for quality management (EFQM) and business performance. This article accomplishes that the impact of excellence enablers on business performance, in part, mediates innovation performance.

Mikalef et al. [26] proposed the big data analytics capability (BDAC) for exploring the mediating roles of capabilities and the dynamic relationship between competitive performances. The outcomes demonstrate that a strong BDAC can support companies to build a competitive benefit using partially square structural equation models.

Yiu et al. [27] discussed the Service-Dominant Orientation (SDO) on the innovation performance of technology firms. The outcomes illustrated that SDO's relationship learning mediates external networks, innovation performance, knowledge-sharing, and innovation performance.

Morales et al. [28] proposed the moderated mediation model (MMM) for helping behaviors at work stimulate innovation in the organization. Furthermore, a higher level of support improves innovation and strengthens the positive link between intervention and innovation performance.

Based on the above discussion, there are certain differences in the research conclusions on the mechanism of business model innovation in enterprise performance. It is necessary to introduce relevant variables to deeply explore the mechanism of action between the two. Because the improvement of organizational learning ability will be affected by the change of the business model of the enterprise, the change of the business model of the enterprise will also have an impact on the original organizational learning ability. Based on this, in order to more objectively analyze the correlation between variables, the data in this paper are all from primary questionnaires. The sources mainly include individual distribution and collective distribution. The collective distribution method mainly uses data collection by outsourced third parties. In this paper, the role of organizational learning in mediating the relationship between business model design and innovation performance uses the Hierarchical Hybridized Linear regression analysis (HHLRA). OLC is a strategic tool for the improvement of OI and OP for competitive advantage following dynamic, rapid knowledge changes. Learning practice is considered to be a key factor in alleviating uncertainty and adopting external changes effectively to gain and maintain a competitive edge. These practices can be organized, analyzed, managed, and efficiently improved to correct management skills.

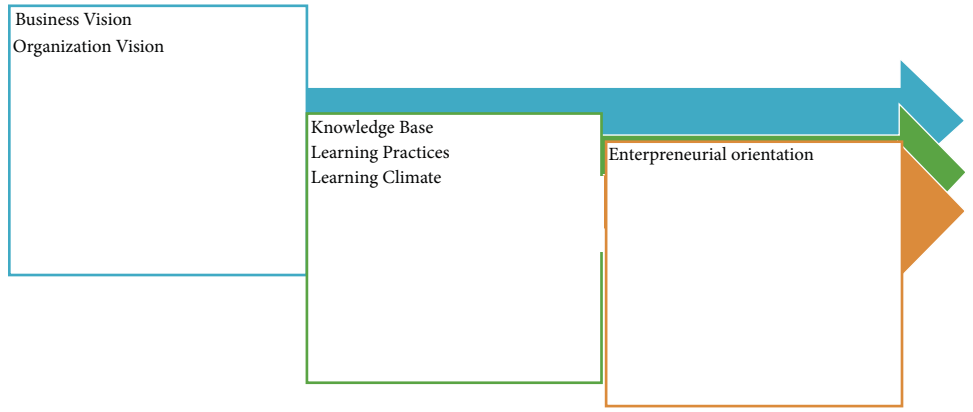

Figure 1: Organizational learning and business model design.

Continuing and effective learning creates an innovative culture that pushes the organizational performance curve up. Innovation can lead an organization, which will finally lead to core competencies and competitive advantage, to grow and improve business processes. In the study variables, the development of organizational performance is important.

2.1. Hierarchical Hybridized Linear Regression Analysis (HHLRA). In this paper, the hierarchical hybridized linear regression analysis (HHLRA) has been proposed to explore the role of organizational learning in mediating the relationship between business model design and innovation performance. Structurally, a business model as a routine has three main linked components: a value dimension, a trans active size, and a resource dimension. There are many moving elements within a business model, all of which must work together [29, 30]. The entire model must be in line with the strategy, culture, and resources of the organization. Figure 2 shows the conceptual model using the proposed HHLRA method.

Business model innovation is a complete change to an enterprise's existing business, its current market environment and competitive landscape, and the creation and realization of brand-new value propositions based on the development of customer needs. The overall performance of the firm will be influenced by innovation. The orientation can have a positive impact on business performance, as change means a competitive advantage. Companies are interested in innovation and concentrate on activities that enhance their capability to do this. This ability drives companies to improve continually and thus improve their business performance.

2.1.1. Postulate 1. BMI has a direct impact on overall organizational performance.

Organizational learning is expressed by four constructs which contains corporate memory, information interpretation, knowledge acquisition, and information distribution. Organizational learning can be considered a dynamic

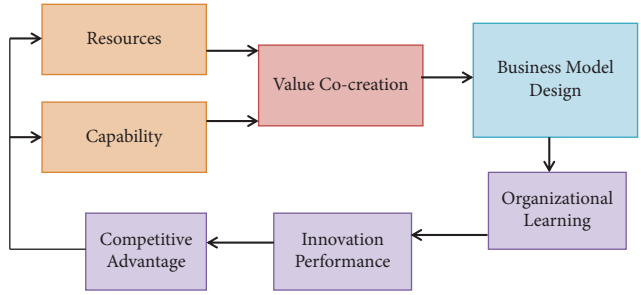

Figure 2: Conceptual model.

process in which knowledge is gained, shared, and used to develop resources and capacity. The acquisition of experience refers to technical expertise to build or generate product knowledge, knowledge of management, and marketing knowledge. Sharing knowledge means spreading what has been learned. The use of expertise means integration of the experience and is, therefore, generalized to new situations and is broadly available.

Companies continue to conduct organizational learning to search and refine areas for improvement, incrementally improve existing revenue models and value creation models, etc. Enhance the content of enterprise innovation, speed up the process of realizing the commercialization of knowledge and market demand, and then stimulate enterprises to reflect and improve their business models, and ultimately ensure the ability of enterprises to innovate business models.

The essential values of a market culture depend on a rational view that highlights competitiveness, productivity, and a precise setting of objectives. Market culture prefers leaders who are very happy to encourage their underlings to attain quick response, and their goals to guarantee modest success are highlighted. A fundamental reason for maintaining a balanced method is the survival of scarce resource competition by organizations. The competitive market culture promotes a tension between the transfer of learning from individual to group and organization and vice versa. Those who work in a market-oriented culture would desire to participate in learning activities that provide categorical

knowledge and monitor the learning procedure carefully to improve knowledge production reliability.

2.1.2. Postulate 2. Organizational learning has a positive effect on business model innovation, while Market Culture positively impacts organizational learning activities.

By building values and recognition of opportunities, BMI can provide opportunities, both in times of rapid economic growth and economic downturn, via the ongoing transformation of the industry, to exploit a market that its competitors are unable to tackle and thereby increase the revenue growth of companies. As an illustration, organizations can create additional access to resources, quickly or in conjunction with new opportunities to integrate services, through the adoption of new collaboration models.

BMI is required to make organizational efforts. To enable companies to renovate their BM, they need to detect new technology and market needs and be open-minded and innovative. This BMI process increases its organizational capacity once the firm starts to explore, design, test, and implement its BMI. Culture is defined as the expression of norms, values, and beliefs that boost business performance at the end of the day. When specific attitudes are adapted to the organizational culture, the consequences of conduct are expanded to compensate for the circumstances, groups, and individuals of the company. A culture that supports the implementation of a strategic attempt is not easy to imitate, as, in our BMI research, it can lead to a competitive, sustainable advantage. The ability to search for opportunities is another organizational capacity that can mediate BMI and its performance. BMI is a consequence of innovation at the BM Company. BMI can, therefore, boost the change of people within the company in different ways, including sharing the whole business idea, building the capacity to search for opportunities, and creating genuine value propositions. Besides, organizational learning is a critical organization, through which information and information and knowledge can be processed and which can alter the organization's attributes, behaviors, capabilities, and performance.

2.1.3. Postulate 3. Organizational capabilities have a positive impact on BMI.

BM Experimentation resources involve budgeting, human capacity, and time spent in support of BM experimental practices by a company. The innovative method in the BM company includes activities related to (a) how to modify the logic of the company, i. e. radically or incrementally, (b) the order in which modifications are made to parts of the company, and (c) (virtual) thinking vs. real experimentation. These activities can be carried out in the context of a BM team, for example, in the context of management work, or through the hiring of external consultants on a financial plan. Let's preassume that resources for a particular task enable more activity to be undertaken.

2.1.4. Postulate 4. BM experimentation resource allocation has a direct impact on BMI.

In Figure 3 shows the business model innovation structure to improve a firm's performance, involving moderating and mediating variables. The production function of the regional innovation output is built from several factors that are multiplicatively associated as follows:

$$X = c * Y_1^{d_1} * Y_2^{d_1} \cdots * Y_m^{d_m} * v. \tag{1}$$

As shown in (1) where Y_1 to Y_m be regional factors are reviewed in the logistic regression analysis, and X indicates the innovation output. C denotes a constant and d_1 to d_m are the coefficients the strengths of every factor influence.

The major attraction of this method is that it can be calculated with an ordinary, square least regression using the following logarithm:

$$\begin{aligned}\log(X) = \log(c) + \log(Y_1) * d_1 + \log(Y_2) * d_2 \\ + \cdots + \log(Y_m) * d_m + \log(v).\end{aligned} \tag{2}$$

The advantage of this type of function is the elasticity of coefficients. The relationship between regional factors and innovative output must be log-linear. When applying the log-linear production of knowledge, it is implicitly assumed that no innovations are to be expected in a region with a lot of enterprises and public research, not organizations' employees. Because regional factors are connected multiply in the nontransformed version, a value of null in one infers that no new output is predictable.

This issue is overcome by supposing an ordinary linear relationship with additionally linked regional factors, which is determined as follows:

$$X = c + a_1 Y_1 + a_2 Y_2 + \cdots + a_m Y_m + v. \tag{3}$$

As inferred from (3) where $Y_1 - Y_m$ is the m regional factors reviewed in this analysis, and X indicates the innovation output. V is the statistical error term with the characteristics, c is a constant and a_1 to a_m is the regression coefficient that indicates the strength of every factor's influence. The relationship between regional and regional innovation factors is calculated twice for each sector. The first is to apply the standard model of linear regression, and the second is the log-linear model. It is tested that the expectations for their application are fulfilled to check which model is best suited.

Some of the regional factors contain 0 values, which avoids taking the logarithm, and it is essential for the log-linear model. The total geographical factors are thus transformed as follows:

$$\widetilde{Y} = 10 * (Y + 1). \tag{4}$$

In our study, regional factors are theoretically determined to produce coherent, theoretical significance for each of the first components. Organizational learning decentralizes the decision-making process and supports to development of creative and innovative behavior. Organizational learning, therefore, affects the innovation

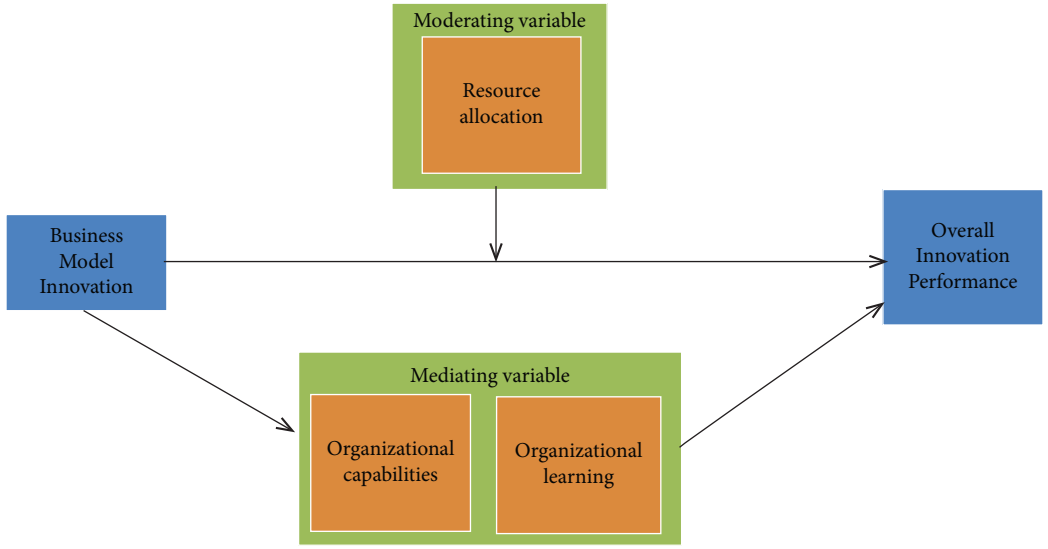

Figure 3: BMI structure to enhance a firm's performance.

Table 1: Descriptive statistics.

Variable	Standard deviation	Mean	Number of observations
Firm size	0.03	0.4	120
Organizational learning	0.04	0.6	120
BMI	0.01	0.7	120
Firm size	0.05	0.3	120
Fitness value	0.1	0.8	120
Firm experience	0.2	0.5	120
Innovation performance	0.32	0.8	120

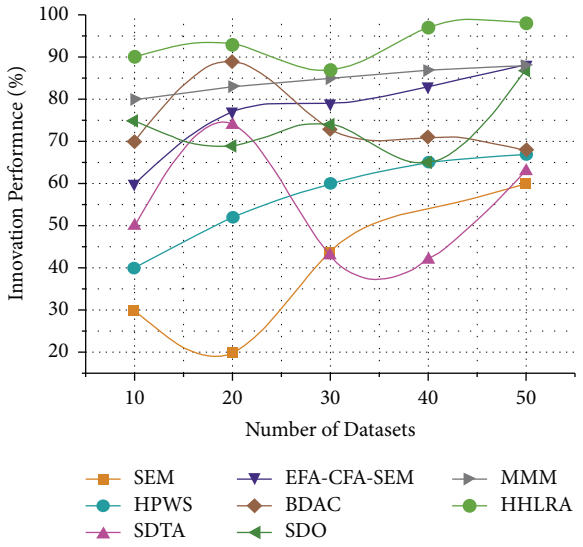

Figure 4: Innovation performance.

skills of the company. Regulatory learning activities are fundamental organizational capacities to achieve corporate success and improve performance in business model innovation. This paper has demonstrated the theoretically positive results of organizational learning performance as a result of the independence between transfers of learning and knowledge accumulation at various organizational levels.

3. Experimental Results and Discussion

The data has been analyzed statistically to test the above postulates. First, standard deviation (SD), intercorrelation validity, and reliability have been calculated. The correlation analysis has been utilized to observe the relationship between various types of culture, innovation performance, BMI, and organizational learning. Table 1 shows the significant correlation that exists between variables, which can further determine the relationships between them through the proposed hierarchical hybridized linear regression analysis (HHLRA).

Figure 4 shows the innovation performance in business model innovation. The study explores the mechanism of effects inherent to the change between OL and BM, consequently contributing to the theoretical development of business model innovation by introducing resources integration capacity into the conceptual framework. This shows that it is wise to improve the ability to integrate resources through organizational learning if the company wants to introduce an innovation in business models. When an enterprise has a good organizational learning ability, it can use this ability to identify external market opportunities in a timely and accurate manner, effectively use the internal resources of the enterprise, control the risks existing outside the enterprise, and improve the efficiency of enterprise organizational reform and value creation, which is

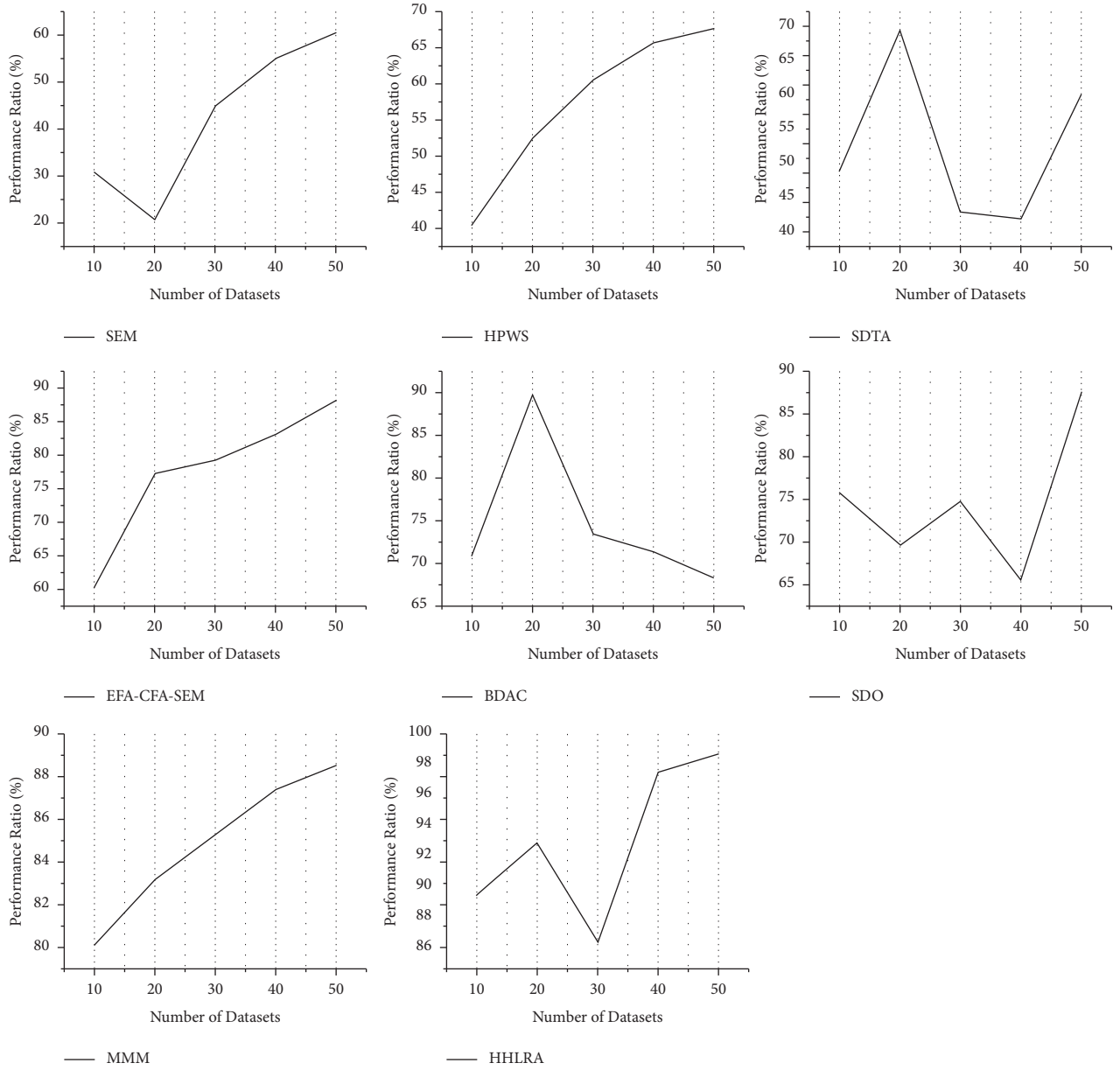

Figure 5: Knowledge Performance gain.

Table 2: Balanced Performance ratio.

Number of datasets	SEM	HPWS	SDTA	EFA-CFA-SEM	BDAC	SDO	MMM	HHLRA
10	30.7	40.4	50.3	60.3	70.9	75.8	80.1	90.4
20	20.7	52.4	74.3	77.2	89.7	69.7	83.2	93.5
30	44.8	60.5	43.3	79.2	73.5	74.7	85.3	87.6
40	54.9	65.6	42.2	83.1	71.4	65.6	87.4	97.7
50	60.3	67.6	63.3	88.2	68.3	87.5	88.5	98.8

conducive to appropriately innovating existing business models and exploring business models suitable for its own development. Companies should actively encourage employees to obtain information and knowledge from clients, partners, competitors, and benchmarking firms and promote cross-company knowledge flows. The capacity to integrate resources is helpful to absorb the knowledge performance gained from the organization's learning and thus encourage innovation in business models, as shown in Figure 5.

Market culture prefers leaders who are very happy to encourage their underlings to attain quick response, and their goals to guarantee modest success are highlighted. A fundamental reason for maintaining a balanced method is

Table 3: Postulate and results.

	Postulate	Results
P1	BM experimentation resource allocation has a direct impact on business model experimentation practices.	Sustained
P2	Organizational learning has a positive impact on business model innovation.	Sustained
P3	Innovativeness has a direct impact on overall organizational performance	Sustained
P4	Organizational capabilities has a positive impact on business model innovation	Sustained
P5	Market culture positively impacts organizational learning activities.	Sustained

the survival of scarce resource competition by organizations. The competitive market culture promotes a tension between the transfer of learning from individual to group and organization and vice versa, as shown in Table 2, based on an innovative balanced performance ratio.

In Table 2 shows the organization's innovation performance using the proposed HHLRA method. The development and operation of a new BM may have a more powerful effect on company performance in a more dynamic setting. Regulatory changes, on the contrary, can affect the performance of continuing BM innovations both within and outside the industry.

The structural model outcomes reveal that the resources of business model experiments have positive effects and relationships with the business model as well as with innovation performance. Besides, a mediation test has been conducted to analyze if the relationship between BM's experimental resources and the strategic implementation practices of the BM has mediated the company's overall performance. The outcomes have shown that business model experimentation mediates the relationship between business model plan practice and the global firm's performance partially. Table 3 shows the postulate test and statistical results.

This paper specifies the multidimensional learning features of an organization and has verified their leading role in increasing organizational performance. Firstly, learning at multiple levels is the main capacity for organizations to address changing environments. The organization, therefore, requires to progress workroom learning tools like shared practices, mentorship programs, and workplace training that can foster learning via close relationships and promote the development of the learning tool. The research indicates that firms with a single type of culture cannot encourage innovation and education. Firms need to guarantee they have a mix of cultures that promote creativity, teamwork, and risk becoming capable of less structured and courteous policies.

4. Conclusion

This paper presents the hierarchical hybridized linear regression analysis (HHLRA) to explore the role of organizational learning in mediating the relationship between business model design and innovation performance. Firstly, business model design has a significant positive impact on the overall innovation performance; that is, the stronger the business model design capability, the better the innovation performance. This conclusion is consistent with the null hypothesis. Secondly, the improvement of business model design ability has a significant positive impact on organizational learning. Finally, the impact of business model design on innovation performance can be achieved through the mediating role of organizational learning capabilities. This paper opens the "black box" between business model and enterprise performance clarifies the mechanism of action and realization path, further enriches the relevant theoretical research on business model design, organizational learning, and innovation performance, provides an idea for follow up research and provides a theoretical basis and management support for how to quickly improve the performance of late developing enterprises. Regulatory learning companies tend to obtain certain kinds of knowledge from customers, competitors, partners, and employees. Organizations can update the knowledge system and bridge the inertia that forms the basis of innovation. Organizational learning, therefore, contributes to change in the BM.

Based on the above discussion, thus firms with higher organizational learning can improve the performance of innovation. The benefit of utilizing the proposed HHLRA method offers an accepted mathematical method for analysis postulates in a generalizable way. This article suggests that business model innovation practices deliberating and trying out modifications in the business model positively impact firm performance. Therefore, organizational learning fully mediates the relationship between corporate innovation and business model design. Business model innovation is the innovation of a system, and activities consist of value acquisition and value creation.

5. Research Implications

Organizational learning is the driving force for enterprises to move forward. In today's era, enterprises are faced with continuous changes in the environment and the continuous updating of knowledge. The development of a knowledge economy requires enterprises to learn continuously and effectively in order to obtain sustainable competitive advantages. An organizational learning mechanism is an effective way for enterprises to communicate, communicate and cooperate with the external environment. To establish an organizational learning mechanism, firstly, the

management should take the lead and put learning and innovation in the first place; secondly, it is necessary to improve the incentive mechanism to encourage employees to actively learn; and finally, to improve the enterprise training system and create a good organizational learning atmosphere for the enterprise.

Data Availability

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Strategies of GIS-Based Urban Country Park Planning and Ecological Restoration

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Purpose. This study centers around the Wangzhanghe Country Park located in Jiaozuo City as the research object. Through analysis of the site's evolution by GPS and its status-quo by GIS, the map of spatial distribution suitability has been illustrated. *Design*. Based on the major principle of achieving sustainable development of the ecosystem and the derived concept of building a diversified landscape, we have developed the overall scheme of planning and landscape layout of the country park. Specifically, the area of ecological restoration is further divided into the areas of quarry restoration, bare land restoration, slope protection, vegetation, and dam maintenance, and restorative measures are put forward accordingly. *Findings*. Our research findings indicate that thanks to the vegetation restoration of the side slope, the area of bare land in mountain farmland has been evidently reduced, whereas the severely damaged ash pits and green spots have also been restored. Originality: in the meantime, we have leveraged the flat space at the foot of the mountain to foster a viewing experience and provide recreational activities for citizens, so that they are able to effectively increase their access to outdoor events and improve their sense of engagement and experience in the events, thereby providing a reference for building a green, diverse, and sustainable system of ecological services for the urban country park.

1. Introduction

The country park serves as the link between the city and the countryside and plays a protective role in preserving the ecosystem and enhancing the environmental quality of surrounding areas. Due to the impact imposed by natural conditions and human activities, urban country parks are still encountered with such issues as improper spatial layout, severe soil pollution, and local soil erosion, thus hindering the advancement of ecological civilization and sustainable development in cities [1–5]. Therefore, it has become the current research focus of numerous scholars at home and abroad to elaborate on the question of how to build urban country parks in a healthy, ecofriendly, balanced, and diverse manner from the ecological perspective.

Ecological restoration serves the goal of enhancing the stability and sustainability of ecosystems through the integrated use of chemical restoration, physical restoration, and engineering technical measures. It involves the process of facilitating the restoration, reconstruction, and improvement of the ecosystems subject to degradation, damage, or even complete destruction [6–9]. The technologies commonly used at present include but are not limited to the technologies for soil remediation, phytoremediation, landscape remediation, and rewilding [10–14]. Numerous scholars tend to focus on the impact imposed by ecological restoration on the resilience of biological resources and biodiversity from the macro perspective while analyzing the effects of ecological restoration based on the assessment of the maintenance function of biodiversity. In China, efforts of ecological restoration mainly focus on the farmlands, grasslands, rivers, forests, and mining wasteland, which are subject to the intervention and impact of human beings. Moreover, the studies on the effect of ecological restoration

tend to focus on the assessment of the extent of environmental quality improvement, but the reports on such studies merely account for a small proportion [15–17].

This study centers around the Wangzhanghe Country Park located in the northern mountainous area of Jiaozuo City as the research object. Based on the field survey and analysis of the evolution of the site and environmental conditions of the ecosystem, we have analyzed such factors as the elevation, slope gradient, and slope aspect with GIS to further verify the core construction space of the country park. In addition, judging from the perspective of ecological restoration, we have put forward a green, diversified, and sustainable strategy for ecological planning to meet the needs of citizens for the natural experience of the ecosystem, as well as cultural activities, thereby providing a reference for the planning and positioning of the country park in Jiaozuo City [18–21].

2. Digital Analysis of the Status-Quo and Evolution of the Site

2.1. Overview of the Site. The research site is located to the northwest of the boundary of the major urban area of Jiaozuo City in Henan Province, which is part of the Northern Mountain of Jiaozuo City and covers an area of 15 hectares. The highways adjacent to the research site are well developed, but there is no green space in the park, and the site is linked together with the Jiaozuo Film Studio and the scenic area of Fengshan Park on the same line. In the northern parts of the site, there are pits and dams in need of maintenance. Moreover, in areas adjacent to the mountain, there are vast stretches of woodland and bare land that are required to be restored. At the foot of the mountain, there are also small factories, buildings, and farmland (as illustrated in Figure 1). Subsequent to numerous years of development, the mining industry in the Wangzhanghe area of Northern Mountain has become the major growth engine of Jiaozuo City. However, the local mountains are riddled with holes due to years of private digging and mining, as well as illegal operations and processing by individual market entities. Therefore, it has become the primary task for Jiaozuo City to develop a proper system of ecological conservation in the northern mountainous area so as to restore the local destroyed environment, which is also consistent with the need of achieving sustainable development in the city.

2.2. GPS Analysis of the Evolution of the Site. Judging from the analysis with GPS, the area of bare land of the current land in 2010 was rather extensive (26.15%), and the mountain was severely damaged. In addition, the flat land at the foot of the mountain was basically occupied by farmlands and buildings, whereas the local residents suffered from the impact of suboptimal ecological conditions and overcrowded life. In 2014, the area of bare land was diminished to a significant extent in the mountain, 11.86% less than in 2010. However, large-scale factories were found at the foot of the mountain. In 2017, the scale of the factory was further expanded, the farmland area was reduced by 1.92%, and many farmlands were gradually turned into forests. In 2020, more evident effects were shown in terms of the environmental governance in the mountain. The area of bare land decreased by 17.51% compared with 2010, as evidenced by the significant reduction of the area of bare land and gradual relocation of factories, as well as the transition of the majority of farmlands into woodlands (Figure 2).

2.3. GIS Analysis of the Status-Quo of the Site. This study involves the use of such factors as elevation, slope gradient, and slope aspect with the tentative use of weighted stacking to illustrate a map of distribution suitability [22–24], thereby verifying the core construction space of the country park and providing a reference for its positioning in Jiaozuo City. Judging from the GIS analysis of elevation, slope gradient, and slope aspect, it is found that there is a huge height difference in the site at present. The gap between the maximum altitude and the minimum altitude amounts to 216 m, whereas the overall slope is rather small. About 39% of the areas of the site have a slope of less than 9°, whereas roughly 25% of the areas of the site have a slope ranging between 9° and 15°. Moreover, the areas of the site that have a slope of over 15° account for about 36%. In the majority of the areas of the site, there are sunny slopes and woodland, whereas only a small proportion of the site consists of shady slopes, which are located in the valleys and the northern slopes. In addition, there are certain buildings and stretches of bare land in the southern part of the site, whereas the ash pits account for a large proportion of the mountains, which is huge. Through GIS analysis, we have recorded the damage incurred to mountains, waters, woodlands, fields, lakes, and grasslands in the ecological fracture space located in the Wangzhanghe in the Northern Mountain, thereby providing a reference for the ecological restoration in the next step (Figure 3).

3. Planning Strategies Based on Ecological Conservation

For humankind, health and survival are closely linked to the varying elements of mountains, water, woodland, fields, lakes, and grassland, and they are coexistent with each other in symbiosis. The research is guided by the concept of ecological restoration of mountains, waters, woodland, fields, lakes, and grasslands life community [25–29] and centers on the major thinking of "one belt (Ecological Civilization Corridor), two rings (main roads + main water systems), and two points ("ash pit" + "dam") so as to elaborate on and extend the overall planning and landscape layout (Figure 4).

First, based on the map on the distribution of ecological sensitivity and the holistic analytical results of the status-quo of the site, the ecological restoration area is further divided into the areas of quarry restoration, bare land restoration, slope protection, vegetation restoration, and dam maintenance. In this way, ecological restoration is carried out in partitions to better restore the overall ecological balance. Second, through varying means of landscape construction,

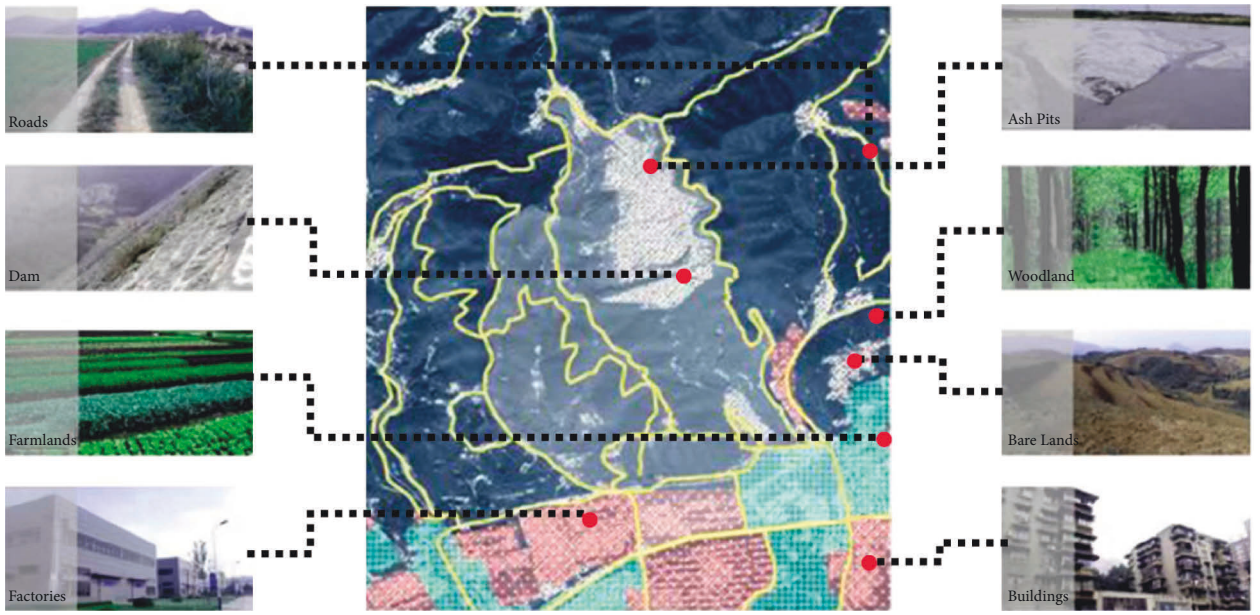


Figure 1: The status-quo of the site (illustrated by the author).

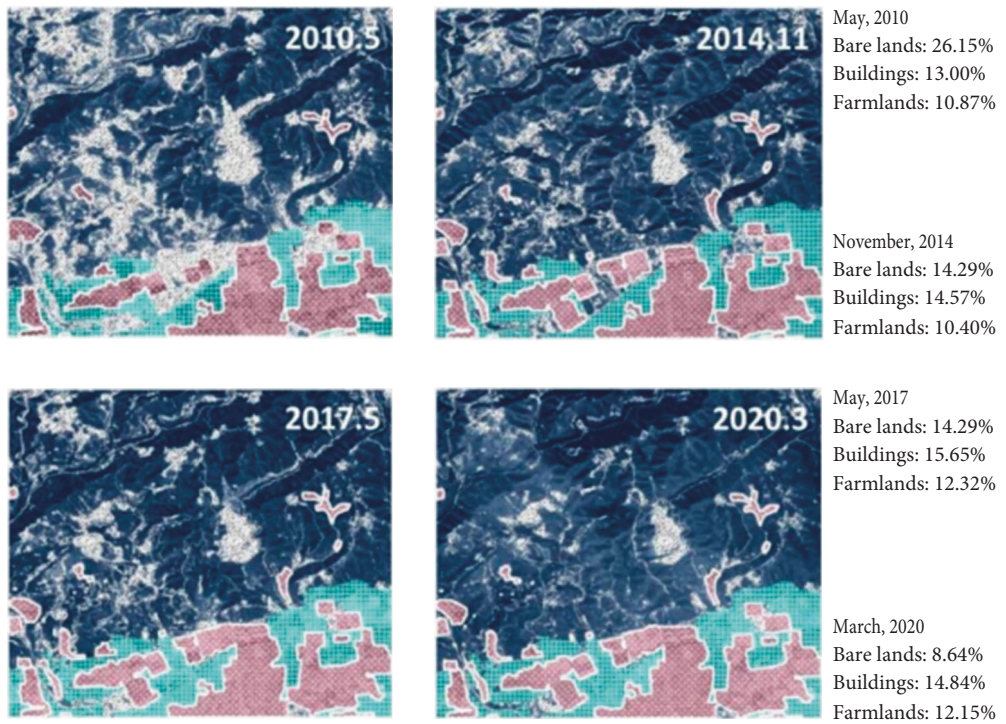


Figure 2: Analytical diagram on the evolution of the site (extracted from Google Earth).

efforts are made to enhance the structuring of space for resting, exchanges, and fitness activities. In the meantime, we attach importance to the public nature and diversified functions of the site and intend to enhance the sense of engagement and experience of tourists. For instance, we have established classrooms for quarry culture and ecological education, mini-programs for experience activities, and cultural exhibition boards, among other forms of presentation, so as to enrich the cultural ambiance of the site. In addition, we have established such facilities as a campsite, an area of agricultural experience, a platform for sightseeing, a bird observatory, and fitness climbing walls, so as to enhance the intelligent experience and to integrate the three elements of the ecosystem, human settlement, and culture for the maximum efficacy of country parks.

During the development and design of the roads in the park, we attach importance to the ways of connecting relevant road systems of the town while strengthening its links

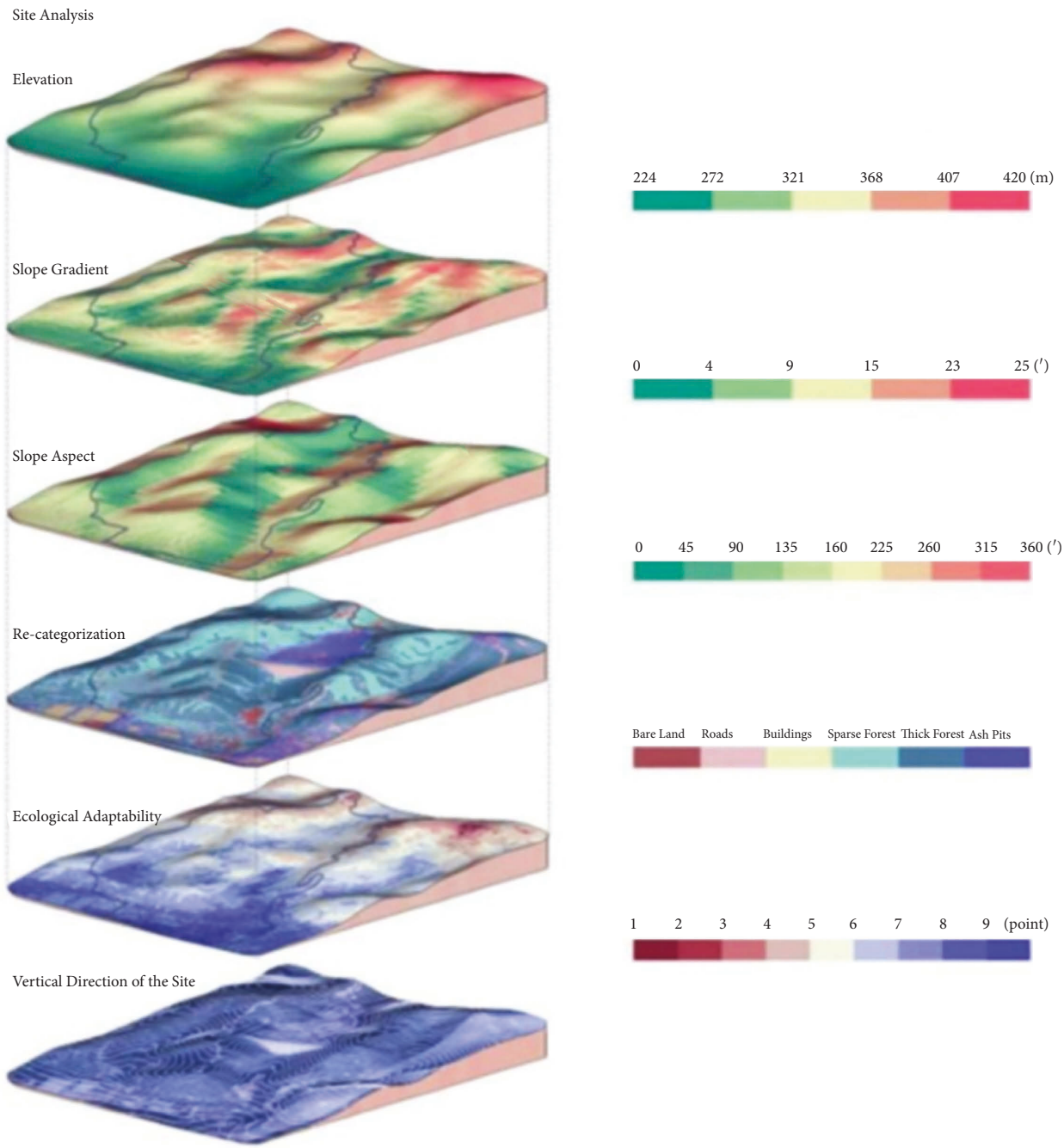


Figure 3: Diagram on the GIS analysis of the site status (extracted from ArcGIS).

with external transportation and enhancing its integration with the urban atmosphere [30–34]. The road systems are designed based on the positioning of the park in the city as well as the traffic carrying capacity subsequent to comprehensive development. In addition, the public infrastructure is established in light of the functional areas of the site as well as the internal road systems. There are four parking lots set up at the south entrance, east entrance, and west entrance, respectively. In particular, the south entrance serves as the main entrance with a large flow of traffic. Next to each of the parking lots, a tourist service center is established to improve the overall experience of services for visitors. Apart from the nodes of sightseeing, we have set up 9 additional nodes of engagement to enrich the tourist experience, which are located in the experience area of the mountain, and the three entrances located in the south, west, and east (Figure 5). Participatory activities set up include farmland planting experience, vegetable and fruit picking, interaction with pets, ancient temple worship, fishing, barbecue cooking, photography sketching, and other participatory activities, which

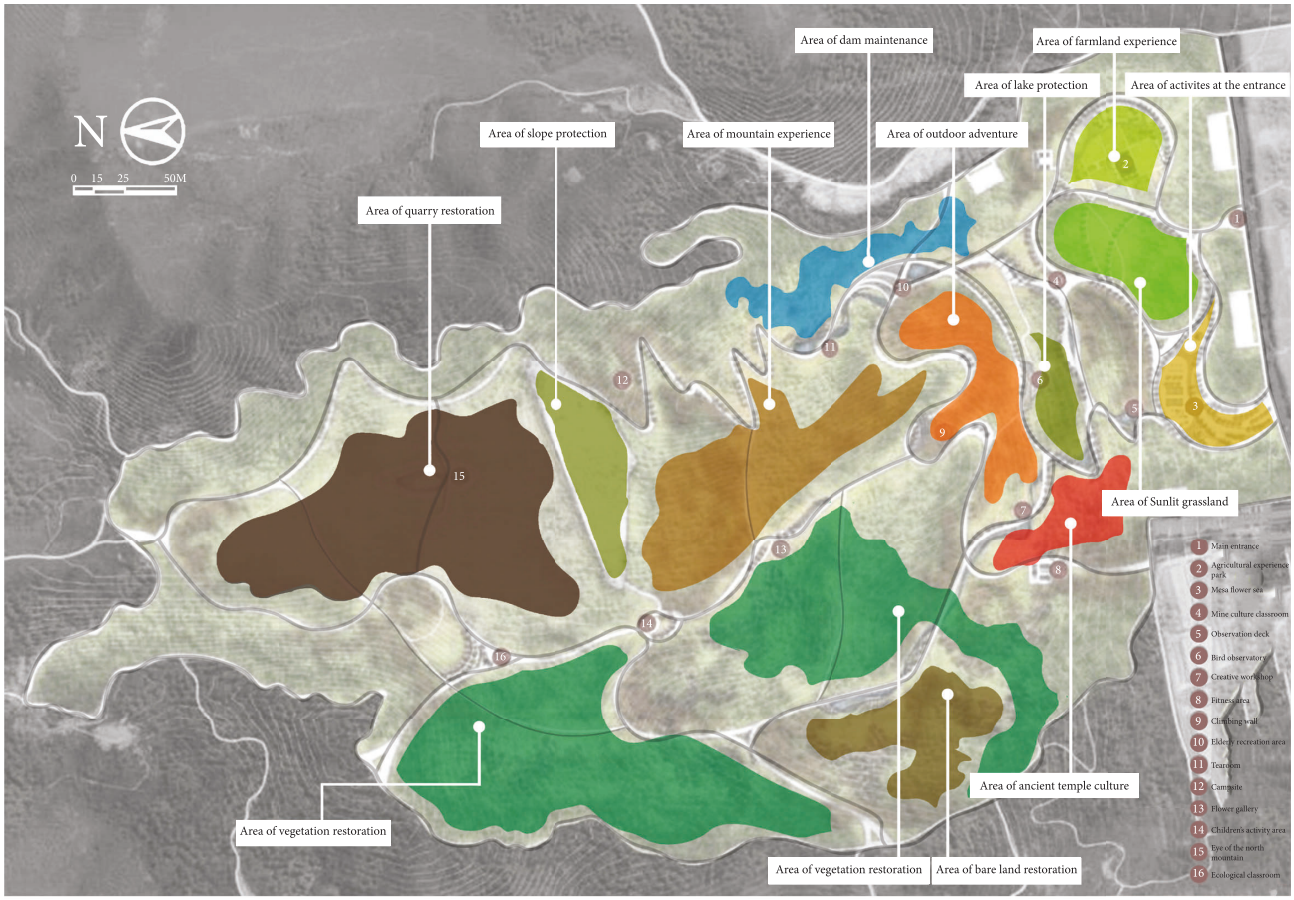


Figure 4: Overall planning and landscape layout (illustrated by the author).

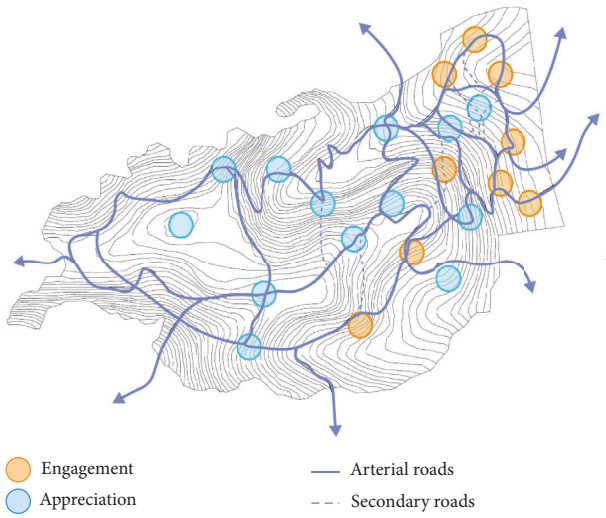


Figure 5: Map on the distribution of road systems and landscape nodes (illustrated by the author).

not only create diversified landscape nodes and sightseeing characteristics but also sort out the relationship between woodland, mountains, farmland, and water. While sorting out the four relationships of woodland, mountains, farmland, and water, we will restore the ecology and create diversified landscape nodes to create rich experiences and sightseeing characteristics.

4. Specific Strategies for Ecological Restoration

4.1. Steps of Implementing the Ecological Restoration. First, from the three aspects of ecological pressure, status, and response, assessment measures are taken to evaluate the ecological pattern or the spots, corridors, and substrates of the site of Wangzhanghe in Northern Mountain. Second, based on the current conditions of the elevation, slope gradient, slope aspect, categorization, and vertical direction of the site, evaluation and analysis are carried out on the sensitivity, adaptability, and risks of the ecological environment, whereas the primary environmental issues faced by the area are clarified to further identify the features and distribution of sensitive areas of the ecological environment. Third, based on the varying levels of sensitivity, the ecological environment is categorized with comprehensive zoning in light of the ecological sensitivity in varying areas. Fourth, numerous regulations are imposed and early warning infrastructure is built to curb pollution and alleviate damage incurred to the ecological environment. Last, starting from such aspects as the vegetation, microorganism, and chemistry, compound measures of restoration and design are taken to cope with the damaged ecological

environment so as to meet the needs of varying groups of people and to enrich the activity of the site as well as the experience of sightseeing and tourism.

4.2. Strategy for Ecological Restoration from Varying Angles. From the angle of ecological conservation, measures are taken to link the multitiered and diversified landscape environment with ecological restoration that combines natural and artificial means. We closely focus on the combination of ecology, human settlements, and culture, according to the main purpose of "green diversity, sustainable," supplemented by the function of "fitness and leisure, new experience" and the theme of "memory inheritance and new humanities," create a diversified landscape experience country park based on ecological restoration. From the angle of human settlement, the diverse tourism experience with minimal environmental intervention is integrated with the site design in consistence with the needs of varying groups of people. For example, the combination of parking lots and tourist service centers meets the needs of different groups of people. From the angle of cultural promotion, the environment for learning and disseminating ecological knowledge is established, through mine cultural propaganda, ecological education exhibitions, and other activities, enabling citizens to understand and publicize the quarry culture while sparking a new sense of pride for the culture of Jiaozuo City. From the angle of ecological restoration, the strategy for designing diversified urban country parks is put forward in combination with such theories as landscape ecology, art aesthetics, and social psychology. We realize the ecological restoration concept of "mountain, water, forest, field, lake, and grass" life community.

4.3. Strategy for Sponge City. The development of the sponge city serves the purpose of restoring and rebuilding the structures and functions of the water ecosystem, including but not limited to the absorption, storage, seepage, and purification of water when it rains and the release of the stored water when necessary, so as to improve the natural ecological balance of the city [35–39]. This study elaborates on the use of the strategy for sponge cities in dams and slope protection areas while focusing on the six aspects of seepage, retention, storage, purification, utilization, and drainage. Judging from the study, it is recommended to use the recycling system to recycle rainwater for irrigation with the collected rainwater; to adopt the design of vertical landscape and emergency discharge for alleviating the issue of urban waterlogging, to carry out the design of high-performance green space for sewage interception so as to facilitate decentralized governance and popularize scientific education; to conduct the planning of sunken green land and the design of permeable pavement for soil protection and modification; and to set up the multifunctional space for activities with seasonal landscapes and flood detention gardens. In addition, special measures of purification are taken to transform the original slope terrain prone to dispersion in water flowing with an utterly low ratio of rainwater into a terrace, thus facilitating the absorption and purification of rainwater. On the terrace, solar radiation helps to promote the light-driven conversion of pollutants, whereas sand facilitates physical adsorption and purification. Moreover, the roots of plants are used to further absorb and convert the pollutants (Figure 6).

4.4. Strategy for Plant Growing and Restoration. Phytoremediation refers to the method of plant extraction and phytostabilization to enhance the capabilities of plants in absorbing heavy metals, or the utilization of plant roots and their secretions to accumulate, precipitate, and convert heavy metal pollutants for minimizing the activity and toxicity of such pollutants [14, 40, 41]. At present, this approach is regarded as the most widely used technology with the lowest cost and no secondary pollution. Moreover, measures are taken to enhance the effect of phytoremediation, including but not limited to the agronomy, chemical induction, and inoculation of rhizosphere microorganisms, so as to impose an impact on the biomass of enriched plants and to improve the absorption capacity of heavy metals. In terms of the selection of hyperaccumulator plants, it is recommended to opt for plants with efficacy in such areas as the resistance to water and humidity, capacity of absorbing heavy metals, release of fungicides, prevention of noise and dust, fixing of carbon, and reduction of soil salinity. The main tree species used are *Platanus acerifolia*, *Cedrus deodara*, *Platycladus oricentalis*, *Tamarix chinensis*, *Albizia julibrissin*, and *Ulmus pumila*. The main use of herbal enrichment plants is Bidens pilosa, palm grass, Sedum Alfredia Hance, leaf bud rat ear mustard, and Pteris Nervosa.

4.5. Strategy for Ecological Restoration of the Ash Pit. As the core node of the whole planning and design, the damaged mining area will be repaired from the "scars" of the city to the "landscape" of the city. First, the survey is conducted and measurements are made of the ash pit as a whole, whereas the sketch of its overall shape is drafted accordingly. Based on the sketch, overall planning of layout is conducted on the establishment of water supply and drainage facilities as well as the planting of vegetation, whereas the partial excavation is carried out accordingly (Figure 7(a)). Next, the ash pit is filled with fly ash, which facilitates the management of open pit disasters and lowers the requirements for capital input at the same time (Figure 7(b)). Subsequent to the filling of fly ash, a layer of guest soil is laid on top to lower the concentration of pollutants in the soil while minimizing the contact of pollutants with plant roots. At present, this approach is widely adopted in numerous countries with evident effects (Figure 7(c)). Moreover, the site is leveraged to shape the terrain, collect rainwater, and set up the water supply and drainage facilities, thus guaranteeing the irrigation of plants in subsequent stages (Figure 7(d)). The compound treatment approach is adopted in plants and microorganisms for degrading and eliminating environmental pollutants. Given that this approach consumes less energy, has little environmental damage, and incurs lower costs, it is suitable for pollution treatment in a large area

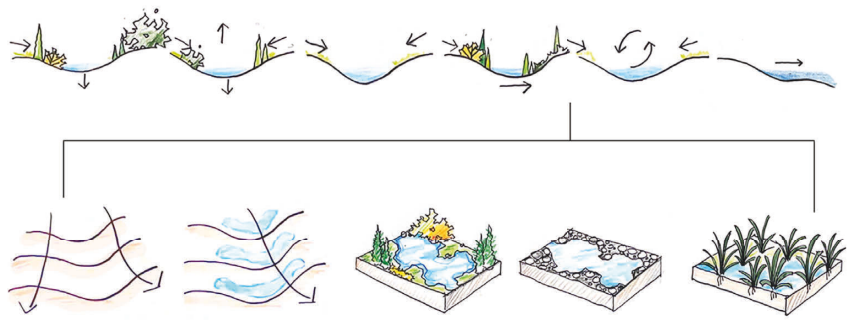


Figure 6: Strategy of sponge city (illustrated by the author).

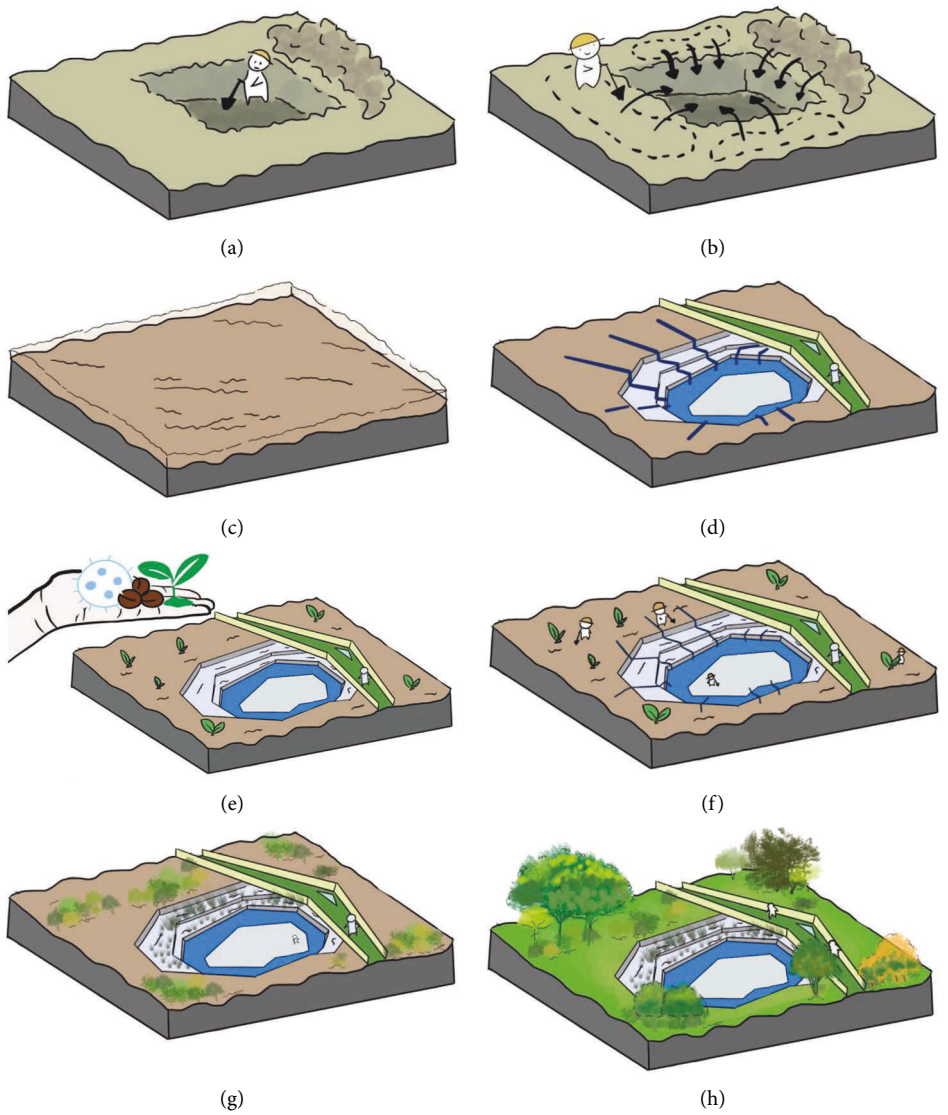
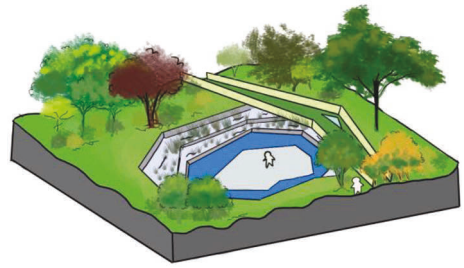


Figure 7: Continued.



(i)

Figure 7: Strategy for the ecological restoration of the ash pit from A to I (illustrated by the author).

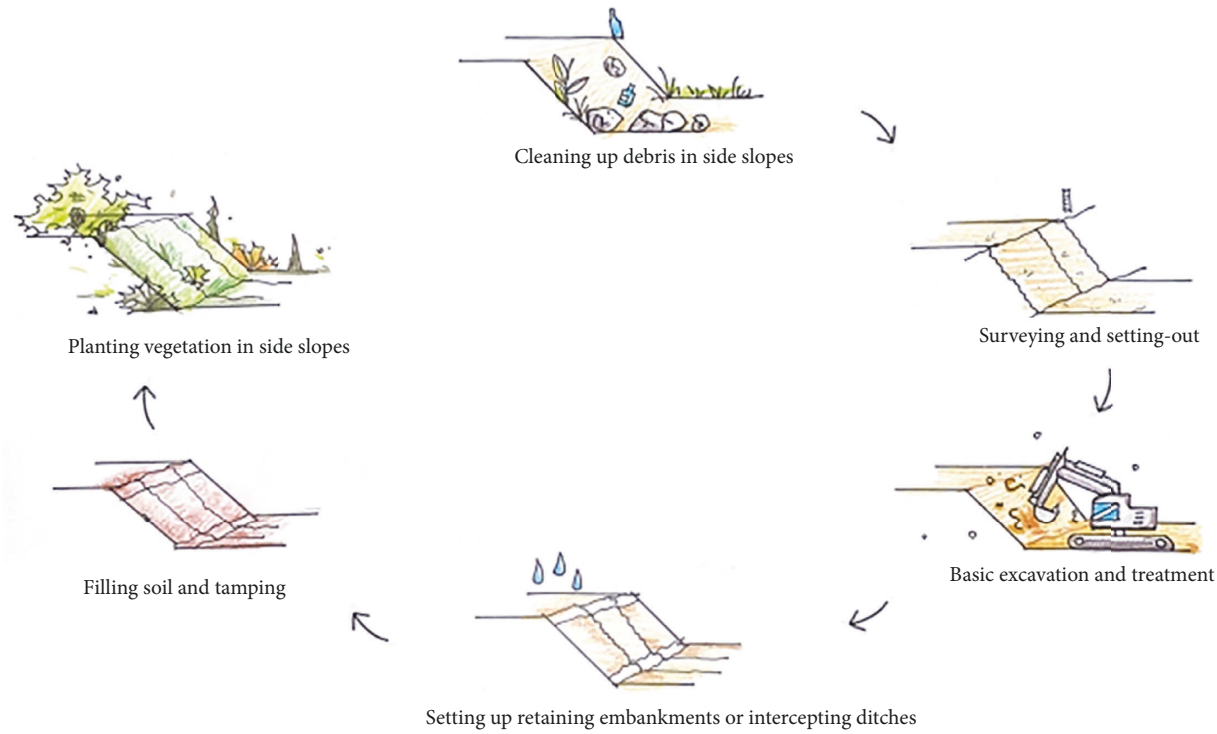


Figure 8: Mind map on the strategy for slope restoration (illustrated by the author).

(Figure 7(e)). Last but not least, we carry out local soil remediation and artificial intervention planting in the remediation area to make its natural resistance work, gradually expand the green spots, and build relevant prevention infrastructure to prevent repollution (Figure 7(f)). In terms of the effects shown in the restoration of the ash pit, the growth of herbaceous plants can be seen in the short-term; growth of shrubs can be seen in the mid-term, whereas the layers of arbors, shrubs, and grass can be gradually formed in the long term (Figures 7(g)–7(i)).

4.6. Strategy for Slope Restoration. In this study, the methods of soil engineering and vegetation planting are adopted to stabilize the slope. First, a detailed survey is conducted to figure out whether there are potential hazards undermining the stability of the slope, including but not limited to collapse, falling rocks, mudslides, landslides, water gushing, and caverns, and then the debris is cleaned up on the surface of the slope in advance so as to ensure that the slope is generally flat for vegetation restoration [42]. Second, efforts are made to review the measurement of the layout plan, to design a proper slope, and to excavate planting holes, whereas the retaining embankments or intercepting ditches are established outside the top slope to prevent surface water from scouring the slope. Last but not least, vegetation is planted on the soil-filled slopes, whereas those tree species with well-developed roots, vigorous growth, and strong resistance to disease are selected to facilitate soil and water conservation while improving the ecological landscape. The roots or stems of vegetation planted at varying positions on the slope are used to reinforce and stabilize the slope. Such vegetation is expected to help intercept rainfall, control soil erosion, promote water circulation in soil, facilitate the growth of plants, and maintain biodiversity (Figure 8).

5. Conclusion

Strategies related to ecological restoration are vital measures for speeding up the building of ecological civilization. During the construction of urban country parks, it is required to take into account the changes taking place in environmental factors and to properly formulate the schemes for ecological restoration while referring to the local ecosystem. Such measures will enable the restoration of the ecosystem from the structural to the functional aspects [43]. Compared with foreign countries, the ecological restoration of urban country parks in Chinese cities still lacks systematic and holistic guidance in terms of ecological theories, has limited practical experience in relevant fields, and is faced with numerous problems.

Judging from the perspective of ecological civilization built upon a sound ecosystem, this study centers on the overall layout and design of the ecological restoration of the site. Based on the spatial features and attributes as well as the shaping of the topography of the site, we intend to create such facilities as road systems, landscape nodes, and infrastructure to enrich the recreational entertainment of the site. In addition, we have adopted numerous strategies of ecological restoration to improve the ecological environment of the site, so as to enhance the mutual complementarity of ecological civilization and ecological restoration. Therefore, in light of the issues taking place in varying regions, we need to opt for corresponding technologies of restoration to build an urban ecological country park with green, diversified, leisurely, and health-promoting features. With these attributes, we aim to enhance the sense of engagement and experience and maintain the sustainability, stability, and continuity of ecosystems in the country park, so as to gain the benefits of ecological services at varying levels.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

A Study on Early Warning of Financial Indicators of Listed Companies Based on Random Forest

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Financial crises can have a negative impact on business operations, and in serious cases, they directly affect the survival and growth of a company. Therefore, the study of financial early warning based on financial indicators is particularly important. However, there are still some shortcomings in the current research on financial early warning, for example, it still evaluates the scoring method or only uses a single model to participate in the construction of financial early warning algorithm. In view of the above problems, this study will mainly use the random forest method combined with the decision tree algorithm to study the financial early warning problem of listed companies in China. Firstly, this paper uses the literature review method to analyse the relevant literature and generate the financial indicator system for this study. Subsequently, by collecting the financial data of A-share listed companies in China from 2013 to 2018 as the research object, the importance ranking of financial indicators was generated by using random forest modelling after data preprocessing. On this basis, CART decision tree modelling was applied to generate financial indicator early warning determination rules and analyse them. The results of the study show the importance ranking of financial indicators and the six financial warning rules based on the CART decision tree. Through this research, it is expected to achieve the objective of providing early warning for the risk of financial crisis and to provide constructive financial warning solutions for relevant stakeholders.

1. Introduction

The establishment of early warning indicators for financial risks and the exploration of related models have always been a priority in corporate financial management. As economic globalisation progresses, competition between enterprises intensifies, and the market becomes saturated, as well as the risks to the survival and development of enterprises increase. If an enterprise is not prudent enough in the internal control of financial risks, it may lead to an avalanche of financial crises. In many cases, it is the internal financial situation that has led to the downfall of a company. Therefore, early warning analysis, alerting, and control of the financial situation have become the key to the financial management of many companies.

There are many kinds of methods and models for conducting financial early warning. This paper will use the random forest method to rank the importance of a number of financial indicators on the screened financial data of listed companies in China. In addition, this paper will use the CART algorithm to analyse the factors influencing the generation of financial crises of listed companies in China based on the ranking of the importance of financial indicators. Based on the results of the final financial warning rule construction, the paper will be summarised and evaluated in order to obtain a reasonable and effective financial warning solution that is practically meaningful to the relevant stakeholders of the listed companies in China.

2. Theory and Methodology of Financial Early Warning

2.1. Theory of Financial Early Warning. In general, the financial situation of a company is a key lifeline for its sustainability. As a result, early warning of financial crises is a key element of the financial management process.

In the early stage of financial early warning research, Fitzpatrick [1] was a pioneer in introducing quantitative analysis to financial risk early warning, with his innovative classification of financial indicators and the related study of a sample divided into insolvency and noninsolvency data sets. At the same time, he used a single ratio of corporate financial data as the independent variable factor and combined it with an innovative method of multiratio fusion analysis. Beaver [2] then identified better financial warning indicators such as gearing and return on assets. This led to the development of an effective early warning model using a fusion of multiple ratios.

Subsequently, around 1980, Altman [3] designed the Z-value model, which was very new at the time and applied it to the field of financial early warning. The Z-score was generated by selecting factors as discriminatory variables to determine the financial condition (insolvency or otherwise) of a company. A few years later, Altman et al. [4] developed the ZETA model after nearly six years of research, collecting and studying financial data from over fifty insolvent companies at the time. Later, in order to overcome the shortcomings inherent in linear discriminant models, Martin [5] made an innovative use of logistic models in his study on predicting bank failures.

Around the 1990s, Zmijewski [6] followed the logistic model made by Martin and developed the complex Probit model. In addition, the study of financial early warning based on neural network technology is also worthy of attention. Lapedes and Farber [7] first applied neural network techniques to early warning and analysis of credit risk in banking practice. Several years later, Wilson and Sharda [8] also used neural network techniques in their study of corporate operating insolvency risk, building models with an accuracy of 97%. At the same time, they compared various models used to identify corporate insolvency and finally found that the neural network-based technique had some advantages.

At the beginning of the 21st century, Breiman [9] first proposed the random forest algorithm based on the basic machine learning algorithm decision trees. Since then, Richard et al. [10] has argued that the random forest algorithm has high classification accuracy, as well as the advantage of high flexibility in unsupervised learning, regression, and classification. In terms of innovation, Bernard et al. [11] proposes an innovative dynamic random forest algorithm (DRF), which is a random forest induction algorithm developed based on adaptive decision tree induction. By guiding decision tree induction to enrich existing decision trees as much as possible to enhance the sampling rate, satisfactory prediction rates are eventually obtained. Based on previous research, Hapfelmeier [12] et al. concluded that the random forest algorithm can achieve good prediction rates for this after a large number of experiments related to indicator data that need to be integrated and complex indicator correlations. In addition, in terms of neural network-based technology, Yang [13] et al. applied a forward neural network model (with a three-layer model of the output layer, hidden layer, and output layer) for early warning of financial crises of enterprises, and the results surface that the method is effective. Thereafter, Liu and He [14] optimized and built an artificial network financial early warning model.

In the last three years, research on financial early warning using data mining methods has remained popular. In 2020, Liu [15] et al. proposed a financial early warning model based on the AdaBoost strong classifier and selected 1350 groups of enterprise financial data for classification. The experimental results showed that the accuracy of the AdaBoost-based strong classifier was higher than that of the BP neural network-based weak classifier. In 2021, Jia [16] constructed a corporate financial crisis early warning model based on time series and the random forest algorithm and proposed an improved K-fold random forest algorithm, whose model accuracy improved by 1.54% compared with the traditional random forest model. In 2022, Wang [17] et al. applied the Wilcoxon rank sum nonparametric test and principal component analysis for feature engineering and used the logistic regression model to study the financial early warning of forestry listed companies in Shanghai and Shenzhen A-shares in China, and the accuracy of their model reached more than 80%.

It is clear from the above literature that financial early warning is still highly dependent on the construction of models and that the key to the construction of each model is many input financial indicators. At the same time, we can also see that random forest has significant advantages in the selection of indicators for the models. Therefore, this study aims to combine the random forest algorithm and the CART tree model in order to analyse the factors influencing the financial crisis of the listed companies in China.

2.2. Approach to Financial Early Warning. Financial early warning is a key task in the financial management of an enterprise. In the financial practice of enterprises, financial early warning usually requires the selection and setting of indicators in advance of the relevant financial data. Based on these predefined sets of indicators and according to certain judgment rules, the occurrence of financial crises is monitored and predicted in advance. The use of computer technology (e.g., decision trees, neurons, and random forests) is therefore almost always an important part of the process of detecting and forecasting financial indicators.

3. Design of the Financial Early Warning Method Based on Random Forest

3.1. Random Forest Based Indicator Selection

3.1.1. The Idea of a Random Forest. A random forest is the result of multiple optimisation of decision trees, both in terms of the integration of decision tree forests with the idea of rich randomisation. The basic principle is that, firstly, the basic elements of each random forest are both mutually unrelated decision trees $t_1(x)$ and $t_2(x)$, $t_3(x)$, ..., $t_n(x)$. Since they are called decision trees, they may contain both imprecise and efficient binomial trees and precise and inefficient multinomial trees. We then introduce our dataset

into these randomly generated decision trees to determine the classification, which we refer to as the act of building a random forest classifier. At the same time, we vote on the classification results of the relevant datasets from the many randomly generated decision trees to obtain the final classification results. In short, the purpose of building a random forest classifier is to determine which class an input dataset belongs to. The purpose of voting on the classification results is to find the classification that is chosen most often. Here, we define the total data set as $S(x) = \{S(x_{a1}, x_{a2}, x_{a3}, \ldots, x_{aF})\}_{a=1}^{N} S(x) = \{S(x_{a1}, x_{a2}, x_{a3}, x)\}_{aFa=1}^{N}$. Here, there are N subdata in the $S(x)$ dataset, and each dataset corresponds to F features as x_{a1}, x_{a2}, ..., x_{aF} etc.

Usually, the discriminatory F features $\{x_{a1}, x_{a2},..., x_{aF}\}$ is by calculating the degree of uncertainty of the sources between the different features (also known as information entropy). There are generally three decision tree methods from front to back: ID3, C4.5, C5.0, CART, whose corresponding calculated values are the information gain value, the information gain ratio value, and the Gini index value, respectively. By calculating these information entropy values, we can obtain the optimal splitting attribute at a node. If the relevant attribute value meets the discrete condition, then forking can continue. The relevant formula is as follows.

The information entropy of the total sample $S(x)$ is judged to be directly related to the purity of the source data in information theory by Shannon as follows:

$$\text{Entropy}(S(x)) = -\sum_{i=1}^{c} P_i \log_2 P_i. \tag{1}$$

In the above formula P_i is the proportion of samples of type i to the total sample $S(x)$ of the total sample. Since for the F kinds of characteristics x_{a1} , x_{a2} ,..., x_{aF} for decision bifurcation, the total sample $S(x)$ is divided into a total of k parts. The resulting calculated information entropy values as well as the information gain values are as follows:

$$\text{Entropy}(S(x_{an})) = -\sum_{j=1}^{k} \frac{|S_j|}{|S|}, \text{Entropy}(S_J), \tag{2}$$

$$\text{Gain}(S(x), x_{an}) = \text{Entropy}(S(x)) - \text{Entropy}(S(x_{an})). \tag{3}$$

Thereafter, the information gain rate discriminant, which improves on the information gain as follows, is judged with even better accuracy due to the penalty factor of information attached to its denominator.

$$\text{GainRation}(S(x), x_{an}) = \frac{\text{Gain}(S(x), x_{an})}{\text{SplitEntropy}(S(x), x_{an})}, \tag{4}$$

$$\text{SplitEntropy}(S(x), x_{an}) = -\sum_{i=1}^{a} \frac{|S_i|}{|S|} \log_2 \frac{|S_i|}{|S|}. \tag{5}$$

The Gini coefficient is a discriminant of information purity invented after the information gain rate and has higher discriminant efficiency because it is free from the calculation of the log-log function, which is as follows:

$$\text{Gini}(S(x)) = 1 - \sum_{i}^{c} P_i^2, \tag{6}$$

$$\text{Gini}(S(x), x_{an}) = \sum_{j=1}^{k} \frac{|S_J|}{S} \text{Gini}(S_j). \tag{7}$$

As the three information purity discriminants above have less influence on the final result, the Gini coefficient will be chosen as the criterion for discriminating at the random forest nodes. Finally, the random forest ends when the feature attributes have been exhausted, the decision tree has been classified to its maximum depth, the Gini coefficient has reached a previously determined threshold, and the number of data sets at the end has reached a previously given value.

3.1.2. Indicator Screening Design for Random Forests. Due to the ease of operation of the random forest, the process design consists of only an input layer and an output layer. The input data contains the number of classes F of features, the total sample set $S(x)$, the size of all decision trees Tree, the depth of the tree h, and related parameters, as well as the filtering end algorithm. The output layer contains the results of the random forest feature selection and the model built by the random forest. The specific random forest process has seven steps as follows:

Step 1: for the total data set $S(x)$, expect to generate a random forest with a total of j trees $j = 1$: nTree

Step 2: using bootstrap-based bagging sampling, repeat sampling with put-back and selection of a training set of dataset size X

Step 3: select F signs at the nodal forks of the decision tree, filter and find the best features, and then divide the data set in this way

Step 4: generate all decision trees accordingly, completing the algorithm

Step 5: calculate the probability that a given uncertain sample a and is classified as N in the test set in which test learning is performed

$$P\left(\frac{N}{a}\right) = \left(\frac{1}{n\text{Tree}}\right), \sum_{i=1}^{k} h_i\left(\frac{N}{a}\right). \tag{8}$$

Step 6 : obtaining the classification error while selecting the best category N after voting

Step 7 : return the classification results generated by the random forest and the model

3.1.3. Evaluation of Indicator Screening Results for Random Forests. The process of constructing a financial early warning model using the random forest algorithm generates two pieces of data, the OOB (out-of-bag) error rate and the AUC value under the ROC curve. The smaller the out-of-bag error rate or the higher the AUC value, the more effective the random forest model will be.

3.2. CART-Based Decision Tree Model Construction

3.2.1. The Idea of a CART Decision Tree. The core of the CART decision tree algorithm is the selection of features for the original dataset and the pruning of the decision tree after forking.

For a dataset $S(x)$ CART decision tree T constructed, a total of N feature categories are covered in the dataset, and Pj is defined as the data with feature category j as a percentage of the total dataset $S(x)$ of the probability, which can be given by the following formula:

$$gini\left(S\left(x_j\right)\right) = 1 - \sum_{i=1}^{n} P_j^2. \tag{9}$$

Sort the data set at the node $S(x)$. Classify into subsets $S(x_1)$ and subsets $S(x_2)$, whose Gini index is calculated as follows:

$$gini\left(S(x_1), S(x_2)\right) = \frac{|S_1|}{S} gini\left(S_1\right) + \frac{|S_2|}{S} gini\left(S_2\right). \tag{10}$$

After selecting the best feature indicator and the value of the feature indicator at the bifurcation node by the above formula, the data set is $S(x)$. If the Boolean value of a piece of data is true, the data will be placed in the left leaf node of the bifurcation tree at that node, and if it is false, it will also be placed in the right node. By calculating and placing the data in this order, a CART decision tree can eventually be constructed.

3.2.2. Design of the CART Decision Tree. The data set is now defined $S(x)$. A total of N data exist for each category of indicators. The algorithm consists of a total of input and output layers. Among the data that should be input are the total data set $S(x)$ and relevant threshold conditions. The specific process steps are as follows:

Step 1: enter the relevant dataset data and associated threshold conditions.

Step 2: calculate the total data set at the node $S(x)$ of the overall Gini index, meanwhile, calculate the corresponding sample eigenvalues K based on different sample features K.Subsequently, this is followed by dividing the datasets $S(x_1)$ and $S(x_2)$ according to the Boolean case of the sample dataset with K features and the overall eigenvalue K,and then calculating the Gini index after the division.

Step 3: after all features with K and the feature value of k, the feature with the smallest Gini index and its eigenvalue are selected and used as the node segmentation indicator to assign the data.

Step 4: repeat steps 1 to 3 until the stop building condition is met.

Step 5: return the classification results from the CART decision tree and the model.

3.2.3. Evaluation of the Results of the CART Decision Tree. As the CART decision tree is constructed, the corresponding confidence values are calculated. In layman's terms, the confidence level reflects how trustworthy the tested data features in the total data set are compared to the tested values. It can be interpreted as both the accuracy and reliability of the algorithm. The higher the confidence level of an algorithm or rule, the better the prediction of the system.

4. Example Analysis of Financial Early Warning Based on Random Forest

4.1. Selection of the Sample. The aforementioned method of determining the financial crisis of the listed companies in China has been described in detail at this stage of the consensus of the academic community and the security industry. Therefore, this paper adopts the indicator of "whether a listed company is on the ST warning board" as the basis for judging whether a company is in financial crisis. Companies on the ST warning board (including ST companies and ∗ ST companies) are considered to be in financial crisis, while companies not on the ST warning board are considered to be in financial health. Generally speaking, a company will only be placed on the ST Alert if its net asset value per share is lower than its value per share in the market, and if the company's annual reports for two consecutive financial periods show consecutive losses (i.e., the net profit of the company's financial statements for two consecutive years is less than the total cost of ownership).

In this paper, the relevant financial data of all A-share listed companies from 2013 to 2018 were collected from the Wind database, and the data of all ST companies (148 companies in total) in these six years were extracted and sorted. Subsequently, in order to avoid the impact of data imbalance (both too few ST companies) on the subsequent experiments, 302 non-ST companies in the A-share market from 2013 to 2018 were randomly selected to jointly construct a data pool of A-share listed companies in China (a total of 450) in this paper.

4.2. Determination of Financial Indicators. By combining the statistics of the indicator results of the financial early warning indicator system in the literature reviewing process (check Table1) and the analysis of specific financial indicators of A-share listed companies in China, we finally identified a total of 24 financial indicators to be used in the random forest model. We finally determined a total of 24 financial indicators (check Table 2) of A-share listed companies in China to participate in the construction of the random forest model, and the specific indicators are listed in the following table.

Table 1: Actual financial indicators used.

Financial indicators	Variables
Gross margin of sales	Grossprofitmargin
Net sales margin	Netprofitmargin
Return on net assets	roe_avg
Total return on assets	roa2
Current ratio	Current
Quick ratio	Quick
Total equity/liabilities attributable to shareholders of the parent company	Equitytodebt
All debt/EBITDA	Tltoebitda
Net cash flows from operating activities/total liabilities	Ocftodebt
Net profit (year-on-year growth)	Yoyprofit
Total assets (year-on-year growth)	yoy_assets
Inventory turnover rate	Invturn
Accounts receivable turnover ratio	Arturn
Current asset turnover ratio	Caturn
Fixed asset turnover rate	Faturn
Total asset turnover ratio	assetsturn1
Cash received from sales of goods and services/operating income	Salescashintoor
Net cash flow per share	Cfps
Corporate free cash flow	Fcff
Gearing ratio	Debttoasset
Equity attributable to shareholders of the parent company/all invested capital	Equitytototalcapital
Earnings per share (basic)	eps_basic
Earnings per share (diluted)	eps_diluted
Net assets per share	Bps

4.3. Data Standardisation of Financial Indicators. Firstly, since the missing values account for a small proportion of the total data and are numeric, we can usually fill in missing values with a mean value. In addition, since the data are in line with normal distribution. The principle of missing value filling proposed by Anderson [18] et al. is that "under normal distribution, the sample mean is the best possible value to be estimated." Therefore, in order to ensure the integrity of the experimental data and the reasonableness of the results as far as possible, filling the mean value is the best solution at this stage.

At the same time, as the final financial indicators identified in this paper have a large number of data lines and the data vary greatly in order of magnitude, a data standardisation operation should be performed prior to data analysis. If such raw data with widely different data characteristics are directly operated, it will cause the final results to be biased towards data-based indicators in order to lead to poor model building results.

There are many methods of data normalisation, such as extreme value normalisation, Z-score normalisation, normalisation, and so on. Each of them has its own corresponding advantages. Due to the more constrained and effective nature of polar normalisation, we will now focus on polar normalisation. Extreme value normalisation, also known as extreme value difference normalisation, is the process of deflating data to between 0 and 1 by varying it by equal proportions. For data columns $x_1, x_2, x_3, \ldots, x_n$, extreme value normalisation is performed to produce a normalised data column $y_1, y_2, y_3, \ldots, y_n$, and the transformation formula is as follows:

$$y_i = \frac{x_i - \min\limits_{1 \le j \le n}\{x_j\}}{\max\limits_{1 \le j \le n}\{x_j\} - \min\limits_{1 \le j \le n}\{x_j\}}. \tag{11}$$

The raw data will fall between 0 and 1 when transformed by polar normalisation while eliminating its original dimensional limits and the effects of different orders of magnitude and facilitating the subsequent conduct of the test.

4.4. Results and Analysis of Random Forest Modelling

4.4.1. Optimization of Parameters for Random Forest Modelling. Due to the advantage of random forest in being able to handle a large number of features well, this paper puts all the financial indicators identified above into the random forest algorithm to construct the corresponding financial warning model. The 24 identified financial indicators such as gross sales margin, net sales margin, return on net assets, return on total assets, and current ratio are used as independent variables, while whether the listed company is placed on the ST warning board (hereinafter referred to as ST, with non-ST company value being 0 and ST company value being 1) is used as the dependent variable for prediction. On top of this, 70 per cent of the sample data set was divided into training samples, and the remaining 30 per cent was divided into test samples to participate in the construction of the random forest model.

Subsequently, we obtained the in-bag error rate of the model corresponding to each mtryvalue by traversing all mtry (which refers to both the number of random variables

Table 2: Statistics table of the financial warning indicators.

Indicator	Wu [22]	Zhang [23]	Zhou [24]	Meng [25]	Zhang [26]	Yang [27]	Wu [28]	Song [29]	Yang [30]	Lu [31]	Fu [32]	Wang [33]	Feng [34]	Chen [35]	Wang [36]	Counting
Inventory turnover ratio	√	√	√	√	√	√	√	√	√	√		√	√	√	√	14
Current ratio	√		√	√	√	√	√	√	√	√	√	√	√		√	13
Accounts receivable turnover ratio	√		√	√	√	√	√	√	√	√		√	√	√	√	13
Gearing ratio		√	√	√	√	√		√		√	√	√	√	√	√	12
Quick ratio	√		√	√	√	√	√	√	√	√			√		√	11
Total assets growth rate	√	√	√	√		√	√		√			√	√	√	√	11
Total assets turnover ratio	√		√	√	√			√	√	√		√	√	√	√	11
Return on net assets			√		√	√		√	√	√			√	√	√	9
Fixed assets turnover ratio			√	√	√		√		√			√	√		√	8
Current assets turnover ratio				√	√	√	√	√		√		√			√	8
Return on total assets				√		√	√	√			√	√	√		√	8
Interest cover multiplier	√						√		√				√	√	√	6
Cash ratio		√	√				√	√		√					√	6
Net profit growth rate			√	√		√				√				√	√	6
Gross sales margin				√	√		√	√		√						5
Return on total assets			√		√				√					√		4
Earnings per share			√		√		√			√						4
Net assets per share			√		√					√					√	4
EBIT debt ratio					√			√	√	√						4
Current liabilities to total liabilities			√		√			√			√					4
Operating profit margin						√			√	√					√	4
Total net asset margin							√			√			√		√	4
Growth rate of revenue from main business	√									√		√				3
Cash flow from operating activities per share				√	√				√							3
Net sales margin					√		√			√						3
Percentage of long-term debt	√						√	√								3
Profit margin from main business	√											√				2
Growth rate of shareholders' equity	√												√			2
Cash ratio from sales		√		√												2
Operating cash flow growth rate		√								√						2
Interest payment multiplier			√									√				2
Cash current liabilities ratio			√						√							2
Shareholder equity ratio				√								√				2
Shareholder equity to debt ratio					√								√			2
Operating cash debt ratio					√								√			2
Equity multiplier					√			√								2
Current assets to total assets ratio					√			√								2
Cost margin						√	√									2
Operating income growth rate						√							√			2

Table 2: Continued.

Indicator	Wu [22]	Zhang [23]	Zhou [24]	Meng [25]	Zhang [26]	Yang [27]	Wu [28]	Song [29]	Yang [30]	Lu [31]	Fu [32]	Wang [33]	Feng [34]	Chen [35]	Wang [36]	Counting
Net asset growth rate						√								√		2
Net profit total operating income ratio							√	√								2
Net cash flow from operating activities operating income ratio							√	√								2
Total operating income							√	√								2
Net cash flow from operating activities total liabilities ratio							√	√								2
EBITDA								√			√					2
Operating profit growth rate									√				√			2
Equity ratio										√					√	2

```
> print (err)
 [1] 0. 043258226 0. 010354549 0. 004983789 0. 004343646 0. 004224496 0. 004666905 0. 004177031 0. 003686504 0. 004289552 0. 004221901 0. 004164435 0. 003835454
[13] 0. 004105213 0. 003911085 0. 003952671 0. 004096224 0. 004241499 0. 003981544 0. 004461810 0. 004099474 0. 004251103 0. 004229795 0. 004324168 0. 004775342
[25] 0. 004663714 0. 004272235 0. 004845236 0. 005055579 0. 005583973 0. 005767815 0. 005177871
```

Figure 1: Results of mtry value traversal for random forest parameter search.

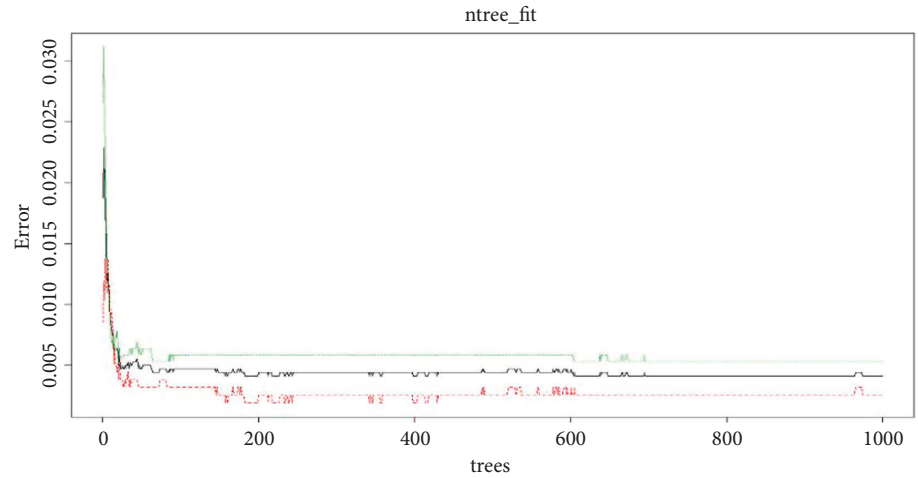

Figure 2: Results of ntree value traversal for random forest parameter search.

in the process of constructing a random forest) in the range of 1 to 24. As shown in Figure 1, the eighth modelled in-bag error rate of the parameter search reaches the lowest value, i.e., when the mtry value is 8, the in-bag error rate is 0.0036, which is the lowest value. At the same time, the in-bag error rate for subsequent iterations increases sequentially, so the optimal value of mtry for this model is 8.

Similarly, we modelled and traversed a range of ntrees (i.e., the number of decision trees in the random forest construction process) again at the lowest in-bag error rate mtry value (both 8) above to obtain a graph of the change in the in-bag error rate of the model as the ntree value changed. As shown in Figure 2, the in-bag error rate tends to stabilise when the ntree value is greater than 800.

Through the parameter search process, we found that either too high or too low mtry values will affect the final random forest prediction. At the same time, a high ntree value will cause a rapid increase in model complexity and affect the computational efficiency, while a low ntree value will directly affect the model performance. The result of the above parameter search is that the mtry value is 8 and the ntree value is 800, and the error rate of the random forest model constructed in this paper is the lowest and the best.

4.4.2. Random Forest Model Results. Using the final optimisation results of the above algorithm for the mtry and ntree values, we can determine that the best prediction efficiency of the random forest is achieved when the mtry value of the proposed model is 8, while the ntree value is 800 and is therefore modelled with these optimal parameters. Figures 3–5 show the final results of random forest modelling.

At the same time, the results of the R-language random forest operations in Figure 3 show that when the random

```
        OOB estimate of  error rate: 8.41%
Confusion matrix:
    0  1 class.error
0 192 15  0.07246377
1  11 91  0.10784314
```

Figure 3: Results of R code for random forest.

forest-based financial early warning model is constructed with the settings described above, the out-of-bag data error rate of the final model is 8.41%. From the perspective of the out-of-bag error rate, this random forest model has excellent prediction results.

The final ranking of the metrics generated according to the random forest algorithm takes two forms, one of which, the left-hand graph in Figure 4, is composed according to mean decrease accuracy (MDA). This evaluation scale is generated based on the out-of-bag error rate (OOB). Under this measure, the horizontal coordinate indicates the extent to which the prediction rate of the constructed model decreases when a variable is replaced with a random number. Thus, if the value of an indicator is larger in this indicator ranking form, it indicates that the level of the indicator is more important. Secondly, the right-hand panel of Figure 4 is constructed on the basis of the mean decrease Gini. This evaluation scale is based on the Gini coefficient. The horizontal coordinate indicates the differential impact of a feature on the observed training values at the nodes of the random decision tree when it is replaced. Similarly, a larger value of the horizontal coordinate of a feature indicator indicates that the feature is more important.

One of the evaluation rules based on mean decrease accuracy is based on the out-of-bag error rate (OOB ERROR), which embodies the core bagging algorithm idea of the random forest algorithm. It ensures that the distribution

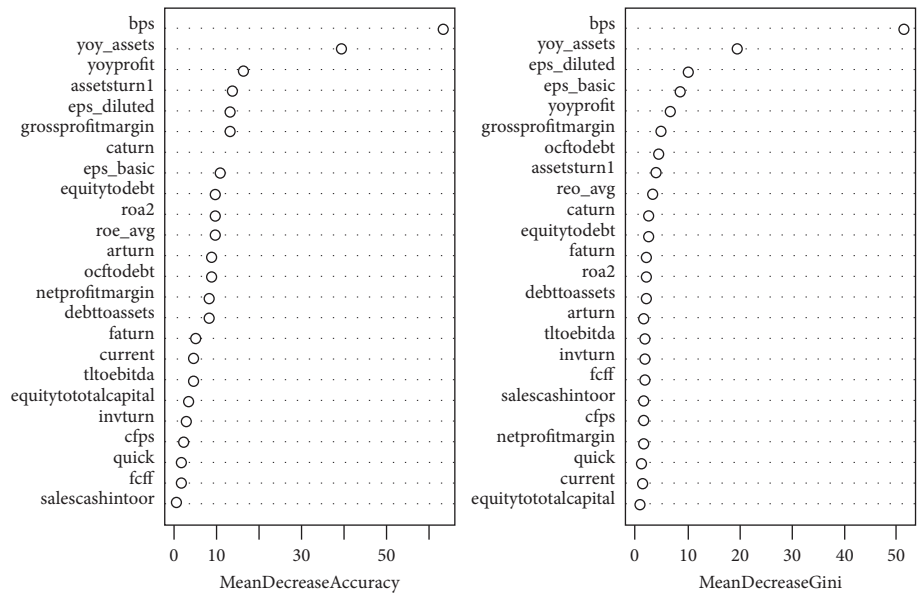

Figure 4: Ranking the importance of indicators in random forests.

of the data after feature replacement is infinitely close to the original (with both put-back resampling). In contrast, the mean decrease Gini-based evaluation rule is based on the binomial distribution idea of the CART algorithm, which is more incompatible with the overall idea of the random forest algorithm. Therefore, the importance ranking of financial indicators based on mean decrease accuracy is more scientific. The results of the specific indicator importance ranking are as follows: (1). net assets per share; (2). total assets (year-on-year growth rate); (3). net profit (year-on-year growth rate); (4). total asset turnover ratio; (5). earnings per share (diluted).

Figure 5 shows the ROC plots for the final random forest financial early warning model of this paper. As can be seen, the AUC value of the financial early warning model constructed in this paper is 0.909, which is at a fairly high value level. Therefore, from the perspective of the ROC curve, this model has a very high predictive performance.

Taken together, the financial early warning model constructed in this paper has a low out-of-bag error rate (OOB ERROR = 8.41%) as well as a very high AUC value (AUC = 0.909).

The OOB rate for the risk evaluation of real estate projects using the random forest algorithm by Li and Shenjiang [19] et al. is 10.53%. The OOB rate for the financial failure prediction of the listed companies using the random forest algorithm by Zhou [20] et al. is 26.37%. Zhang [21] used the shuffle-based random forest technology to establish an AUC value of 0.8666, while he used the embedded-based random forest technology to establish an AUC value of 0.8404.

In addition, among the latest financial early warning research results in the past three years, Liu [15] et al. used a financial early warning model based on the AdaBoost strong classifier with an accuracy of 96%, which was higher than the accuracy of the weak classifier model based on the BP neural

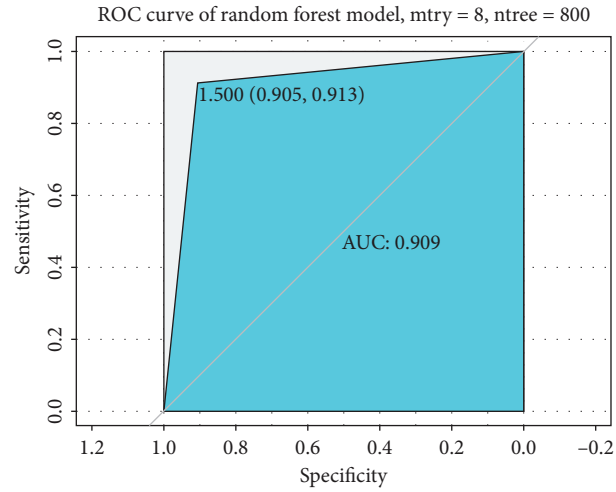

Figure 5: Plot of ROC results for random forest.

network (91.54%). Jia [16] used an improved K-fold random forest algorithm based on time series for financial early warning with an accuracy of 90.327%. The final accuracy of Wang and Lu[17] financial early warning modelling using a logistic model and a PCA method based on the Wilcoxon rank sum nonparametric test for processing financial data of A-share listed forestry companies was 86.7%.

Therefore, the OOB of the financial early warning model of the listed companies in this paper is 8.41%, and the AUC of this model is 0.909, which can be concluded that the model possesses a good predictive effect.

4.5. Discovery of Financial Warning Rules Based on CART Decision Tree Construction. Through the screening process for the listed companies' financial data columns after the standardisation process above, we imported these data into

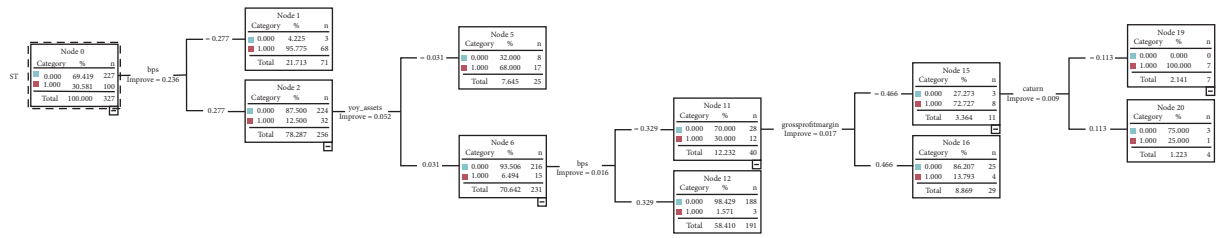

Figure 6: CART decision tree diagram.

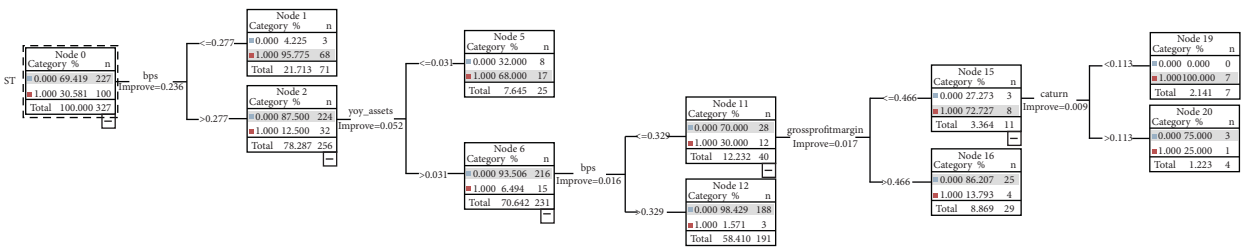

Figure 7: CART decision tree diagram.

the SPSS modeler software for rule building based on the CART decision tree, and after computing, the CART tree diagram was drawn as shown in Figure 6, in which the four financial indicators of net assets per share, total assets (year-on-year growth rate), gross sales margin, and current assets turnover ratio were retained down to participate in the construction of the CART decision tree (check Figure 7).

The early warning rules based on the CART decision tree and their confidence values are shown in Figure 6. There are three rules for determining that a company is in financial crisis (i.e., the company is ST), and at the same time, there are three rules for determining that a company is financially healthy (i.e., the company is not ST).

The rules for determining when an enterprise is in financial crisis are analysed as follows: firstly, an enterprise is considered to be in financial crisis when its net assets per share (normalised by the extreme values described above and the same for all the indicators below) are less than or equal to 0.277. The confidence level for this rule was 95.8%, and 71 data items were used for training. Secondly, a company was identified as being in financial crisis when its net assets per share were greater than 0.277, but its total assets (year-on-year growth rate) were less than or equal to 0.031. The confidence level of this rule is 68%, and there are 25 data items involved in the training; thirdly, when the net asset per share of an enterprise is greater than 0.277 and its total assets (year-on-year growth rate) are greater than 0.031, but its net asset per share is less than or equal to 0.329, its gross sales margin is less than or equal to 0.466, and its current asset turnover ratio is less than or equal to 0.113, then the enterprise is considered to be in financial crisis. This rule has a confidence level of 100% and a total of seven data items were involved in the training.

The rules for determining the financial health of an enterprise are as follows: first, when the net asset per share of an enterprise is greater than 0.277 and less than or equal to 0.329, and its total assets (year-on-year growth rate) are greater than 0.031, gross sales margin is less than or equal to 0.466, and current asset turnover ratio is greater than 0.113, then the enterprise is considered to be financially healthy. The confidence level of this rule is 75%, and a total of 4 data items are involved in the training. Secondly, when the net asset per share of a company is greater than 0.277 and less than or equal to 0.329, and the total assets (year-on-year growth rate) are greater than 0.031 and the gross sales margin is greater than 0.466, then the company is considered to be a financially healthy company. The confidence level of this rule is 86.2%, and a total of 29 data items are involved in the training. Thirdly, when the net assets per share of a company are greater than 0.329 and the total assets (year-on-year growth rate) are greater than 0.031, then the company is considered to be a financially healthy company. The confidence level of this rule was 98.4%, and a total of 191 data items were involved in the training.

5. Conclusion

In view of the actual situation of the financial data of the listed companies in China, we constructed a financial early warning model based on the random forest algorithm and the CART decision tree algorithm. The method uses the random forest algorithm to rank the importance of many financial indicators, which can significantly improve the predictive effect of subsequent modelling and is in line with the principles underlying the establishment of financial warning models. In addition, the quantitative analysis of the filtered indicators using the CART decision tree algorithm to determine the decision thresholds for specific financial warning indicators can significantly improve the operability of the model. The results of the study show that the method has an excellent predictive effect. At the same time, the method can provide the listed companies' management and

investors with a prediction model that can quantify the financial situation of the listed companies.

Data Availability

The Wind China Listed Companies Dataset was used to support the findings of this study.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Decision-Making Mechanism of Cooperative Innovation between Clients and Service Providers Based on Evolutionary Game Theory

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With the maturity of the service outsourcing market and the development of business relations, the core of outsourcing is shifting from transactional services to risk sharing and value creation. The client and service provider have an increasing interest in service innovation. Although cooperative innovation between them has many benefits, the two parties do not necessarily establish a cooperative innovation relationship. Regarding this issue, an evolutionary game focusing on client-service provider cooperative innovation behavior is constructed and solved. Based on the results and a corresponding numerical simulation, the decision-making mechanism of the cooperative innovation behavior is studied, and suggestions are provided regarding how to promote cooperative innovation. The results show that the benefits of both the client and service provider when they innovate cooperatively being greater than that when they innovate independently cannot guarantee that the system will certainly evolve to a stable state in which both parties adopt a cooperation strategy. However, as long as a condition in which either party gains more than zero when it innovates independently is established in addition to the preceding condition, the system will certainly evolve to a stable state in which both parties adopt a cooperative strategy. The following measures can be taken to promote client-service provider cooperation: improving the initial probabilities of the two parties choosing the cooperative strategy; increasing the innovation benefit when one party innovates independently; reducing the innovation cost and spillover coefficient when one party innovates independently; increasing the penalty when one party cooperates and the other party does not; decreasing the innovation cost when the two parties both choose the cooperation strategy; increasing the excess benefit when the two parties both cooperate; setting reasonable benefit distribution and cost sharing proportions.

1. Introduction

With the maturity of the service outsourcing market and the development of business relations, the core of outsourcing is shifting from transactional services to risk sharing and value creation [1]. The client and service provider have an increasing interest in service innovation. For clients, the cost-effectiveness due to transactional labor arbitrage is gradually weakening, and they hope to obtain new advantages as well as operational and even strategic benefits through service innovation [2]. Meanwhile, delivering innovative services as a means to strengthen client relations and improve client dependence as well as improve their own competitiveness is becoming a common practice for service providers [3].

Service innovation occurs in the service system. Thus, the characteristics of service, especially the synchronicity of production and consumption [4] and value cocreation [5], mean that the client and service provider must participate or invest in service innovation together [6]. Cooperative innovation between the two parties not only is conducive to service providers delivering high-level innovative services and then improving the overall performance of clients [7] but also helps the two parties establish cooperative partnerships and obtain long-term benefits [8].

Although cooperative innovation can bring many advantages, the client and service provider rarely form a cooperative innovation relationship in reality [9]. For the client, weak innovation awareness, lack of funds, and other

factors hinder innovation [10]. For the service provider, the fear that it will be unable to obtain the corresponding benefit but, rather, have to pay the innovation cost reduces the willingness to innovate [11]. In addition, outsourcing contracts often require the service provider to provide services in strict accordance with service level agreements, which greatly shrinks its innovation space [12]. Moreover, even if the synergy effect generated from cooperation stimulates both parties to invest in innovation activity, the spillover effect induces the "free rider" phenomenon, in which one party cooperates but the other does not [13].

Our research objective is to explore how the client and service provider can form a stable cooperative innovation relationship in the process of service innovation. Based on the evolutionary theory, we see the cooperative innovation between the two parties as a dynamic evolution process; the two parties constantly adjust their strategies and make their decision in the evolutionary system. We analyze the inner mechanism of the two parties' strategy choice, as well as the evolutionary trajectory and trend of the two parties' cooperative behavior. Specifically, we address the following questions:

(1) Under what conditions will the client and service provider choose to innovate or not?

(2) How will the system parameters influence the evolution system to an ideal (stable) state in which both the client and service provider choose the cooperation strategy?

Our analysis reveals that the benefits of both the client and service provider when they innovate cooperatively being greater than that when they innovate independently cannot guarantee that the system will certainly evolve to the ideal state. However, as long as the condition that either party gains more than zero when it innovates independently is established along with the preceding state of affairs, the system will certainly evolve to the ideal state.

We also find that the increase of the following factors is helpful for the system to evolve to the ideal state: the initial probabilities of the two parties choosing the cooperative strategy, the innovation benefit when one party innovates independently, the penalty when one party cooperates and the other party does not, and the excess benefit when the two parties both cooperate. In addition, the following measures can be taken to promote client-service provider cooperation: reducing the innovation cost and spillover coefficient when one party innovates independently, decreasing the innovation cost when the two parties both choose the cooperation strategy, and setting reasonable benefit distribution and cost sharing proportions.

The study is organized as follows. We review the related literature in the next section. In the subsequent section, we illustrate the problem description and formulation. We conduct the evolutionary game analysis in Section 4 and numerical simulation under double equilibrium in Section 5. We then summarize our work and conclude by providing key managerial insights. The source code is presented in Appendix A.

2. Literature Review

This study builds upon two major streams of research: the cooperative innovation between clients and service providers and the evolutionary game theory.

2.1. Cooperative Innovation between Clients and Service Providers. Many scholars have investigated cooperative innovation between clients and service providers. Whitley and Willcocks [14] proposed a cooperative innovation framework including four steps (leadership, contract, organization, and implementation) and illustrated how the framework could be applied to the practice process based on three actual cases of information technology and business process outsourcing. Sutter and Sutter [15] studied how clients and logistics service providers carry out cooperative innovation projects and obtain benefits from them. Lacity and Willcocks [16] proposed the concept of dynamic innovation and studied how clients and service providers cultivate dynamic innovation together. Kranz and Leonhardt [17] studied how knowledge transfer and successful cooperative innovation in the context of information service outsourcing affect clients' employees' ability to find entrepreneurial opportunities and start businesses. Nardelli and Broumels [18] analyzed how various stakeholders manage the innovation process to achieve value cocreation. Sinkovics et al. [7] studied how to realize value cocreation between clients and logistics service providers. Wang et al. [19] introduced the concept of collaborative innovation in the context of logistics service outsourcing, analyzed what actions should be taken to achieve collaborative innovation, and discussed the impact of collaborative innovation on logistics service performance and client market performance.

The previous research mainly examines the implementation process of cooperative innovation between clients and service providers as well as the impact of important factors on the implementation process, while introducing specific guidance frameworks and implementation methods. A small number of studies focus on the benefit that successful cooperative innovation can bring to the client, the service provider, and the relationship between the two. However, there is a lack of research on the decision-making mechanism of cooperative innovation behavior between clients and service providers and how to promote such cooperative innovation.

2.2. Evolutionary Game Theory. Being different classical game theory, which assumes that the participants are all completely rational [20–22], evolutionary game theory focuses more on the dynamics of strategy change [23]. In the evolutionary game process, participants are bounded rationally and dynamically adjust their strategies based on observing and learning other participants' strategy [24]. Evolutionary game theory has been deeply developed and widely used in many fields, such as social physics [25], computer science [26], and management [27]. For instance,

Helbing et al. [28] employed evolutionary game theory to analyze the crime-fighting problem. Deng et al. [26] studied the information fusion and combination of evidence by utilizing evolutionary game theory. Li et al. [29] carried out a research on the green behavior of construction and demolition waste recycling units with and without remanufacturing capabilities. Long et al. [30] investigated the effect of green development performance and the government's reward–penalty mechanism on the decision-making process of production and recycling units by using evolutionary game theory. Wang et al. [31] utilized evolutionary game theory method to study how to promote the developments of hydrogen powered vehicle, hydrogen production, and solar powered vehicle industry in China. Utsumi et al. [32] investigated whether a resource-storing mechanism effectively propels based on cooperation evolutionary game theory. Wang et al. [33] employed a model based on evolutionary game theory to investigate crisis communication on social media. Pan et al. [34] adopted evolutionary game theory to analyze the sustainability of professional liability insurance market in the construction industry.

As rational "economic entities," clients and service providers determine whether to cooperate in service innovation based on their payoffs [35]. In fact, the process of cooperative innovation is a long-term one, and the two parties constantly adjust their strategies of cooperating or not under the premise of limited rationality [36]. Their cooperative innovation behavior dynamically evolves over the course of a long-term game, and the corresponding decision-making process is actually a dynamic evolution process [37]. Therefore, this study utilizes evolutionary game theory as the theoretical basis to conduct the research.

To the author's best knowledge, no study has been conducted on decision-making mechanism of cooperative innovation between clients and service providers based on evolutionary game theory. To fill this gap, this paper constructs an evolutionary game model of the cooperative innovation behavior of clients and service providers, explores the decision-making mechanism of their cooperative innovation behavior, reveals the internal mechanism of the strategic choice of clients and service providers' cooperative behavior, analyzes how clients and service providers can form a stable cooperative relationship in the process of service innovation, and provides management suggestions regarding how to promote client-service provider cooperative innovation.

3. Problem Description and Formulation

We consider two groups: one of clients and one of service providers. One client and one service provider are randomly matched in each iteration to play a game. The client and service provider are bounded rationally and constantly change their strategies through learning until they reach an equilibrium [38]. The strategy set of client and service provider in the process of service innovation is both (cooperation and noncooperation). The party that chooses a cooperation strategy is required to invest time and effort in innovation activity and exchanges knowledge and information. In contrast, choosing a noncooperation strategy means that the party does not conduct or participate in innovation activity.

We make the following basic assumptions.

Assumption 1. When both parties adopt the noncooperation strategy, neither party invests in innovation activity, and such activities do not occur. Both parties only obtain their own basic benefit on the basis of the signed service contract between them: the client accepts services provided by the service provider, and the service provider receives remuneration from the client. The basic benefits of the client and service provider are π_c, π_s, respectively.

Assumption 2. If one party adopts the cooperation strategy, it makes an investment in innovation activity. When innovation activity occurs, both parties can obtain additional benefits through it. In this case, the total benefit obtained by both parties is the sum of the basic benefit and additional benefit.

Assumption 3. When both parties adopt the cooperation strategy, the internal knowledge of the client and the professional ability of the service provider are complementary [39], resulting in a "$1 + 1 > 2$" synergy effect [40] and generating innovation benefit (excess benefit) π', but the two parties must share innovation cost C'.

By adopting the revenue sharing and cost sharing mechanisms [41], the additional benefits obtained by the client and service provider through innovation activity are $\mu\pi' - \theta C'$, $(1-\mu)\pi' - (1-\theta)C'$, and the total benefits obtained by them are $\Pi_{cc}^{c} = \pi_c + \mu\pi' - \theta C'$, $\Pi_{cc}^{s} = \pi_s + (1-\mu)\pi' - (1-\theta)C'$, where μ, $1-\mu$ are the benefit distribution proportions of the client and service provider, and $\theta, 1-\theta$ are their cost sharing proportions.

Assumption 4. When one party adopts the cooperation strategy while the other party does not, the party adopting the cooperation strategy performs innovation activity independently. According to the logic of the spillover effect, the party that adopts a non-cooperative strategy gains a spillover benefit [42]. For example, when the client performs innovation activity while the service provider does not, the service provider can experience and learn the innovation achievements and apply them to the other clients, thus obtaining spillover benefits. When the service provider performs innovation activity and the client does not, the innovative achievements can not only optimize the service processes and reduce the service costs but also bring higher quality services to the client, and the client gains the spillover benefit [43].

In addition, a punishment mechanism [44] is introduced to encourage the two parties to participate in innovation activity: when one party cooperates and the other does not, the noncooperative party pays a fine, P, to the cooperative one.

Specifically, when the client cooperates and the service provider does not (i.e., the client innovates independently), the innovation benefit obtained by the client is π_c', the

Table 1: Payoff matrix.

		Service provider	
		Cooperation	Noncooperation
Client	Cooperation	$\pi_c + \mu\pi' - \theta C'$; $\pi_s + (1-\mu)\pi' - (1-\theta)C'$	$\pi_c + \pi_c' - C_c + P$; $\pi_s + \beta\pi_c' - P$
	Noncooperation	$\pi_c + \alpha\pi_s' - P$; $\pi_s + \pi_s' - C_s + P$	π_c; π_s

corresponding innovation cost is C_c, and the spillover benefit obtained by the service provider due to the spillover effect is $\beta\pi_c'$, where β is the client's spillover coefficient [45, 46]. In this case, the additional benefits obtained by the client and service provider through innovation activity are $\pi_c' - (C_c + P)$ and $(\beta\pi_c' - P)$, respectively, and the final benefits obtained by the client and service provider are $\Pi_{cn}^c = \pi_c + \pi_c' - C_c + P$, $\Pi_{cn}^s = \pi_s + \beta\pi_c' - P$.

When the service provider cooperates and the client does not (i.e., the service provider innovates independently), the innovation benefit obtained by the service provider is π_s', the corresponding innovation cost is C_s, and the spillover benefit obtained by the client due to the spillover effect is $\alpha\pi_s'$, where α is the service provider's spillover coefficient [45, 46]. In this case, the additional benefits obtained by the client and service provider through innovation activity are $(\alpha\pi_s' - P)$ and $\pi_s' - (C_s + P)$, respectively, and the final benefits obtained by the client and service provider are $\Pi_{nc}^c = \pi_c + \alpha\pi_s' - P$; $\Pi_{nc}^s = \pi_s + \pi_s' - C_s + P$.

A payoff matrix based on the preceding assumptions is provided in Table 1.

For ease of reference, a list of notations is provided in Table 2.

4. Evolutionary Game Analysis

Based on evolutionary game theory, we consider two groups: a client group and a service provider group. In the client group, the proportion of the members choosing the cooperation strategy to all the members is $x\,(0 \le x \le 1)$, and the proportion of the members choosing the noncooperation strategy to all the members is $(1 - x)$. Thus, when a client is randomly selected to pair up and play a game with a service provider, the probability of the client choosing the cooperative strategy is x, whereas the probability of the client choosing the noncooperative strategy is $(1 - x)$ [24].

In the service provider group, the proportion of the members choosing the cooperation strategy to all the members is $y\,(0 \le y \le 1)$, and the proportion of the members choosing the noncooperation strategy to all the members is $(1 - y)$. Thus, when a service provider is randomly selected to pair up and play a game with a client, the probability of the service provider choosing the cooperative strategy is x, whereas the probability of the service provider choosing the noncooperative strategy is $(1 - x)$ [24].

Thus, when the client chooses the cooperation strategy, its benefit is as follows:

$$U_{cc} = y\left(\pi_c + \mu\pi' - \theta C'\right) + (1-y)\left(\pi_c + \pi_c' - C_c + P\right). \quad (1)$$

When the client chooses the noncooperation strategy, its benefit is as follows:

$$U_{cn} = y\left(\pi_c + \alpha\pi_s' - P\right) + (1-y)\pi_c. \quad (2)$$

The client's average revenue is as follows:

$$\overline{U_c} = xU_{cc} + (1-x)U_{cn}. \quad (3)$$

The corresponding duplicate dynamic equation is as follows:

$$\begin{aligned} F(x) &= \frac{dx}{dt} = x(1-x)\left(U_{cc} - U_{cn}\right) \\ &= x(1-x)\left[y\left(\mu\pi' - \theta C' - \alpha\pi_s' - \pi_c' + C_c\right) + \pi_c' - C_c + P\right], \\ U_{sc} &= x\left(\pi_s + (1-\mu)\pi' - (1-\theta)C'\right) \\ &\quad + (1-x)\left(\pi_s + \pi_s' - C_s + P\right), \\ U_{sn} &= x\left(\pi_s + \beta\pi_c' - P\right) + (1-x)\pi_s. \end{aligned} \quad (4)$$

Similarly, the service provider's average revenue is as follows:

$$\overline{U_s} = yU_{sc} + (1-y)U_{sn}. \quad (5)$$

The corresponding duplicate dynamic equation is as follows:

$$F(y) = \frac{\mathrm{d}y}{\mathrm{d}t} = y(1-y)\left[x\left((1-\mu)\pi' - (1-\theta)C' - \beta\pi_c' - \pi_s' + C_s\right) + \pi_s' - C_s + P\right]. \quad (6)$$

Assigning $(x) = 0, F(y) = 0$, we can obtain four pure strategy equilibrium points $A(0,0), B(0,1), C(1,0), D(1,1)$ and one possible mixed strategy equilibrium point $E(x^*, y^*)$, where

$$\begin{aligned} x^* &= \frac{\pi_s' - C_s + P}{(1-\theta)C' + \beta\pi_c' - (1-\mu)\pi' + \pi_s' - C_s}, \\ y^* &= \frac{\pi_c' - C_c + P}{\theta C' + \alpha\pi_s' - \mu\pi' + \pi_c' - C_c}. \end{aligned} \quad (7)$$

Table 2: List of notations.

Symbol	Description
π_c	Basic benefit of the client when both parties adopt the noncooperation strategy
π_s	Basic benefit of the service provider when both parties adopt the noncooperation strategy
π_c'	Innovation benefit obtained by client when it innovates independently
C_c	Innovation cost bore by client when it innovates independently
β	Spillover coefficient when the client innovates independently
π_s'	Innovation benefit obtained by the service provider when it innovates independently
C_s	Innovation cost bore by the service provider when it innovates independently
α	Spillover coefficient when the service provider innovates independently
P	Penalty amount for the party that does not adopt the cooperation strategy while the other party does
$\pi\prime$	Excess benefit when the two parties both adopt the cooperation strategy
μ	Benefit distribution proportion of the client when the two parties both adopt the cooperation strategy
$C\prime$	Innovation cost when the two parties both adopt the cooperation strategy
θ	Cost sharing proportion of the client when the two parties both adopt the cooperation strategy

The Jacobian matrix of the evolutionary system is as follows:

$$J = \begin{bmatrix} (1-2x)\left[y\left(\mu\pi' - \theta C' - \alpha\pi_s' - \pi_c' + C_c\right) + \pi_c' - C_c + P\right] & x(1-x)\left(\mu\pi' - \theta C' - \alpha\pi_s' - \pi_c' + C_c\right) \\ y(1-y)\left[(1-\mu)\pi' - (1-\theta)C' - \beta\pi_c' - \pi_s' + C_s\right] & (1-2y)\left[x\left((1-\mu)\pi' - (1-\theta)C' - \beta\pi_c' - \pi_s' + C_s\right) + \pi_s' - C_s + P\right] \end{bmatrix}. \tag{8}$$

The determinant and the trace of the Jacobian matrix are as follows:

$$\begin{aligned} \det J &= \frac{\partial F(x)}{\partial x}\frac{\partial F(y)}{\partial y} - \frac{\partial F(y)}{\partial x}\frac{\partial F(x)}{\partial y}, \\ \operatorname{tr} J &= \frac{\partial F(x)}{\partial x} + \frac{\partial F(y)}{\partial y}. \end{aligned} \tag{9}$$

The determinant and trace of the Jacobian matrix corresponding to each (possible) equilibrium point are shown in Table 3. It can be inferred that the following four polynomials being positive or negative not only determines the number of equilibrium points but also influences the nature of each equilibrium point and the evolution stable state of the system:

$$\begin{aligned} &\pi_s' - C_s + P, \pi_c' - C_c + P, (1-\theta)C' + \beta\pi_c' - (1-\mu)\pi' - P, \\ &\theta C' + \alpha\pi_s' - \mu\pi' - P. \end{aligned} \tag{10}$$

4.1. Equilibrium Characteristics. According to the positive and negative of the preceding four polynomials, the following 8 conditions can be defined.

Condition 1. $\mu\pi' - \theta C' < \pi_s' - P$; that is, when the service provider chooses the cooperation strategy, the additional benefit obtained by the client when it chooses the cooperation strategy is less than that of choosing the noncooperation strategy.

Condition 2. $(1-\mu)\pi'(1-\theta)C'\beta\pi_c' - P$; that is, when the client chooses the cooperation strategy, the additional benefit obtained by the service provider when it chooses the cooperation strategy is less than that of choosing the noncooperation strategy.

Condition 3. $(\pi_s' - C_s) + P < 0$; that is, when the client chooses the noncooperation strategy and the service provider chooses the cooperation strategy, the additional benefit obtained by the service provider is less than zero.

Condition 4. $\pi_c' - C_c + P < 0$; that is, when the service provider chooses the noncooperation strategy and the client chooses the cooperation strategy, the additional benefit obtained by the client is less than zero.

Condition 5. $\mu\pi' - \theta C' > \alpha\pi_s' - P$; that is, when the service provider chooses the cooperation strategy, the additional benefit obtained by the client when it chooses the cooperation strategy is more than that of choosing the noncooperation strategy.

Condition 6. $(1-\mu)\pi' - (1-\theta)C' > \beta\pi_c' - P$; that is, when the client chooses the cooperation strategy, the additional benefit obtained by the service provider when it chooses the cooperation strategy is more than that of choosing the noncooperation strategy.

Condition 7. $(\pi_s' - C_s) + P > 0$; that is, when the client chooses the noncooperation strategy and the service provider chooses the cooperation strategy, the additional benefit obtained by the service provider is more than zero.

Condition 8. $(\pi_c' - C_c) + P > 0$; that is, when the service provider chooses the noncooperation strategy and the client chooses the cooperation strategy, the additional benefit obtained by the client is more than zero.

Table 3: Determinant and trace of the Jacobian matrix corresponding to each (possible) equilibrium point.

Equilibrium points	det$J$	tr$J$
$(0,0)$	$(\pi_c' - C_c + P)(\pi_s' - C_s + P)$	$\pi_c' - C_c + \pi_s' - C_s + 2P$
$(0,1)$	$(\mu\pi' - \theta C' - \alpha\pi_s' + P)(C_s - \pi_s' - P)$	$\mu\pi' - \theta C' - \alpha\pi_s' + P + C_s - \pi_s' - P$
$(1,0)$	$[(1-\mu)\pi' - (1-\theta)C' - \beta\pi_c' + P](-\pi_c' + C_c - P)$	$(1-\mu)\pi' - (1-\theta)C' - \beta\pi_c' + P - \pi_c' + C_c - P$
$(1,1)$	$(\theta C' + \alpha\pi_s' - \mu\pi' - P) * [(1-\theta)C' + \beta\pi_c' - (1-\mu)\pi' - P]$	$\theta C' + \alpha\pi_s' - \mu\pi' + (1-\theta)C' + \beta\pi_c' - (1-\mu)\pi' - 2P$
(x^*, y^*)	$-[(1-\theta)C' + \beta\pi_c' - (1-\mu)\pi' - P](\pi_s' - C_s + P)/$ $(1-\theta)C' + \beta\pi_c' - (1-\mu)\pi' + \pi_s' - C_s(\theta C' + \alpha\pi_s' - \mu\pi' - P)(\pi_c' - C_c + P)/\theta C' + \alpha\pi_s' - \mu\pi' + \pi_c' - C_c$	0

Table 4: Properties of the equilibrium points in Cases 1 and 2.

Equilibrium points	Case 1			Case 2		
	det$J$	tr$J$	Properties	det$J$	tr$J$	Properties
$A(0,0)$	+	+	Unstable	+	−	Stable
$B(0,1)$	+	−	Stable	+	+	Unstable
$C(1,0)$	+	−	Stable	+	+	Unstable
$D(1,1)$	+	+	Unstable	+	−	Stable
$E(x^*, y^*)$	−	0	Saddle point	−	0	Saddle point

According to the preceding conditions, there may be 16 different cases in the evolution system. The properties of each equilibrium point of the different cases can be obtained by analyzing its corresponding Jacobian matrix. When the determinant of its Jacobian matrix is negative, the equilibrium point is a saddle point; when the determinant of its Jacobian matrix is positive and the trace is negative, the equilibrium point is stable; and when both the determinant and trace are positive, the equilibrium point is an unstable point [24].

When Conditions 1, 2, 7, and 8 are simultaneously established (Case 1) or Conditions 3, 4, 5, and 6 are simultaneously established (Case 2), $0 < x^*, y^* < 1$, there are five equilibrium points in the evolution system: $A(0,0), B(0,1), C(1,0), D(1,1)$,

$$E\left(\frac{\pi_s' - (C_s + P)}{(1-\theta)C' + \beta\pi_c' - (1-\mu)\pi' + \pi_s' - C_s}, \frac{\pi_c' - (C_c + P)}{\theta C' + \alpha\pi_s' - \mu\pi' + \pi_c' - C_c}\right). \tag{11}$$

In the other 14 cases, there are four equilibrium points in the evolution system: $A(0,0), B(0,1), C(1,0), D(1,1)$.

4.2. System Evolution Path and Analysis. The properties of the equilibrium points in Cases 1 and 2 are shown in Table 4. The properties of the equilibrium points in Cases 3–16 are shown in Table 5. The system evolution path in each case is shown in Figure 1.

Case 1. When Conditions 1, 2, 7, and 8 are simultaneously established, there are two stable points $B(0,1), C(1,0)$ in the system. If the initial state is in the region ABDE, the system converges to the stable point $B(0,1)$, and the evolutionary stability strategy of the set is (noncooperation, cooperation). If the initial state is in the region ACDE, the system converges to the stable point $C(1,0)$, and the evolutionary stability strategy set is (cooperation, noncooperation).

Case 2. When Conditions 3, 4, 5, and 6 are simultaneously established, there are two stable points $A(0,0), D(1,1)$ in the system. If the initial state is in the region CABE, the system converges to the stable point $A(0,0)$, and the evolutionary stability strategy set is (noncooperation, noncooperation). If the initial state is in the region BDCE, the system converges to the stable point $D(1,1)$, and the evolutionary stability strategy set is (cooperation, cooperation).

Case 3. When Conditions 3, 5, 6, and 8 are simultaneously established, there is one stable point $D(1,1)$ in the system. Regardless of initial state, the system converges to the stable point $D(1,1)$, and the evolutionary stability strategy set is (cooperation, cooperation).

Case 4. When Conditions 5, 6, 7, and 8 are simultaneously established, there is one stable point $D(1,1)$ in the system. Regardless of initial state, the system converges to the stable point $D(1,1)$, and the evolutionary stability strategy set is (cooperation, cooperation).

Case 5. When Conditions 4, 5, 6, and 7 are simultaneously established, there is one stable point $D(1,1)$ in the system. Regardless of initial state, the system converges to the stable point $D(1,1)$, and the evolutionary stability strategy set is (cooperation, cooperation).

Case 6. When Conditions 2, 3, 4, and 5 are simultaneously established, there is one stable point $A(0,0)$ in the system. Regardless of initial state, the system converges to the stable point $A(0,0)$, and the evolutionary stability strategy of set is (noncooperation, noncooperation).

Table 5: Properties of the equilibrium points in Cases 3–16.

Equilibrium points	Properties													
	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16
$A(0,0)$	Saddle point	Unstable	Saddle point	Stable	Saddle point	Saddle point	Unstable	Saddle point	Stable	Saddle point	Unstable	Saddle point	Stable	Saddle point
$B(0,1)$	Unstable	Saddle point	Saddle point	Unstable	Unstable	Saddle point	Saddle point	Stable	Saddle point	Saddle point	Stable	Stable	Saddle point	Saddle point
$C(1,0)$	Saddle point	Saddle point	Unstable	Saddle point	Stable	Saddle point	Stable	Saddle point	Saddle point	Stable	Saddle point	Unstable	Unstable	Saddle point
$D(1,1)$	Stable	Stable	Stable	Saddle point	Saddle point	Saddle point	Saddle point	Unstable	Unstable	Unstable	Saddle point	Saddle point	Saddle point	Saddle point

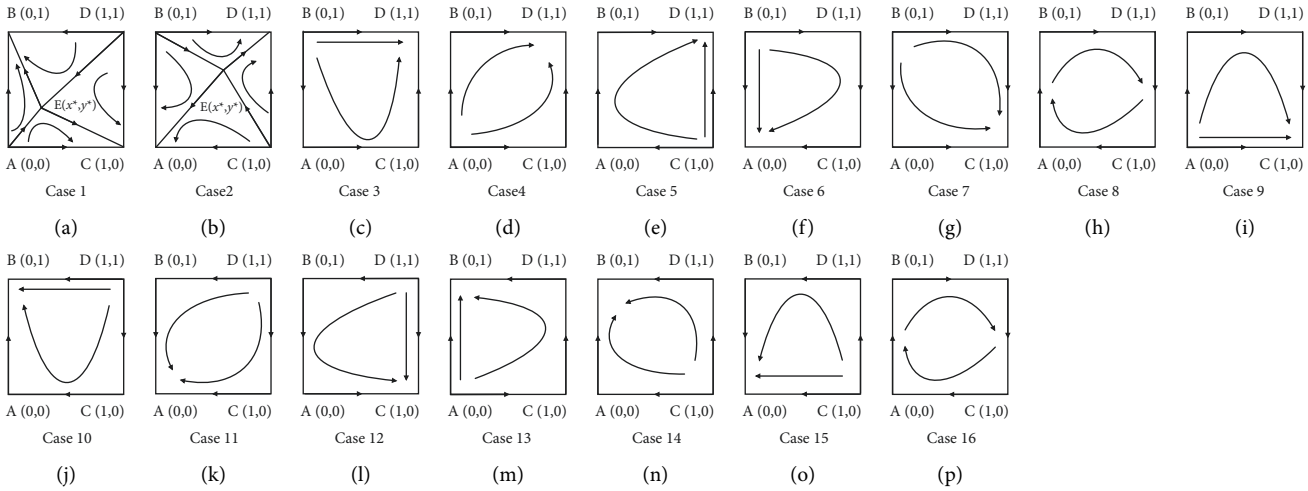

Figure 1: System evolution path in each case. (a) Case 1; (b) Case 2; (c) Case 3; (d) Case 4; (e) Case 5; (f) Case 6; (g) Case 7; (h) Case 8; (i) Case 9; (j) Case 10; (k) Case 11; (l) Case 12; (m) Case 13; (n) Case 14; (o) Case 15; (p) Case 16.

Case 7. When Conditions 2, 3, 5, and 8 are simultaneously established, there is one stable point $C(1,0)$ in the system. Regardless of initial state, the system converges to the stable point $C(1,0)$, and the evolutionary stability strategy set is (cooperation, noncooperation).

Case 8. When Conditions 2, 4, 5, and 7 are simultaneously established, there is no stable point in the system. Regardless of initial state, the system will not converge, and there is no evolutionary stability strategy for the system.

Case 9. When Conditions 2, 5, 7, and 8 are simultaneously established, there is one stable point $C(1,0)$ in the system. Regardless of initial state, the system converges to the stable point $C(1,0)$, and the evolutionary stability strategy set is (cooperation, noncooperation).

Case 10. When Conditions 1, 2, 4, and 7 are simultaneously established, there is one stable point $B(0,1)$ in the system. Regardless of initial state, the system converges to the stable point $B(0,1)$, and the evolutionary stability strategy set is (noncooperation, cooperation).

Case 11. When Conditions 1, 2, 3, and 4 are simultaneously established, there is one stable point $A(0,0)$ in the system. Regardless of initial state, the system converges to the stable point $A(0,0)$, and the evolutionary stability strategy set is (noncooperation, noncooperation).

Case 12. When Conditions 1, 2, 3, and 8 are simultaneously established, there is one stable point $C(1,0)$ in the system. Regardless of initial state, the system converges to the stable point $C(1,0)$, and the evolutionary stability strategy set is (cooperation, noncooperation).

Case 13. When Conditions 1, 6, 7, and 8 are simultaneously established, there is one stable point $B(0,1)$ in the system. Regardless of initial state, the system converges to the stable point $B(0,1)$, and the evolutionary stability strategy set is (noncooperation, cooperation).

Case 14. When Conditions 1, 4, 6, and 7 are simultaneously established, there is one stable point $B(0,1)$ in the system. Regardless of initial state, the system converges to the stable point $B(0,1)$, and the evolutionary stability strategy set is (noncooperation, cooperation).

Case 15. When Conditions 1, 3, 4, and 6 are simultaneously established, there is one stable point $A(0,0)$ in the system. Regardless of initial state, the system converges to the stable point $A(0,0)$, and the evolutionary stability strategy set is (noncooperation, noncooperation).

Case 16. When Conditions 1, 3, 6, and 8 are simultaneously established, there is no stable point in the system. Regardless of initial state, the system will not converge, and there is no evolutionary stability strategy for the system.

According to Cases 2, 6, 11, and 15, the establishment of Conditions 3 and 4 is the necessary condition for the evolutionary stability strategy set to be (noncooperation, noncooperation). That is, if the system evolves to a stable state in which the two parties both choose the noncooperation strategy, the additional benefit obtained by the service provider is certain to be less than zero when the client chooses the noncooperation strategy and the service provider chooses the cooperation strategy, and the additional benefit obtained by the client is certain to be less than zero when the service provider chooses the noncooperation strategy and the client chooses the cooperation strategy.

According to Cases 1, 10, 13, and 14, the establishment of Conditions 1 and 7 is the necessary condition for the evolutionary stability strategy set to be (noncooperation, cooperation). That is, if the system evolves to a stable state in which the client chooses the noncooperation strategy and the service provider chooses the cooperation strategy, the additional benefit obtained by the client when it chooses the

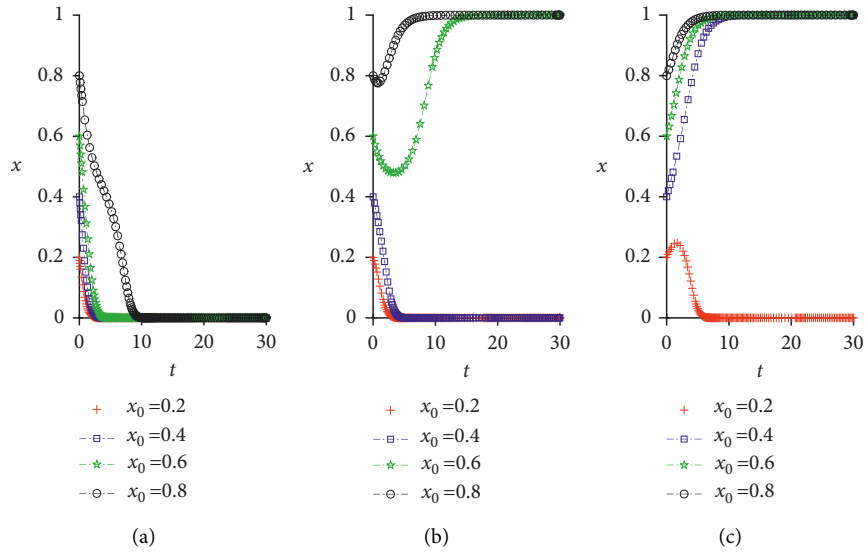

FIGURE 2: Impact of the initial probabilities of the two parties choosing the cooperative strategy on system evolution. Comparing (a), (b), and (c), as y_0 (initial probability of the two parties choosing the cooperation strategy) increases, the probability of the system evolving to the ideal state increases. (a) $y_0 = 0.5$; (b) $y_0 = 0.7$; (c) $y_0 = 0.9$.

cooperation strategy is certain to be less than that of choosing the noncooperation strategy when the service provider chooses the cooperation strategy, and the additional benefit obtained by the service provider is certain to be more than zero when the client chooses the noncooperation strategy and the service provider chooses the cooperation strategy.

According to Cases 1, 7, 9, and 12, the establishment of Conditions 2 and 8 is the necessary condition for the evolutionary stability strategy set to be (cooperation, noncooperation). That is, if the system evolves to a stable state in which the client chooses the cooperation strategy and the service provider chooses the noncooperation strategy, the additional benefit obtained by the service provider when it chooses the cooperation strategy is certain to be less than that of choosing the noncooperation strategy when the client chooses the cooperation strategy, and the additional benefit obtained by the client is certain to be more than zero when the service provider chooses the noncooperation strategy and the client chooses the cooperation strategy.

To simplify the statement, we define the stable state in which the evolutionary stability strategy set is (cooperation, cooperation) as the ideal state and the stable state in which the evolutionary stability strategy set is (noncooperation, noncooperation) as the worst state. The ideal state is the primary concern of this paper, and only Cases 2, 3, 4, and 5, in which the ideal state exists, are analyzed below.

According to Cases 2, 3, 4, and 5, the establishment of Conditions 5 and 6 is the necessary condition for the evolutionary stability strategy set to be (cooperation, cooperation). Under the premise that Conditions 5 and 6 are established, as long as the additional benefit obtained by the client or the service provider when the other party engages in innovation activity independently is more than zero, the system is certain to evolve to a stable state in which the two parties both choose the cooperation strategy, i.e., the ideal state.

That is, the benefits of both the client and service provider when they innovate cooperatively being greater than that when they innovate independently cannot guarantee that the system will certainly evolve to the ideal state. However, as long as the condition that either party gains more than zero when it innovates independently is established along with the preceding state of affairs, the system will certainly evolve to the ideal state.

5. Numerical Simulation under Double Equilibrium

In Cases 3, 4, and 5, the evolutionary stability strategy set is (cooperation, cooperation), and we do not discuss these cases further in this paper. In Case 2, the evolutionary stability strategy set is either (cooperation, cooperation) or (noncooperation, noncooperation), which is a double equilibrium state. We use MATLAB to conduct numerical simulation and analyze the impact of different system parameters on the evolution of the system to generate suggestions on how to improve the probability that both parties choose cooperation strategies in Case 2.

Suppose x_0 and y_0 are the initial probabilities of the client and service provider choosing the cooperation strategy, respectively. The establishment of Conditions 3, 4, 5, and 6 is the prerequisite for the system evolving to the double equilibrium state, in which the evolutionary stability strategy set is either (cooperation, cooperation) or (noncooperation, noncooperation). To satisfy Conditions 3, 4, 5, and 6 (i.e., $(\pi_s' - C_s) + P < 0$; $(\pi_c' - C_c) + P < 0$; $\mu\pi' - \theta C' > \alpha\pi_s' - P$; $(1-\mu)\pi' - (1-\theta)C' > \beta\pi_c' - P$), we suppose that the initial values of the parameters are

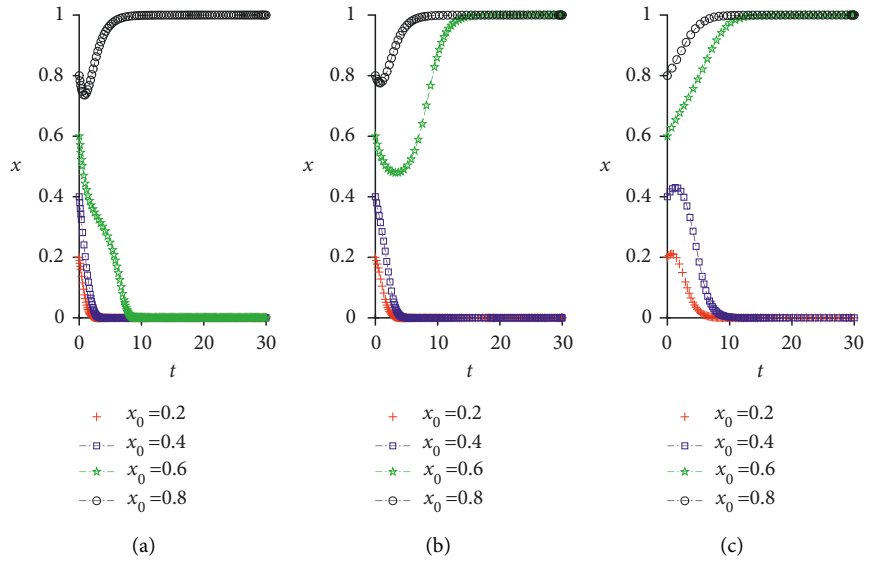

FIGURE 3: Impact of π_c' on system evolution. Comparing (a), (b), and (c), as π_c' (innovation benefit of the client when it innovates independently) increases, the probability of the system evolving to the ideal state increases. (a) $\pi_c' = 1$; (b) $\pi_c' = 3$; (c) $\pi_c' = 5$.

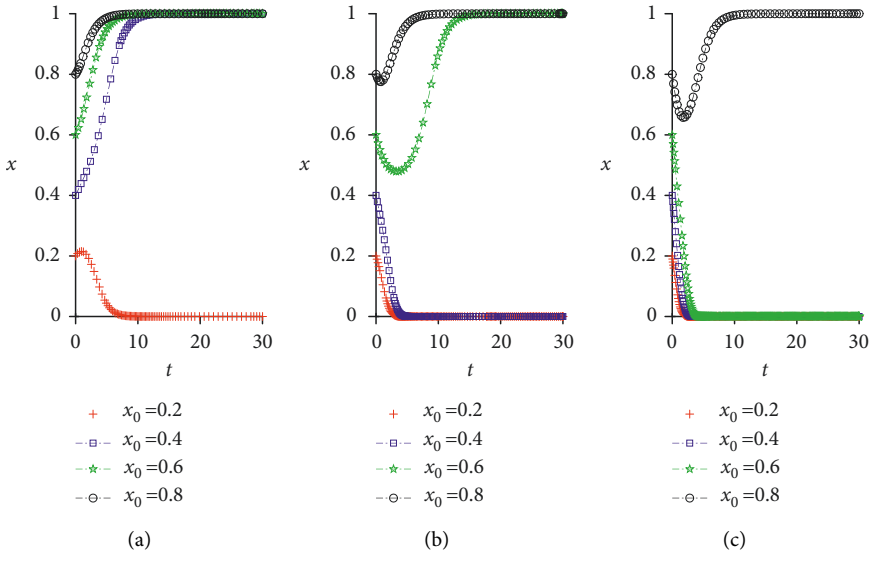

FIGURE 4: Impact of C_c on system evolution. Comparing (a), (b), and (c), as C_c (cost borne by the client when it innovates independently) decreases, the probability of the system evolving to the ideal state increases. (a) $C_c = 5$; (b) $C_c = 7$; (c) $C_c = 9$.

$\pi_c' = 3, C_c = 5, \beta = 0.4, \pi_s' = 4, C_s = 6, \alpha = 0.45, P = 1, \pi' = 7, \mu = 0.5, C' = 4, \theta = 0.5, y_0 = 0.7$. During the analysis, all parameters are initial values except the value of the target parameter changes. To clearly show the impact of the parameters on system evolution, the system evolution curves when x_0 is taken as 0.2, 0.4, 0.6, and 0.8 are provided in each diagram.

5.1. Impact of the Initial Probabilities of the Two Parties Choosing the Cooperation Strategy on System Evolution. The impact of the initial probabilities of the two parties choosing the cooperation strategy on system evolution is shown in Figure 2. Comparing 2(a)–2(c), one can note that with the increase in the initial probability of the two parties choosing the cooperation strategy the probability of the system evolving to the ideal state increases. It can also be seen from 2(b) or 2(c) that the higher the initial probability of the client choosing the cooperation strategy is, the faster the system converges to the ideal state. Therefore, it can be inferred that enhancing the cooperation willingness of both parties in the early stage is conducive to the evolution of the system to the ideal state.

5.2. Impact of π_c' on System Evolution. The impact of π_c' on system evolution is shown in Figure 3. One can note that with the increase in π_c' the probability of system evolution to the ideal state increases, and the convergence speed accelerates.

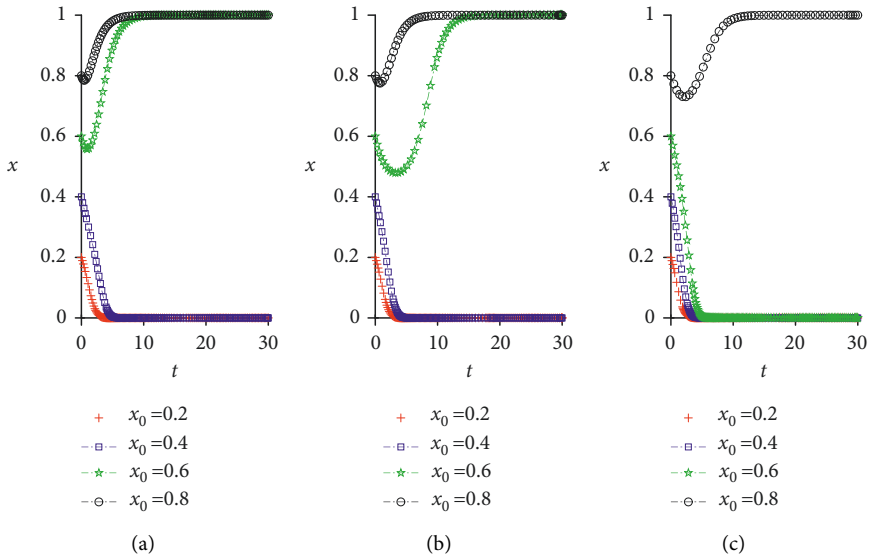

FIGURE 5: Impact of β on system evolution. Comparing (a), (b), and (c), as β (client's spillover coefficient) increases, the probability of the system evolving to the ideal state decreases. (a) $\beta = 0.2$; (b) $\beta = 0.4$; (c) $\beta = 0.6$.

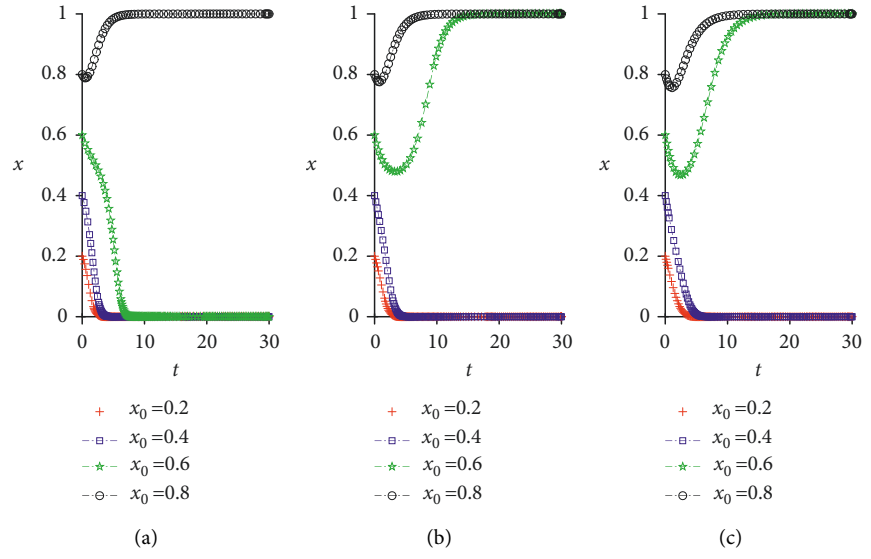

FIGURE 6: Impact of π_s' on system evolution. Comparing (a), (b), and (c), as π_s' (innovation benefit of the service provider when it innovates independently) increases, the probability of the system evolving to the ideal state increases. (a) $\pi_s' = 3.6$; (b) $\pi_s' = 4$; (c) $\pi_s' = 4.4$.

In Case 2, $\Pi_{cn}^c < 0$. When π_c' increases, the client's benefit Π_{cn}^c increases. When π_c' increases to a certain value, $\Pi_{cn}^c > 0$, the system changes from Case 2 to 3, in which the system is certain to evolve to the ideal state.

Therefore, increasing the innovation benefit of the client when it innovates independently always increases the probability of the system evolving to the ideal stable state. Moreover, when the above benefit is large enough, the system is certain to evolve to the ideal state, in which the two parties both adopt a cooperation strategy.

5.3. Impact of C_c on System Evolution. The impact of C_c on system evolution is shown in Figure 4. It can be found that, with the increase in C_c, the probability of system evolution to the ideal state decreases, and the convergence speed slows. The greater the cost borne by the client when it innovates independently is, the less the benefit the client obtains and the more reluctant it is to adopt the cooperation strategy. Therefore, decreasing the cost borne by the client when it innovates independently increases the probability of the system evolving to the ideal state.

5.4. Impact of β on System Evolution. The impact of β on system evolution is shown in Figure 5. One can note that with the increase in β the probability of the system evolving to the ideal state decreases, and the convergence speed slows. The larger the spillover coefficient, the greater the additional benefit and total benefit obtained by the service provider

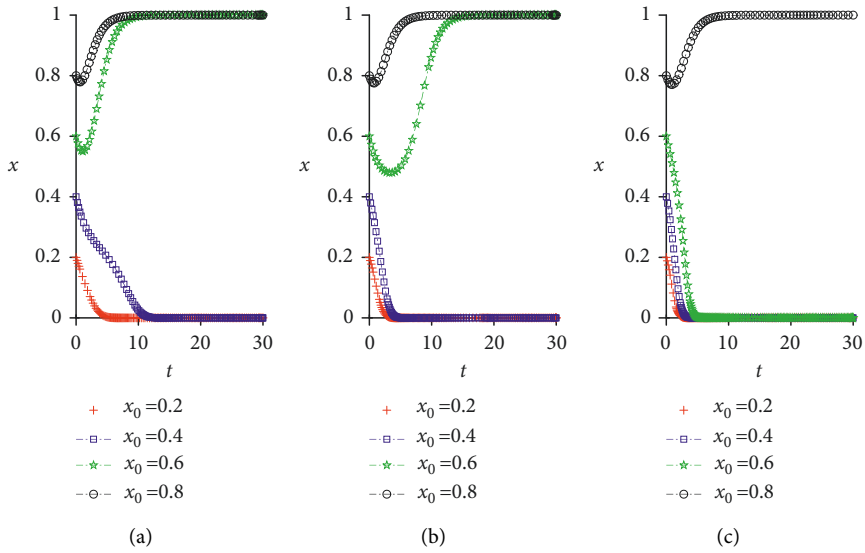

FIGURE 7: Impact of C_s on system evolution. Comparing (a), (b), and (c), as C_s (cost borne by the service provider when it innovates independently) decreases, the probability of the system evolving to the ideal state increases. (a) $C_s = 5.4$; (b) $C_s = 6$; (c) $C_s = 6.6$.

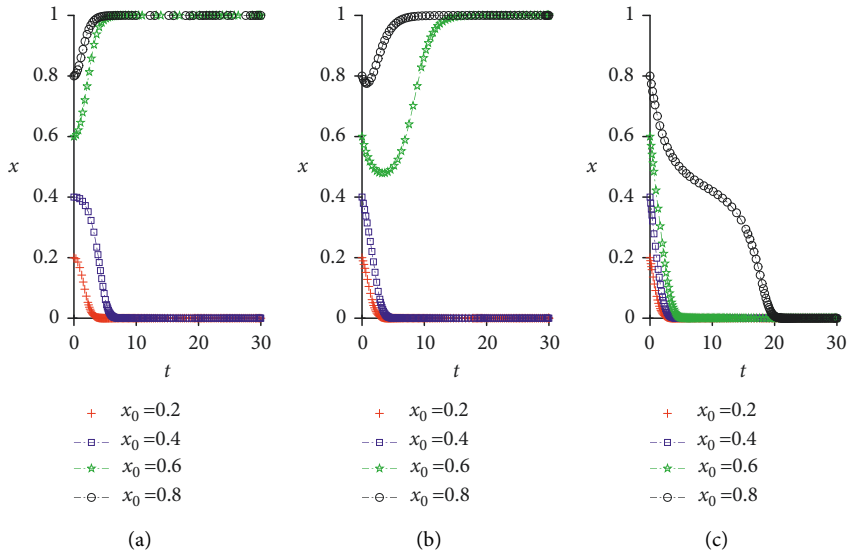

FIGURE 8: Impact of α on system evolution. Comparing (a), (b), and (c), as α (service provider's spillover coefficient) decreases, the probability of the system evolving to the ideal state increases. (a) $\alpha = 0.3$; (b) $\alpha = 0.45$; (c) $\alpha = 0.6$.

when it adopts a noncooperation strategy, the more inclined it is to be a "free rider" and adopt the noncooperation strategy, and the higher the probability of the system evolving to the worst state. Therefore, decreasing the client's spillover coefficient decreases the benefit of the service provider but increases the probability of the two parties both adopting the cooperation strategy.

5.5. Impact of π_s' on System Evolution. The impact of π_s' on system evolution is shown in Figure 6. One can note that with the increase in π_s' the probability of the system evolving to the ideal state increases, and the convergence speed accelerates.

In Case 2, $\Pi_{nc}^s < 0$. When π_s' increases, the client's benefit Π_{nc}^s increases. When π_s' increases to a certain value, $\Pi_{nc}^s > 0$, the system changes from Case 2 to 4, in which the system is certain to evolve to the ideal state.

Therefore, increasing the innovation benefit of the service provider when it innovates independently always increases the probability of the system evolving to the ideal stable state. Moreover, when the above innovation benefit is large enough, the system is certain to evolve to the ideal state, in which the two parties both adopt a cooperation strategy.

5.6. Impact of C_s on System Evolution. The impact of C_s on system evolution is shown in Figure 7. One can note that

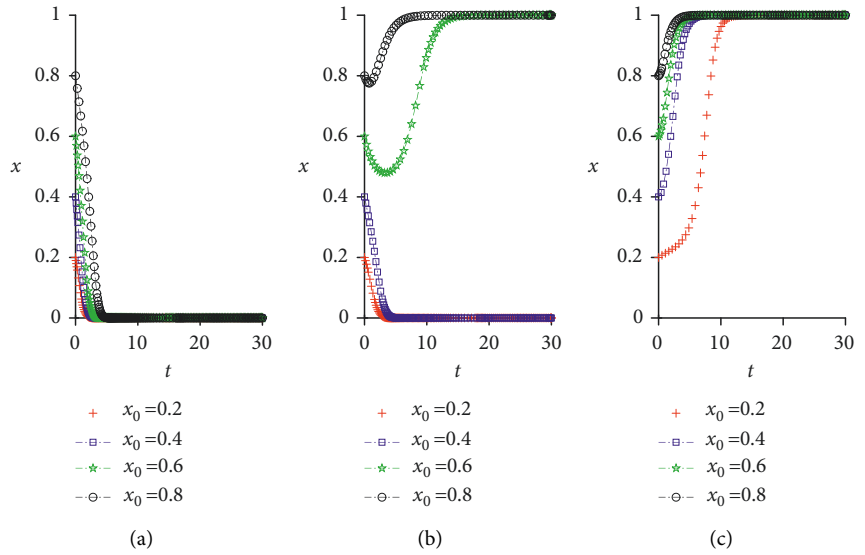

Figure 9: Impact of P on system evolution. Comparing (a), (b), and (c), as P (the fine to the party that adopts a noncooperation strategy) increases, the probability of the system evolving to the ideal state increases. (a) $P = 0.5$; (b) $P = 1$; (c) $P = 1.5$.

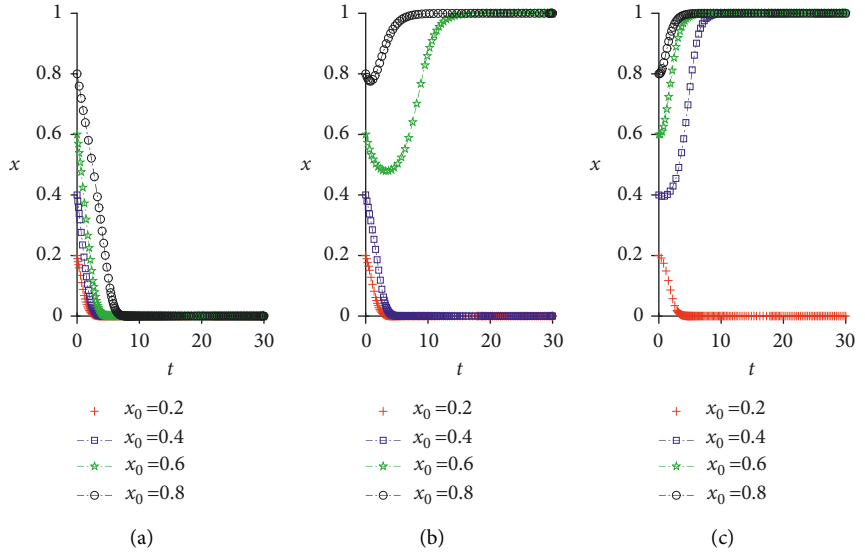

Figure 10: Impact of π' on system evolution. Comparing (a), (b), and (c), as π' (innovation benefit when both parties choose the cooperation strategy) increases, the probability of the system evolving to the ideal state increases. (a) $\pi' = 6$; (b) $\pi' = 7$; (c) $\pi' = 8$.

with the increase in C_s the probability of system evolution to the ideal state decreases, and the convergence speed slows. The greater the cost borne by the service provider when it innovates independently is, the less the benefit it obtains and the more reluctant it is to adopt the cooperation strategy. Therefore, decreasing the cost borne by the service provider when it innovates independently will increase the probability of the system evolving to an ideal state.

5.7. Impact of α on System Evolution. The impact of α on system evolution is shown in Figure 8. One can note that with the increase in α the probability of the system evolving to the ideal state decreases, and the convergence speed slows. The larger the spillover coefficient, the greater the additional benefit and total benefit obtained by the client when it adopts the noncooperation strategy, the more inclined it is to be a "free rider" and adopt the noncooperation strategy, and the higher the probability of the system evolving to the worst state. Therefore, decreasing the service provider's spillover coefficient will decrease the benefit of the client but increase the probability of the two parties both adopting the cooperation strategy.

5.8. Impact of P on System Evolution. The impact of P on system evolution is shown in Figure 9. One can note that with the increase in P the probability of the system evolving to an ideal stable state increases, and the convergence rate accelerates. When P is larger than a certain value, the system

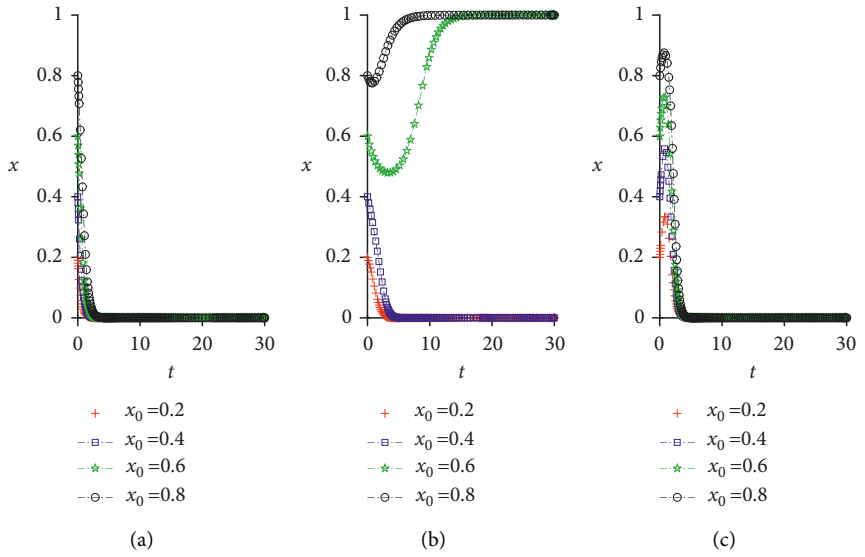

FIGURE 11: Impact of μ on system evolution. According to (b), when the benefit distribution proportions of the two parties are equal, the system may evolve to the ideal or worst state, while according to (a) and (c), when one party's benefit distribution proportion is much smaller than that of the other, the system will evolve to the worst state. (a) $\mu = 0.1$; (b) $\mu = 0.5$; (c) $\mu = 0.9$.

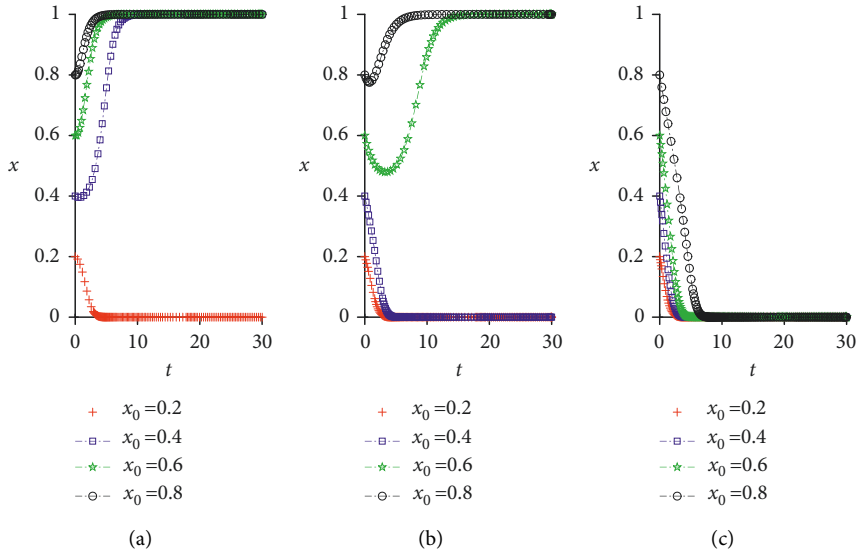

FIGURE 12: Impact of C' on system evolution. Comparing (a), (b), and (c), as C' (innovation cost when the two parties both choose the cooperation strategy) decreases, the probability of the system evolving to the ideal state increases. (a) $C' = 3$; (b) $C' = 4$; (c) $C' = 5$.

is certain to evolve to the ideal state. With the increase in P, the benefit of the party that adopts the noncooperation strategy decreases. When P is large enough, the benefit of the party that adopts the noncooperation strategy becomes negative. Thus, the party that adopts a noncooperation strategy tends to change its strategy to a cooperation strategy when the other party chooses a cooperation strategy. Therefore, increasing the fine to the party that adopts a noncooperation strategy is conducive to the system evolving to the ideal state.

5.9. Impact of π' on System Evolution. The impact of π' on system evolution is shown in Figure 10. One can note that with the increase in π' the probability of the system evolving to the ideal state increases, and the convergence speed accelerates. When π' increases, the benefit obtained by the two parties increases, and they are more inclined to choose the cooperation strategy. Therefore, increasing the innovation benefit when both parties choose the cooperation strategy is conducive to the system evolving to the ideal state.

5.10. Impact of μ on System Evolution. The impact of μ on system evolution is shown in Figure 11. Figure 11(b) shows that when the benefit distribution proportions of the two parties are equal the system may evolve to the ideal state or the worst state. As shown in Figures 11(a) and 11(c), when one party's benefit distribution proportion is much smaller than that of the other party, the

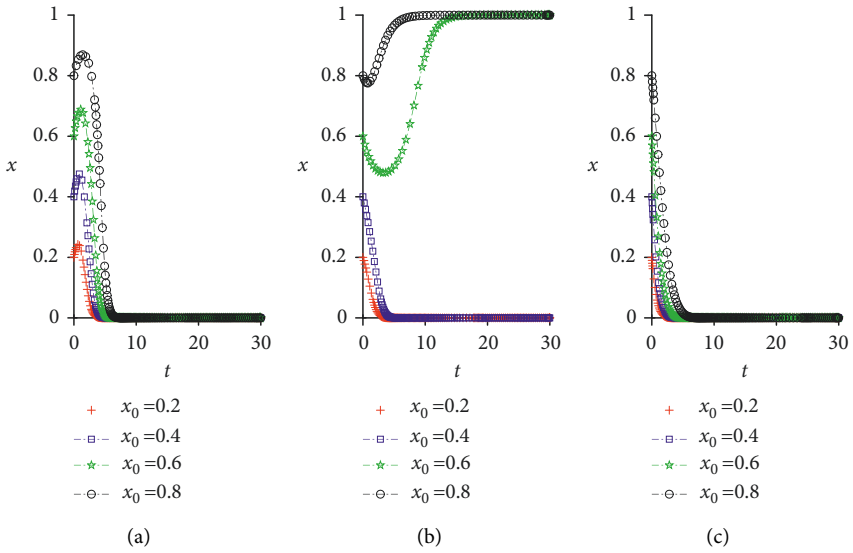

FIGURE 13: Impact of θ on system evolution. According to (b), when the cost sharing proportions of the two parties are equal, the system may evolve to the ideal state or the worst state, while according to (a) and (c), when one party's cost sharing proportion is much smaller than that of the other party, the system will evolve to the worst state. (a) $\theta = 0.1$; (b) $\theta = 0.5$; (c) $\theta = 0.9$.

system will evolve to the worst state. This is because the party with a smaller benefit distribution proportion obtains less additional benefit, or its total benefit may even be negative, and it is more inclined to choose the noncooperation strategy, which eventually leads the system to evolve to the worst state. Therefore, a reasonable benefit distribution proportion should be set to prevent the system from evolving to the worst state.

5.11. Impact of C' on System Evolution. The impact of C' on system evolution is shown in Figure 12. One can note that with the increase in C' the probability of the system evolving to the ideal state decreases, the convergence speed slows.

When C' increases, the benefits obtained by the two parties decrease, and they are more inclined to choose the noncooperation strategy. Therefore, decreasing the innovation cost when the two parties both choose the cooperation strategy is conducive to the system evolving to the ideal state.

5.12. Impact of θ on System Evolution. The impact of θ on system evolution is shown in Figure 13. Figure 13(b) shows that when the cost sharing proportions of the two parties are equal, the system may evolve to the ideal state or the worst state. As shown in Figures 13(a) and 13(c), when one party's share of the cost is much larger than that of the other party, the system will evolve to the worst state. This is because the party with a larger share of the cost bears more innovation costs, or its total benefit is even negative, and it is more inclined to choose the noncooperation strategy, which eventually leads the system to evolve to the worst state. Therefore, a reasonable cost sharing proportion should be set to prevent the system from evolving to the worst state.

6. Conclusion

Although cooperative innovation between clients and service providers has many benefits, the two parties do not necessarily establish a cooperative innovation relationship. Based on evolutionary game theory, this paper investigates the decision-making mechanism of cooperative innovation between clients and service providers and then analyzes how to promote the cooperative innovation between the two parties.

Based on evolutionary game theory, we assume the process of cooperative innovation is a long-term and dynamic evolution one. In the evolution system, the client and service provider are rational "economic entities," they constantly adjust their strategies of cooperating or not, and their cooperative innovation behavior dynamically evolves over the course of a long-term game.

We analyze the properties of the equilibrium points and obtain the evolution paths in 16 different cases of the evolution system. We find that the benefits of both the client and service provider when they innovate cooperatively being greater than that when they innovate independently cannot guarantee that the system will certainly evolve to a stable state in which both parties adopt a cooperation strategy. However, as long as the condition that either party gains more than zero when it innovates independently is established in addition to the preceding condition, the system is certain to evolve to a stable state in which both parties adopt the cooperative strategy.

We conduct numerical simulation to study the effects of cooperation benefits, spillover effects, and other parameters on the stability of the system evolution process. We find that the increase of the following factors is helpful for the system to evolve to the ideal state: the initial probabilities of the two parties choosing the cooperative strategy, the innovation benefit when one party innovates independently, the penalty

when one party cooperates and the other party does not, and the excess benefit when the two parties both cooperate. In addition, the following measures can be taken to promote client-service provider cooperation: reducing the innovation cost and spillover coefficient when one party innovates independently, decreasing the innovation cost when the two parties both choose the cooperation strategy, and setting reasonable benefit distribution and cost sharing proportions.

Based on the preceding conclusions, management suggestions are provided regarding how to promote cooperative innovation between clients and service providers:

(1) For the client, employing a performance-based outsourcing contract, which is helpful in creating an independent innovation space for service providers, and setting up innovation funds are effective ways to encourage service providers to innovate. Service providers can actively tap the potential needs of clients and integrate clients into the innovation process. In addition, communication mechanisms, such as "innovation days," through which the two parties regularly discuss innovation opportunities, could also be established to create good internal and external innovation environments for improving the enthusiasm for cooperative innovation.

(2) The party that chooses the cooperation strategy should "keep an eye on" its innovation achievements and prevent their possible spillover. Establishing an informal contract [47] and incorporating noncooperation penalty clauses in it are effective ways to restrict noncooperation behavior. The relevant authorities are suggested to strengthen guidance, supervision, and management and improve the intellectual property protection system to prevent the "free riding" phenomenon.

(3) In the process of cooperative innovation, to increase the excess benefit generated by cooperative innovation, clients can proactively clarify their pain points and needs and share knowledge resources, such as business processes and internal information, while service providers can mobilize more professional resources, such as innovative technologies and specialists. In addition, the two parties should reduce the cooperative innovation cost as much as possible by, e.g., adopting advanced technical means, clarifying role division, and maintaining work consistency.

In the field of cooperative innovation between clients and service providers, the previous research mainly examines the implementation process of cooperative innovation, including analyzing the impact of important factors on the implementation process and introducing specific guidance frameworks and implementation methods, as well as the benefit of cooperative innovation. Our research focuses on the decision-making mechanism of the cooperative innovation behavior and how to form a stable cooperative innovation relationship, making up for the lack of research on the topic in the previous literature.

Our study enriches the relevant research fields of cooperative innovation between clients and service providers and evolutionary game theory. In addition, the conclusion obtained not only provides a theoretical basis for the clients and service providers to make the best decision, but also offers practical guidance on how to promote client-service provider cooperation in the process of service innovation.

This paper suffers from several limitations. Although the spillover effect, which occurs when one party innovates independently, and the synergy effect, which occurs when both parties innovate cooperatively, are considered, these two effects do not reflect the interaction between the two parties. In fact, there is a coupling effect between the two parties in the process of cooperative innovation [48]; that is, the two parties interact and influence one another when making cooperation decisions. Therefore, future research could focus on how the coupling effect affects the evolution of the client and service provider's cooperative behavior.

Appendix

A. Source Code

The authors employ MATLAB to conduct numerical simulation by two stages. At the first stage, the authors define the differential equation function according to the duplicate dynamic equation in Section 3 and set the initial values of the parameters in the differential equation function.

The corresponding source code is as follows:

```
Function dxdt = differential 1_21(t, x)
a = 0.5;
b = 7;
c = 0.5;
d = 4;
e = 0.45;
f = 4;
g = 3;
h = 9;
i = 0.4;
j = 6;
p = 1;
dxdt = [x(1) * (1 - x(1)) * (x(2) * (a * b - c * d - e *
f - g + h) + g - h + p); x(2) * (1 - x(2)) * (x(1) *
((1 - a) * b - (1 - c) * d - i * g - f + j) + f - j + p)];
End
```

At the second stage, we solve the differential equation and plot the diagram of the system evolution curves. The corresponding source code is as follows:

```
i = 0.2
j = 0.7
[T, Y] = ode45 ('differential 1_21', [0 30], [i j]);
Figure (2)
```

Plot (T, Y(:, 1), '+r');
Hold on
$i = 0.4$
$j = 0.7$
[T, Y] = ode45 ('differential 1_21', [0 30], [i j]);
Figure (2)
Plot (T, Y(:, 1), 'b-.square');
Hold on
$i = 0.6$
$j = 0.7$
[T, Y] = ode45 ('differential 1_21', [0 30], [i j]);
Figure (2)
Plot (T, Y(:, 1), 'g-.pentagram');
Hold on
$i = 0.8$
$j = 0.7$
[T, Y] = ode45 ('differential 1_21', [0 30], [i j]);
Figure (2)
Plot (T, Y(:, 1), 'k-.o');
Hold on
h = legend({'\itx_0 = \rm0.2','\itx_0 = \rm0.4', '\itx_0 = \rm0.6','\itx_0 = \rm0.8',},'Location', 'northeast')
Set (h, 'box', 'off')
Set (gca, 'Font Size', 18)
Set (gca, 'Font name', 'Times New Roman')
x label ('\itt', 'Font name', 'Times New Roman', 'Font Size', 20)
y label ('\itx', 'Font name', 'Times New Roman', 'Font Size', 20)
box off
y lim([0 1])

Note that the above source codes with given parameter values only generate one diagram, i.e., Figure 4(b). The authors get the other diagrams in Section 4 by adjusting the corresponding parameter(s).

Data Availability

The corresponding data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Retraction

Retracted: Population Economic Transfer Function Model Based on Genetic Tabu Search Algorithm

Discrete Dynamics in Nature and Society

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope

(2) Discrepancies in the description of the research reported

(3) Discrepancies between the availability of data and the research described

(4) Inappropriate citations

(5) Incoherent, meaningless and/or irrelevant content included in the article

(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] Q. Wang, "Population Economic Transfer Function Model Based on Genetic Tabu Search Algorithm," *Discrete Dynamics in Nature and Society*, vol. 2022, Article ID 1356909, 8 pages, 2022.

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Research Article

Population Economic Transfer Function Model Based on Genetic Tabu Search Algorithm

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Aiming at the problem that the evaluation effect of the traditional analysis model of population economic transfer is not good, a population economic transfer function model based on the genetic tabu search algorithm is proposed. Firstly, the defects of the genetic algorithm are analyzed, and the tabu search algorithm is integrated into the genetic tabu search algorithm to obtain the genetic tabu search algorithm, which avoids the problems of premature convergence and low search efficiency. Secondly, the population migration algorithm is designed. On this basis, the design process of the population economic transfer function model is determined. Finally, the effectiveness of the model is verified by comparative experiments. The experimental results show that when the population area is 50 km^2 and 500 km^2, the evaluation accuracy of the proposed method is 99% and 97%, respectively, which can avoid falling into a local maximum advantage to a certain extent.

1. Introduction

Generally speaking, population movement refers to all movements of the population in space or geographical position, including population movement and migration. Population migration is the movement of people in the living environment, and it is a kind of population behavior with some spontaneity and relatively poor migration regularity [1–3]. Population migration is the movement of people across specific geographical boundaries to change their permanent residence, which is usually a population behavior with the nature of selection. What are the main drivers of migration? Some migrate because they are pushed out of their places of origin, while others are pulled elsewhere. Evil or repressive laws and heavy tax, bad weather, alien social environment, even forced, all of which have been caused and still cause migration flows, the migration flow without a can and by the majority of your hopes on the amount they are better in material migration caused by the desire to flow compared [4, 5]. Ravenstein's view shows that material and economic factors are the main factors that often play a role in population migration, the population center of gravity shifts along with the economy [6, 7]. In other words, people tend to move to more favorable areas with high economic development levels and more job opportunities [8, 9]. For example, Wang Guixin studied the effects of regional economic development levels and differences on interprovincial population migration and its characteristics in the second half of the 1980s. This study uses per capita national income as the index of regional economic development level. According to the per capita national income of each province in 1990, the economic development level of each province is divided into the following six levels: less than 900 yuan, 900~1000 yuan, 1000~1200 yuan, 1200~1500 yuan, 1500~2000 yuan, and more than 2000 yuan. One of the conclusions of the study is that nearly 70% of the net emigration population is distributed in the lower income areas of 900~1000 yuan, while more than 94% of the net emigration population is distributed in the higher income areas of more than 1500 yuan. This shows that the population migration since the reform of China's economic system has obvious basic characteristics of the flow of people to the rich.

Research shows that relatives and friends (family ties, human relations), media advertising, the labor market, and farmers' market are the main sources of information [10–12]. These media collect information about the

economic situation of preferential areas, such as income and employment opportunities, and disseminate it to potential migrants. Under the guidance and pull of information, population migration occurs [13–15]. If the relative surplus population continues to increase, population pressure will increase and population density will increase too. Areas with high economic development levels will also see the spread of population outward, usually to undeveloped areas with low population density or to areas where it is relatively easy to make a living [16–18].

In recent 30 years, a series of new global optimization search algorithms have appeared. These algorithms are mainly established by simulating the evolution process of a population with some optimization characteristics in the natural domain [19–22]. The typical ones are the genetic algorithm, simulated annealing algorithm, and ant colony algorithm. A genetic algorithm is used to simulate the population genetic evolutionary process of organisms' chromosomes. A simulated annealing algorithm simulates the system in the process of solid annealing atomic groups toward the ground state of the lowest energy process; ant colony algorithm is simulated by the individual information exchange and cooperation between finders of nests to the food source of the shortest path. These algorithms successfully solve many complex optimization problems [23, 24]. The construction method of the algorithm shows that the simulation of the population evolution process with some optimization characteristics is an effective way to establish the global optimization search algorithm [25, 26]. The existing research work pays more attention to the selection of simulation prototypes in the field of nature and pays little attention to the research and excavation in other fields [27–29]. In view of this situation, this paper has carried out some work in this field, focusing on finding the group evolution process with certain optimization characteristics in the research objects of social fields or social science, and then establishing the global optimization search algorithm that simulates the operation mechanism of this process [30–33]. After a period of exploration, the process of population economic migration has been found in the research objects of demography and its related branches, and a more in-depth study has been conducted on it. This article and subsequent articles will introduce the preliminary research results in this field.

Against the above background, this paper proposes a population economic transfer function model based on the genetic tabu search algorithm. The tabu search algorithm is integrated into the genetic tabu search algorithm to avoid the problems of premature convergence and low search efficiency, and the genetic tabu search algorithm is obtained. Based on this, the population migration algorithm is designed and the design process of the population economic transfer function model is determined.

2. Design of Genetic Tabu Search Algorithm Flow

In order to solve the problems of easy premature convergence and low search efficiency in the later stages of the evolution of traditional genetic algorithms, a tabu search algorithm was introduced to obtain a hybrid genetic tabu search algorithm, and the individuals generated by the tabu search algorithm were optimized and mutation operations to generate a new generation of populations to improve the computational performance of the algorithm.

2.1. Genetic Algorithm Defects. A large number of previous research documents have proved that genetic algorithm is an excellent optimization algorithm, but also pointed out that the traditional genetic algorithm has the following two serious defects:

(1) Premature convergence is easy. The traditional genetic algorithm is prone to premature convergence for two reasons: first, in the process of optimization, an evolutionary group can produce a few individual fitness function value that is much better than other individuals, after a few iterations, the offspring of the previous outstanding individuals will occupy almost the whole of the group, and therefore, evolution will convergence in advance; Secondly, in the process of traditional genetic algorithm optimization, the competition between individuals only exists in the offspring, while there is no competition between the offspring and the parent, which will lead to the loss of excellent individuals in the parent generation.

(2) Search efficiency is low in the late evolutionary period. When the traditional genetic algorithm evolves to the vicinity of the optimal solution or has been iterated many times, it is easy to skip the optimal solution because of the large coverage of its crossover operation, resulting in a sharp decrease in the search efficiency in the latter period. And the crossover operation also has a fatal weakness, that is, it is easy to destroy the already searched optimal solution, thus affecting the later search efficiency.

2.2. Tabu Search Algorithm Fusion. The tabu search algorithm is an extension of the traditional local search algorithm, which is a simulation of the human logical thinking process. Compared with traditional local search algorithms, its unique feature is the introduction of a memory function. The tabu algorithm uses a tabu table to record the traversed local optimal solutions, and in the next search, it uses the information in the tabu table to avoid or selectively deal with these solutions, so as to avoid falling into local optimal and ensure that different effective ways are searched. From the above analysis, it can be concluded that the tabu search algorithm can effectively avoid the already searched local optimal solution, thus improving the search efficiency, avoiding the algorithm oscillating near the local optimal solution and better converging to the global optimal solution. The general tabu search process is relatively simple, and its basic process is shown in Figure 1.

According to Figure 1, the following solving steps can be obtained:

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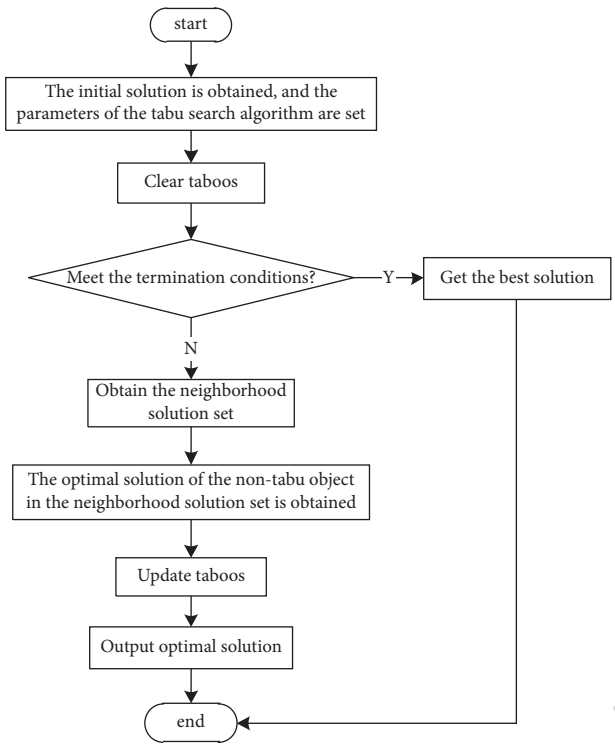

Figure 1: Basic flow of tabu search algorithm.

Step 1: We generate an initial feasible solution, set it as the current solution and the best solution so far, set the parameters of the tabu search algorithm, and empty the tabu table;

Step 2: We judge whether the termination condition is met. If so, the algorithm will stop and output the current solution and the optimal solution. If not, go to Step 3.

Step 3: The neighborhood is defined according to a neighborhood structure definition method, and the neighborhood structure is used to generate the neighborhood solution set of the current solution, and the objective function is used to evaluate the fitness of each solution set.

Step 4: We analyze the neighborhood solution set. If there is a solution set that is better than the best solution so far, amnesty is given to the best solution, and the best solution is set as the new best solution so far; if there is no, the non-tabu best solution in the current solution set is set as the current solution.

Step 5: We update the current taboos table and go to Step 2.

2.3. Process Design of Hybrid Genetic Tabu Search Algorithm. The genetic algorithm (GA) and the tabu search algorithm (TSA) are two widely used meta-heuristic algorithms for solving population economic transfer problems. They are based on natural heuristics and have complementary characteristics in performance. A genetic algorithm is a kind of group parallel search. Its global search ability is good, but the local search ability is poor and prone to precocity. The tabu search algorithm is a serial search, which moves from one solution to another in each iteration. Its local search ability is strong, but the global search ability is poor, and it is easy to fall into the local optimal solution. Therefore, by organically combining the advantages of genetic algorithm and tabu search algorithm, a hybrid genetic tabu search algorithm with strong global search ability and strong local search ability can be obtained.

Because the genetic algorithm only needs to adjust several parameters of the population rather than for a single solution, this paper adopts a hybrid algorithm that integrates the genetic algorithm into the tabu search algorithm. Figure 2 shows the mixed structure diagram of the genetic algorithm and the tabu search method in the genetic tabu search algorithm. Specifically, the multiple new individuals generated by crossover and mutation operations in the genetic algorithm are regarded as the neighborhood $V(X_n)$ of the current solution of X_n in the tabu search method, and then each individual in the neighborhood $V(X_n)$ is traversed. The genetic tabu search algorithm in this paper can select multiple solutions from the neighborhood $V(X_n)$ and then use the tabu table of the genetic tabu search algorithm to screen these solutions. These operations reflect the collective parallel search performance of the genetic algorithm.

Solution flow of hybrid genetic tabu search algorithm is as follows:

Step 1: Initialization generates N feasible solutions, where N is the population size;

Step 2: We evaluate the fitness value of each individual in the population

Step 3:We judge whether the population meets the termination condition. If so, the optimal solution will be output. Otherwise go to Step 4;
Step 4: select a selection strategy to select the next generation population;

Step 4: We perform crossover operation according to crossover probability P_c to generate two new individuals;

Step 5: We perform mutation operation according to mutation probability P_m to generate two new individuals;

Step 6: We use tabu search algorithm to optimize the generated new individuals;

Step 8: We generate a new generation population and return to step 3.

The specific flow chart is shown in Figure 3.

As shown in Figure 3, the hybrid genetic tabu search algorithm achieves the optimization of individuals generated by the tabu search algorithm and generates a new generation of the population through selection strategy, crossover operation, and mutation operation.

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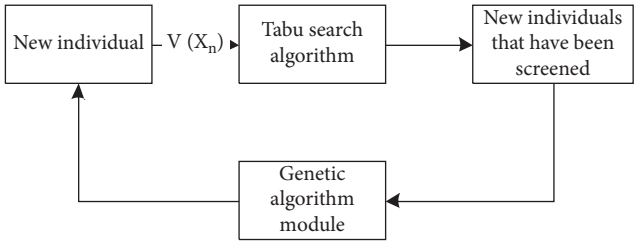

Figure 2: Hybrid genetic tabu search algorithm.

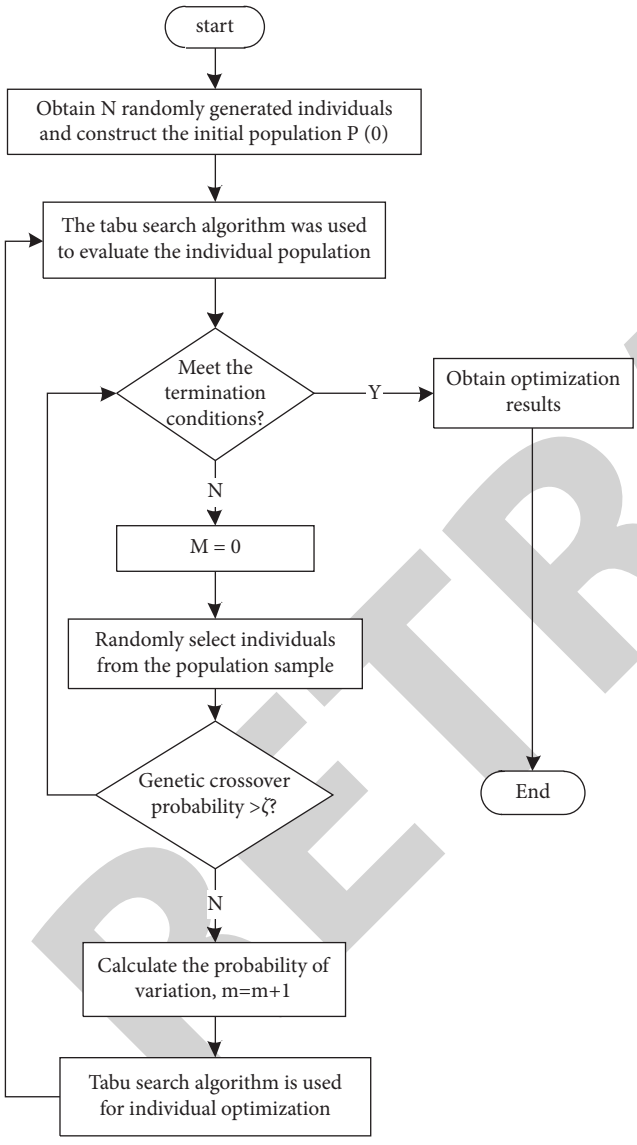

Figure 3: Flow chart of mixed genetic tabu search algorithm.

3. Population Economic Transfer Function Model Based on Genetic Tabu Search

3.1. Population Migration Algorithm Construction. In the following part, combining with the function global optimization problem, we study how to establish a new global optimization search algorithm, namely PMA, by simulating the population economic transfer mechanism. The current study is aimed at forms such as

$$\begin{aligned} &\max f(x), \\ &s.t. x \in S. \end{aligned} \tag{1}$$

For unconstrained function optimization problems, the problem (1), $f: S \longrightarrow R^1$ is a real valued mapping:

$$x \in R^n, S = \prod_{i=1}^{n} [a_i, b_i], \tag{2}$$

where S is the search space and $a_i < b_i$, and it is assumed that problem (1) always has a solution, that is, the global optimal value f^* exists and the global optimal set M is nonempty.

Function optimization is to find the optimal solution in the search space, and population economic transfer is to find preferential areas in the regional space. There are similarities between the two. Table 1 shows the analogy relationship between some elements of the two.

It should be noted that the economic transfer of population is a complex process, which does not completely correspond to the global optimization of function. Therefore, the principle of establishing a global optimization search algorithm by simulating the population economic transfer mechanism is to extract the useful elements in the process of population economic transfer, rather than copy them completely. The simulation implementation of each link is discussed below. Population flow is carried out in each residential area, which originally refers to the space specified on the Earth's surface. When it is extended to the space specified in PMA, the population flow is simulated in each residential area. If it is divided directly by administrative region or longitude and latitude line, then with the increase in the dimension of the optimization problem, the problem of dimension disaster will appear.

In the search space S, N points $x^1, x^2, \ldots, x^N$ are randomly generated. For each point x_i and the predetermined area:

$$\delta^i\left(x^i, \delta^i \in R^n; \delta^i_j > 0; i = 1, 2, \ldots, N; j = 1, 2, \ldots, n\right). \prod_{j=1}^{n} \left[x^i_j - \delta^i_j, x^i_j + \delta^i_j\right]. \tag{3}$$

Considering the poor regularity of the population flow, the population flow is treated as random. In addition, in order to make the search opportunities in the region equal, the population flow is further treated as a uniform random change. In the simulation, several points can be randomly generated in each region, and then these points can be randomly changed. A simpler equivalent method can also be used to deal with the population flow. That is to say, multiple random changes of a point are equivalent to one random change of multiple points. In this way, only one random change point in each region can make a predetermined number of uniform random changes.

Preferential areas attract people from other areas. For simplicity, the process of population economic transfer is

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Table 1: Comparison of function optimization factors and population economic transfer.

Function optimization elements	Factors of population economic transfer
x	Population location
$f(x)$	Economic factors such as income or attractiveness of population location
S	Mobile surface space of population
The best	The highest income point or the most attractive point
Optimal value	The highest income or attraction
Ascent/climb	Move to preferential areas
Break away from local optimum	Population pressure leads to relocation from preferential areas

simplified, that is, all people and their economy migrate to preferential areas. In the simulation, N points are randomly generated in the preferential area to replace the points in other areas. The preferential area is redrawn with the point where the current maximum $f(x)$ value is located as the center. The maximum $f(x)$ value is used to measure the attraction of the preferential zone, and each $f(x)$ value is used to represent the population income of each point. After the population moves into the preferential zone, there are n points in the preferential zone. Every time the N points complete a random change, it is necessary to find out the point with the highest income, and redefine the zone with it as the center. This is to simulate the shift of the population center of gravity with the shift of the economic center of gravity. When the preferential area shrinks to a certain extent, that is, when the population pressure increases to a certain extent, the population will spread outward, and the population will move out of the preferential area and spread to the undeveloped area with low population density. In the search space, N points are randomly generated and the area is redivided. Finally, the simulation of preferential area information media is given. The media such as relatives and friends, media advertising, and the labor market are abstracted as the best recording unit. In the algorithm, the best recording unit records the current maximum value of $f(x)$ and the corresponding point x, which provides the basis for determining the preferential area.

3.2. Design Process of the Population Economic Transfer Function Model. In the algorithm, people and their places are represented by points.

$$x^i = \left(x_1^i, \ldots, x_n^i\right). \tag{4}$$

We denote the i-th point, $x^i \in R^n$, x_j^i we denote the j-th component of the i-th point.

$$\delta^i\left(\delta^i, \ldots, \delta_j^i\right), \delta^i \in R^n, \tag{5}$$

δ_j^i is the j-th component of δ^i, $\delta_j^i > 0$; $i = 1, 2, \ldots, N$, $j = 1, 2, \ldots, n$, N is population size.

Step 1. Wegenerate N points $x^1, x^2, \ldots, x^N$ evenly and randomly in the search space. For each i, let the center center$^i \pm x^i$ of the i-th region determine the upper and lower boundaries of the i-th region, center$^i \pm \delta^i$, where

$$\delta_j^i = \frac{\left(b_j - a_j\right)}{(2N)}, \quad i = 1, 2, \ldots, N, j = 1, 2, \ldots, n. \tag{6}$$

The above-given method of δ_j^i makes each δ^i equal, so the superscript of δ^i is cancelled in the following steps:

Step 2. The income / attraction $f(x^i)$ of each point is calculated.

Step 3. The optimal record value and the optimal record point according to the calculated value obtained in step 2 is intialized.

Step 4. The population flow is carried out in each area.

$$x^i = 2\delta \operatorname{rand}(*) + \left(\text{center}^i - \delta\right), \tag{7}$$

where $\operatorname{rand}(*)$ is a random number function.

$$\begin{cases} x_j^i = a_j & x_j^i < a_j \\ x_j^i = b_j & x_j^i > b_j. \end{cases} \tag{8}$$

Step 5. The income / attraction $f(x^i)$ of each point is calculated.

Step 6. The best value and the best point is recorded.

Step 7. If the number of population movements L is less than the preset number, we go to step 4.

Step 8. Population economic transfer: we take the most attractive point (i.e., the best record point) as the center, determine the preferential area according to the size of each component of δ. in this area, evenly and randomly generate N points to replace the original points.

Step 9. The income / attraction $f(x^i)$ of each point is calculated.

Step 10. The best value and the best point is recorded.

Step 11. The preferential area is reduced:

$$\delta = (1 - \Delta). \tag{9}$$

(Δ is contraction coefficient, $0 < \Delta < 1$).

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Step 12. We then carry out population flow in the preferential area and the population changes with the economic center of gravity: take the most attractive point (i.e. the best record point) as the center, determine the preferential area according to the size of each component of δ. Evenly and randomly generate N points in the area to replace the original points.

Step 13. The income / attraction $f(x^i)$ of each point is calculated.

Step 14. The best value and the best point is recorded.

Step 15. If max $j > \alpha$ (α is the population pressure parameter, the preset positive small amount), we go to step 11.

Step 16. The results are reported.

Step 17. Population diffusion: we evenly and randomly generate N points $x^1, x^2, \ldots, x^N$ in the search space to replace the original points. We determine the population flow area according to the method in step 1.

Step 18. The income / attraction $f(x^i)$ of each point is calculated.

Step 19. The best value and the best point is recorded.

Step 20. The number of iterations is m plus 1. If the number of iterations is less than the specified number, we go to step 4.

Step 21. We thenend the process.

PMA mainly simulates the mechanism of population transfer with the economic center of gravity and disperses with the increase of population pressure. The former promotes the algorithm to select better region search, while the latter can avoid falling into local optimum to a certain extent, so the search process presents the characteristics of alternating centralized search and decentralized search. This reflects the characteristics of the contradictory movement of population and economy in the process of population migration.

4. Experiment

4.1. Experimental Methods. In order to verify the effectiveness of the population economic transfer function model, a simulation experiment is designed. The test environment is a Windows 10 system, including Intel Core i7, RAM16g and Windows iSCSI. This paper uses the population economic transfer function model based on improved density entropy, the population economic transfer function model based on the Markov model, the population economic transfer function model based on lasso variable selection, and the model in this paper to carry out the following experiments.

Table 2: Evaluation accuracy of population economic transfer function under different models.

Area (km^2)	The accuracy of economic transfer function evaluation (%)			
	Improved density entropy model	Markov model	Lasso variable selection model	Model of this paper
50	66	64	81	99
100	76	76	65	98
150	86	76	74	95
200	57	64	78	96
250	76	58	68	95
300	72	73	69	94
350	70	71	73	99
400	59	68	78	97
450	67	75	73	96
500	66	74	77	98
550	80	72	85	97
600	72	78	74	95
650	75	84	64	97
700	71	88	63	93
Mean value	70.9	72.9	73	96

4.2. Evaluation Accuracy of Population Economic Transfer Function. In order to verify the evaluation effect of the population economic transfer function model, the improved density entropy model, the Markov model, the Lasso variable selection model, and the model in this paper are used to verify the evaluation accuracy of the population economic transfer function. The results are shown in Table 2.

According to the analysis of Table 1, the evaluation accuracy of the population economic transfer function model is different under different methods. When the area is 50 km^2, the accuracy of the improved density entropy model is 66%, the Markov model is 64%, the lasso variable selection model is 81%, and the model in this paper is 99%. A comprehensive analysis of the data in the above table shows that this model can effectively improve the accuracy of the results of population economic transfer. This is because the model analyzes the defects of the genetic algorithm and designs a genetic tabu search algorithm on this basis, which improves the convergence of the algorithm, avoids falling into a local optimum, and improves the precision of the design model.

4.3. Correction Effect of Population Economic Transfer Function. In order to verify the evaluation and correction effect of the population economic transfer function model, the improved density entropy model, Markov model, Lasso variable selection model, and the model in this paper are used to verify the correction accuracy of the population economic transfer function. The results are shown in Table 3.

According to the analysis in Table 3, when the area is 500km2, the correction accuracy of the population economic transfer function of the improved density entropy model is 53%, that of the Markov model is 52%, that of the lasso variable selection model is 36%, and that of the model in this paper is as high as 97%. When the area is 700 km^2, the

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Table 3: Correction accuracy of population economic transfer function under different models.

Area (km^2)	Correction accuracy of population economic transfer function (%)			
	Improved density entropy model	Markov model	Lasso variable selection model	Model of this paper
50	68	54	47	89
100	69	57	49	92
150	56	63	63	95
200	37	58	42	97
250	45	51	45	98
300	62	38	54	96
350	42	39	58	92
400	49	46	63	90
450	58	48	51	95
500	53	52	36	97
550	55	57	33	99
600	57	67	37	96
650	62	63	43	98
700	64	69	49	90
Mean value	55.5	54.4	47.8	94.6

accuracy of the modified density entropy model is 64%, the Markov model is 69%, the Lasso variable selection model is 49%, and the accuracy of this model is as high as 90%. The model in this paper has a high correction effect on the population economic transfer function, which shows that the model can effectively improve the correction rate of the population economic transfer function. The results demonstrate the effectiveness of the genetic tabu search algorithm and can effectively improve the accuracy of the design model.

5. Conclusion

This paper proposes a population economic transfer function model based on the genetic tabu search algorithm. The process of the genetic tabu search algorithm is designed; the design process of the population economic transfer function model is determined, and relevant comparative experiments are designed to verify the effectiveness of the model. The experimental results show that the proposed model can improve the accuracy of model evaluation and model correction rate, avoid falling into local optimum to a certain extent, and has good global optimization performance. The application of the population economic transfer function model can effectively improve the accuracy of the model.

The research results on population migration are very rich, and it is necessary to further explore some useful mechanisms to enrich the existing algorithm. The next research will focus on population migration density to further improve the application of the proposed algorithm.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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Research Article

The Impact of Resource Optimization on the Economic Development of the Marine Industry

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The traditional impact analysis method for the economic development of marine industries does not consider the impact weight of different marine industries, which leads to an unsatisfactory effect on sustainable development after the optimized management of resources. Therefore, a new method is designed to solve the above problems; by analyzing the scale, hierarchical system, and optimizing the spatial resource framework of the marine industry, the influence of different marine industries is comprehensively measured, and the final demand dependency of the marine industry economy is obtained. The comprehensive index system is designed to evaluate the economic development of the marine industry, and the linear weighted sum method is used to calculate the sustainable development degree of marine industry economy in different regions. The results show that the final evaluation score of the marine biological industry in Shandong Province is 64.97, which is affected by comprehensive factors. The scores of capital and environmental governance are between 84.03 and 82.87, respectively, which are the main factors to achieve sustainable development. After the optimization of this method, the demand dependence of relevant regions is reduced, and the sustainable development level is effectively improved, indicating that the sustainable state of this method is better. The resource optimization path given by the research can be further applied to the construction process of marine and industrial economic development in other provinces and cities so as to comprehensively improve the quality and effect of marine economic growth.

1. Introduction

With the increasing shortage of land resources in China, the ocean has gradually become the focus of resource development and utilization. With the promotion of the construction of the "maritime power" and the "twenty-first century Maritime Silk Road," China's marine economy has made steady progress and continued development and gradually become the blue engine of China's economic growth. China's marine economic strength cannot be underestimated [1]. The sustainable development of marine economy depends on the input quantity of marine production factors and the quality of their combination. The flow and allocation efficiency of marine production factors affect the speed and quality of marine economic development. Marine production factors include capital, labor, resources, science and technology, and policies, and their contributions to marine economic growth vary. The rational allocation of marine production factors and the efficient development and utilization of marine resources are crucial to the high-quality sustainable development of the marine economy [2].

In view of the close relationship between the marine industry and the sustainable development of the national economy, Zheng *y* and other researchers analyzed the current situation of marine tourism resources and the optimization and upgrading strategy of product development. The research results provided ideas for the rapid development of the marine economy [3, 4]. Tran m h and other scholars constructed the evaluation index system of marine resource development from four aspects: marine biological resources, marine mineral resources, marine space resources, and marine tourism resources. Through the introduction of mathematical analysis models, the research

shows that there is a significant correlation between marine resource development and marine economic growth, and there are obvious regional differences in the corresponding trends of marine economic growth on marine resource development [5]. Tang w's scholars and team believe that China's marine resources have a high degree of constraint on marine economic growth, the overall utilization of marine resources is extensive, and the "tail effect" of marine resources in various regions is significantly different [6, 7].

As for the marine industry, the State Oceanic Administration defines it in the classification of marine and related industries as "the general term of various industrial activities and related activities for the development, utilization, and protection of the ocean." The marine industry refers to the development, utilization, and protection of marine resources. In terms of the performance results of the industry, it can be divided into sectors with production nature, activities with economic nature, and systems with hierarchical nature [8–12]. The classification of the marine industry has two kinds of classification: three industry classifications and a development trend classification.

Classification of three industries: the first marine industry mainly refers to marine aquaculture. The second marine industry includes the seawater salinization and desalination industry, seawater chemical industry (extraction of chemical substances), marine oil and gas and mining industry, marine electricity industry (using tidal energy, wave energy, and thermal energy for power generation), marine construction industry (ports, undersea houses, and tunnels), marine food processing industry, and drug processing industry [13, 14]. The third marine industry includes marine transportation (port and transportation), submarine storage industry, marine tourism industry (coastal island sightseeing, etc.), marine crafts decoration industry, marine information industry (marine environment information prediction and prediction consultation), marine service industry (marine environmental element monitoring, protection, disaster reduction, disaster prevention, and technical services), and so on.

Development trend classification: traditional marine industries include the marine fishing industry, marine salt industry, and other mature industries with a long history, conservative technology, and fixed scale [15–17]. The emerging marine industries include mariculture, the marine chemical industry, coastal tourism, and so on. Driven by scientific progress, they have developed to a certain scale. In the future, marine industries, including marine biopharmaceuticals and health products, marine power and seawater utilization, and marine integrated services, have been applied on a small scale. In the future, with the development of science and technology, it will reach a certain scale of industry [18–21].

Since the beginning, the State Oceanic Administration has adjusted the early statistical indicators of the marine industry and improved the classification of the marine industry. The national standard of the People's Republic of China's classification of marine and related industries has been formulated, which divides the marine industry into four categories: categories, large categories, medium categories, and small categories [22–24]. Among them, the major categories include "marine fishery industry, marine engineering and construction industry, marine transportation industry, coastal shipbuilding industry, marine oil and gas industry, marine chemical industry, marine salt industry, coastal sand mining industry, marine power and sea water utilization industry, marine information service industry, marine biopharmaceutical industry and health care product industry, coastal tourism industry, and other marine industries." In this paper, the marine industry is divided into industrial categories according to the classification of the State Oceanic Administration [25–27].

It is of great significance to effectively analyze the economic development of the marine industry through resource optimization. However, when analyzing the impact of marine industry economic development by current methods, the analysis results are not comprehensive, and the sustainable development degree of the marine industry is not good after resource optimization. In order to improve the allocation efficiency of marine production factors, realize the efficient development and utilization of marine resources and promote the high-quality development of China's marine economy. Therefore, this paper proposes a new method to obtain the final demand dependence of marine industry economy by calculating the influence of the marine industry so as to realize the effective analysis of marine industry economic development; the biggest difficulty in the research is that the influence of the marine industry is affected by many factors, and the impact evaluation is subjective. Specifically, it is as follows: firstly, the influence of different marine industries is comprehensively measured by combining the methods of resource allocation, analysis of scale, hierarchical system, optimization of marine industry spatial resource framework, and others, then a comprehensive index system is designed to evaluate the economic development of marine industries, and the sustainable development degree of marine industry economy in different regions is calculated by using the linear weighted sum method.

2. Optimal Management of Resources

2.1. Resource Allocation. In the research on the evolution of spatial structures in China, many scholars believe that institutional change has led to the evolution of marine industrial economic structures, and port resources are an important competitive factor, which can be controlled by the government through administrative power [28, 29]. Some scholars think that the change in the role of local government leads to the development and evolution of urban space; with his unique research perspective, Li Qiang uses the new institutionalism methodology to establish a new analysis framework for the economic spatial development of China's marine industry, that is, under the specific political, economic, and social institutional environment, the relevant actors interact through behavior selection to promote the internal mechanism of the economic structural development of the marine industry, as shown in Figure 1.

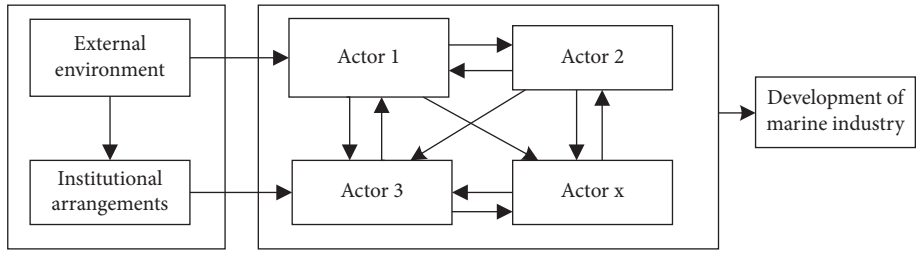

Figure 1: Port space resource structure.

2.2. Analysis Scale. Any research on spatial issues needs to be based on a certain regional scale. For the optimal allocation and control system of port resources, this study analyzes the macroscale, mesoscale, and microanalysis scale. The analysis purposes of the three scales are described as follows:

(1) Macroanalysis scale: To study the economic performance and factor scale efficiency of national port resource allocation, China's regional economic development usually takes the administrative region as the allocation and statistical boundary, but for the port, the administrative division cannot fully reflect its differences, so the study starts from the national level.

(2) Mesoscale analysis: There is no obvious difference in the governance structure and institutional environment of spatial resource allocation, while the spatial behavior related to it reflects the characteristics of spatial dependence, that is, there is a significant interaction between adjacent action units. This paper studies the decision-making and action logic of governance structures at the regional level and selects the spatial scale of adjacent ports.

(3) Microanalysis scale: This paper mainly studies the spatial pattern evolution of port resource allocation. As for the concept of the scale of a metropolitan area, scholars mainly have two ways to define it: one is based on the scope of an administrative region, and the other is based on the scope of functional radiation. However, no matter which way of definition, this regional scale is bound to be a functional nodule area with close social and economic elements and a development trend of integration [30]. In this way, it is meaningful to study its spatial structure, functional form, network connection, and spatial effect on urban governance.

2.3. Hierarchy System. Based on Williamson's hierarchy of social science research, this paper divides the spatial reconstruction effect into three research levels, namely allocation efficiency, governance structure, and institution. The three levels have a close internal logical relationship, and the corresponding relationship is presented between different levels through the mapping of organization and space. Allocation efficiency is the first level of efficiency, and its "tangible" characteristics are also the main characteristics different from the first two levels. Land resource utilization reflects the spatial relations such as geometry, topology, nodes, and networks in space, which are the basic physical characteristics of port space, social, and economic development. It presents the external derivative phenomena such as regional economic agglomeration development, spatial structure evolution, planning implementation effect, and so on; the governance structure is the second level of efficiency. Its behavior is framed in the institutional environment and determines the way of spatial allocation of resources [31]. The decision-making mechanism and results of governance structure directly affect the allocation of resources; the institutional environment (formal system) is the third level of efficiency, which is the institutional constraint on the government and market entities on port resources and related economic activities. Besides the social basis (informal system), it plays a fundamental role in spatial reconstruction. The optimized institutional environment can provide sufficient incentives to ensure the correctness of decision making, and then through the port resource allocation behavior, the institutional environment (formal system) can provide sufficient incentives to ensure the correctness of decision making. We build a superior spatial structure and realize the improvement of the port overall capacity and sustainable economic growth.

2.4. Space Resource Framework. According to the research hierarchy system, this paper constructs the analysis framework, as shown in Figure 2. The analysis starts from three levels: resource allocation, governance structure, and institutional environment. The institutional environment plays a role of constraint and incentive on the first two levels and determines the efficiency of the first level; the governance structure makes decisions on resource allocation behavior, which determines the efficiency of the second level; resource allocation directly affects land resources Source utilization determines the efficiency of the third level. In resource allocation, the self-organization mechanism and the organized mechanism simultaneously determine the development performance of port resource allocation. In addition, resource allocation and governance structures will feed back into the institutional environment in the process of layer by layer, and the institutional environment will be continuously improved, and a new round of resource allocation efficiency will be promoted.

3. Calculation of Marine Industry Influence

Sensitivity refers to the degree to which the demand of a certain marine industry changes with the increase or

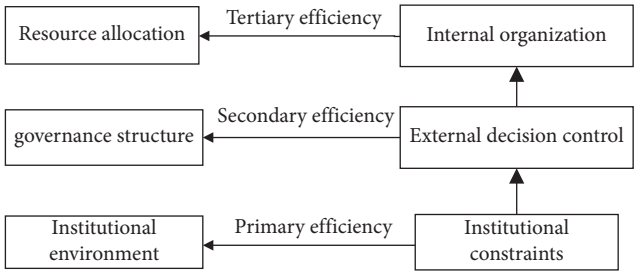

Figure 2: Configuration analysis block diagram.

decrease of the output of other industries. The sensitivity G_i of the marine industry is expressed by (1), that is, the average value of each row of the Leontief inverse matrix of the marine industry divided by the sum of the average values of each row.

$$G_i = \frac{(1/n)\sum_{j=1}^{n} r_{ij}}{1/(1/n)\sum_{i=1}^{n}\left((1/n)\sum_{j=1}^{n} r_{ij}\right)} = \frac{n\sum_{j=1}^{n} r_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} r_{ij}} \quad (i = 1, 2, \ldots n). \tag{1}$$

In equation (1), r_{ij} refers to the Leontief inverse matrix coefficient of the marine industry i to the marine industry j.

Impact refers to the impact of the increase or decrease of the output of a certain marine industry on the demand of other marine industries. The influence F_j of the marine industry is expressed by (2), that is, the average value of each column of the Lions Hoff inverse matrix of the marine industry divided by the sum of the average values of each column.

$$F_j = \frac{(1/n)\sum_{j=1}^{n} r_{ij}}{1/(1/n)\sum_{i=1}^{n}\left((1/n)\sum_{j=1}^{n} r_{ij}\right)} = \frac{n\sum_{j=1}^{n} r_{ij}}{\sum_{j=1}^{n}\sum_{i=1}^{n} r_{ij}} \quad (j = 1, 2, \ldots n). \tag{2}$$

From the perspective of the sensitivity coefficient of the marine industry, the values of "marine fishery," "offshore oil and gas industry," "marine salt industry," "marine shipbuilding industry," "marine biological medicine industry," and "marine engineering construction industry" are relatively low, which indicates that this marine industry is not sensitive to other marine industries and will constitute the development bottleneck of the whole marine industry. In formulating industrial countermeasures, we need to increase the guidance and support of low sensitivity to stimulate the induction of these industries. In terms of the influence coefficient of the marine industry, the values of "marine mining," "marine chemical industry," "marine biological medicine," "sea water utilization industry," "marine transportation," and "seaside tourism" are relatively large, which indicates that the marine industry has a great influence on other marine industries. When this marine industry increases its output, it will greatly stimulate the demand of the rest of the marine industry. Therefore, when formulating the industrial development strategy, these industries often become the leading industries.

It can be seen from the research on the induction coefficient that every increase in the final demand of the marine industry will have a driving effect on the industry. The calculation method of the final demand inducement coefficient is as follows:

$$\text{Production induced coefficient of final demand} = \frac{\text{Induced amount of final demand on production}}{\text{Total final demand of all industries}} \times 100\%. \tag{3}$$

Specifically, (3) can be regarded as follows:

$$T_i = \frac{\sum_{k=1}^{n} C_{ik} f_k}{\sum_{k=1}^{n} f_k} \quad (k = 1, 2, \ldots n). \tag{4}$$

Here, T_i is the induced coefficient generated by the final demand of the i th marine industry sector; $\sum_{k=1}^{n} C_{ik} f_k$ is the sum of the product of the corresponding row vector in the Leontief inverse matrix and the final demand; C_{ik} refers to the corresponding row vector in the Leontief inverse matrix; f_k is the final demand value of each marine industry; $\sum_{k=1}^{n} f_k$ is the sum of the final demand of the marine industry.

Using the same method, the production-induced coefficient of consumption, investment, and transfer out is calculated. The specific meaning of the induced coefficient of marine industry consumption is that with every increase in marine consumption, induced driving creates an effect on a certain marine industry. The specific formula is as follows:

$$\text{Production induced coefficient of consumption} = \frac{\text{The induced amount of consumption on production}}{\text{Total consumption of all industries}} \times 100\%. \tag{5}$$

The specific meaning of the induced coefficient of marine industry investment is with every increase in the marine investment of a unit, induced driving has an effect on a certain marine industry. The specific formula is as follows:

$$\text{Production induced coefficient of investment} = \frac{\text{Induced amount of investment on production}}{\text{Total investment of all industries}} \times 100\%. \tag{6}$$

The specific meaning of the induced coefficient of marine industry transfer out is the inducing and driving effect of each additional unit of marine industry transfer out on a certain marine industry. The specific formula is as follows:

$$\text{Production induction coefficient of transfer out} = \frac{\text{Induced amount of transfer out to production}}{\text{Total transfer out of all industries}} \times 100\%. \tag{7}$$

From the perspective of the marine industry production inducement coefficient, "marine fishery," "marine mining," "marine chemical industry," "marine engineering construction industry," and "marine service industry" have large final demand induction coefficients, and the marine industry is strongly induced by the final demand of this marine industry. The consumption-induced coefficient of the "marine chemical industry," "marine biological medicine industry," "marine power industry," and "marine service industry" is relatively large, and the marine industry is greatly affected by the consumption of this marine industry. The "marine mining industry" and "offshore engineering construction industry" have a large investment induction coefficient, and the marine industry is strongly driven by this marine industry investment. "Marine mining," "offshore engineering construction," "marine power industry," and "marine service industry" have large export induction coefficients, and the marine industry is greatly stimulated by the marine export volume.

The final demand dependence shows that in the marine industry, the induced amount directly and indirectly generated by the final demand of a single industry accounts for the proportion of all the induced amounts. The specific calculation method is as follows:

$$\text{Demand dependence} = \frac{\text{Induced amount of final production demand}}{\text{Total output value of the sector}} \times 100\%. \tag{8}$$

Specifically, formulas (8) can be regarded as formula (9).

$$Y_i = \frac{\sum_{k=1}^{n} C_{ik} f_k}{Q_i} \quad (i = 1, 2, \ldots n). \tag{9}$$

Here, Y_i represents the final demand dependence of the i th marine industry, and Q_i represents the total output value of the i th marine industry.

According to the final demand dependence of marine industries, the marine industries are classified. Among them, "marine fishery," "marine shipbuilding industry," "marine biological medicine industry," "marine electric power industry," "marine transportation industry," and "marine service industry" have a high degree of consumption dependence. "Offshore oil and gas industry," "marine salt industry," "marine chemical industry," "marine engineering construction industry," and "marine transportation industry" have a high degree of investment dependence (more than, they belong to investment-dependent industries). "Marine mining industry," marine engineering construction industry, marine power industry, seawater utilization industry, marine transportation industry, and marine service industry have a high degree of export dependence (more than, they are export-dependent industries). The offshore engineering construction industry has a high degree of dependence on investment and export, which belongs to both investment-dependent and export-dependent industries. The marine power industry and marine service industry processing are both consumption-dependent and export-dependent industries. In addition, the marine transportation industry is strongly dependent on consumption, investment, and export.

4. Experimental Analysis

Generally, the comprehensive evaluation method is used to measure the sustainable development level of the marine biological industry. The indicators selected in this paper are mainly quantitative, so the quantitative method is based on mathematical statistics and measures the level of sustainable development. The specific steps include normalization of indicators, the linear weighted sum method, rating standards, and so on.

(1) Index normalization: due to the obvious difference in data processing of the selected indicators, the data units and orders of magnitude are different, and the comparison of simple data is prone to bias or incompatibility. In order to ensure that these objective factors do not affect the final calculation results, the unit and order of magnitude should be unified before evaluation, and the initial data should be normalized to ensure the final evaluation. The price result is objective and scientific. The maximum and minimum values are used to process the original data to get the normalized quantitative data, and the original index value is transformed into a value between 0 and 1 after normalization.

(2) Linear weighted sum method uses a simple summation linear weighting method to judge the quality or strength of sustainable development with the score value obtained. The formula is as follows:

$$S_i = \sum_{j=1}^{n} X_{ij} \times W_{ij} \times 100\%. \tag{10}$$

Among them, S_i represents the degree of sustainable development, which is the comprehensive evaluation value of the i level, W_{ij} represents the weight of the j evaluation index of the i level, and X_{ij} represents the index value of the i and j evaluation indexes, which is multiplied by 100 to convert into the percentage system.

(3) The evaluation criteria of sustainability can be seen from the above formula that the final score of s value representing the degree of sustainable development is between 0 and 100. When $s = 100$, the highest score means the largest degree of sustainable development. The whole evaluation index system is very perfect, and the industry has embarked on the road of sustainable development; when $s = 0$, the degree of sustainable development is the smallest, which indicates that the industry is in the chaotic and disordered development stage, and the development situation is very bad; when s is between 0 and100, the closer it is to 100, the better the sustainability, and the closer it is to 0, the less sustainable development

can be achieved. In order to make the comprehensive evaluation results easy to distinguish, the evaluation level of sustainable development of the marine biological industry can be divided into four levels. The level with a comprehensive evaluation value of above 80 points is a strong sustainable level, that with a comprehensive evaluation value of 70–80 points is a sustainable level, that with an evaluation score of 60–70 points is a weak sustainable level, and that with less than 60 points is an unsustainable level (see Table 1). After the comprehensive evaluation is obtained without considering the qualitative conditions, the sustainability of development is judged according to the corresponding grades.

This paper analyzes the current situation of the marine biological industry in Shandong Province as a whole and also analyzes the sustainable development of the marine biological industry in coastal cities of Shandong Province. Table 2 is the normalized processing data of six coastal cities in Shandong Province.

According to the data in Tables 1 and 2 and the linear weighted average formula, the marine biological industry affected by the overall factors in Shandong Province is calculated. The final evaluation score is 64.97, and the evaluation standard is 50–65. It can be seen that there are still many deficiencies in the sustainable development of the marine biological industry in Shandong Province. The sustainable development is not strong, so we need to strengthen the development of the marine biological industry from all levels and factors. The overall evaluation score is not high. At the same time, we should find out the weak factors that affect the sustainable development of the marine biological industry and evaluate the factor layer. The scores are shown in Table 3.

According to the scores in Table 3, the scores of capital and environmental governance are between 84.03 and 82.87, respectively, which are both more than 80 points. They are powerful factors for sustainable development and favorable factors for supporting the sustainable development of the marine biological industry. The development of industrial economy, especially the rapid development of the marine industry in Shandong Province, also supports the sustainable development of the marine biological industry. The score of the industrial economic factor is 78.12. In the sustainable range of industrial development, if we continue to promote the development of industrial economy, we will make a greater contribution to the development of the marine biological industry in Shandong Province. The investment in ecological resources is still relatively weak, with a score of 62.27, and the score of the population factor and marine economy is a little more than 50, both of which are in the range of weak sustainability. Therefore, the industry should pay more attention to the maintenance of marine resource ecology, strengthen the control of population factors, and vigorously promote the rapid development of marine economy. At the same time, there are many weak factors, including technology and regional economy. The evaluation score of these factors is below 50, which seriously affects the sustainable development of the marine biological industry. If these factors can be improved rapidly, it will help the marine biological industry to achieve sustainable development.

Table 1: Classification of evaluation criteria for sustainable development.

Comprehensive score	Sustainable development degree
> = 80	Strong sustainability
65 – 80 (including 65)	Sustainable
50 – 65 (including 50)	Weak sustainability
<50	Unsustainable

According to the evaluation criteria of the evaluation system, the evaluation scores and the sustainable status of the six coastal cities in Shandong Province are calculated, and a table is established as shown in Table 4.

From Table 4, we can draw the following conclusions: the development of the marine biological industry in Shandong Province is not balanced. The sustainable development ability of the marine biological industry in each coastal city is not strong. Only Qingdao is in a state of sustainable development. Weihai, Weifang, and Yantai are in a weak sustainable state, and Dongying and Rizhao are in an unsustainable state. According to the analysis results of the above selected indicators, the Qingdao marine biological industry has a strong sustainable development ability, which is suitable to be the leader of this industry in Shandong Province. More support should be given to the scale of the industrial park, scientific and technological innovation, and government support to ensure its sustainable development. On this basis, it will move forward to strong and sustainable development. Weihai, Weifang, and Yantai have certain advantages in the development of the marine biological industry, and the sustainability of the industry is weak in the initial stage. Therefore, it is necessary to strengthen the industrial support and integrate relevant resources as soon as possible so as to make the development of the marine biological industry become a new economic growth point. At present, the sustainable development of the marine biological industry in Dongying and Rizhao is in an unsustainable range. The overall score is low, and the statistical data may be biased. However, generally speaking, the development of the marine biological industry in these two cities is not very obvious and should not be taken as the current key development object.

In order to further verify the economic development of the marine industry after optimization of the method in this paper, the methods of Zhang [11] and Wang et al. [17] and the economic demand dependence of the marine industry after optimization of the method in this paper are calculated, and the results are shown in Figure 3.

Figure 3 shows that different methods have dependence of different requirements. When the number of experiments is 15, the demand dependence of the method of Zhang [11] is 35%, that of the method of Wang et al. [17] is 46%, and that of the method in this paper is 9%. When the number of experiments is 30, the demand dependence of the method of Zhang [11] is 33%, that of the method of Wang et al. [17] is

Table 2: Data processing table of the marine biological industry in Shandong Province.

Factor layer	Index layer	Quantized value
Demographic factors	Natural population growth rate (‰)	0.551564311
	Population density (person/km^2)	0.728464419
	Proportion of nonagricultural population in total population (%)	0.192631579
	Proportion of employees in total population (%)	0.256478148
	Number of people with an education level above junior high school (person)	0.833611506
Capital	Total government funding (10000 yuan)	1
	Total financing amount of financial institutions (10000 yuan)	0.6431
	R&D funds (10000 yuan)	0.824666398
Technology	Internal expenditure of scientific and technological activities (10000 yuan)	0.557363369
	Several industrial patents authorized	0.163876865
	Ratio of senior professional titles to professionals (%)	0.8546
Regional economies	Per capita GDP (yuan/person)	0.367508808
	Annual per capita net income of farmers (yuan/person)	0.28744166
	GDP growth rate (%)	0.365079365
	Proportion of the secondary industry in GDP (%)	0.934724858
Marine economy	Total output of the marine industry (100 million yuan)	0.805845304
	Coastal per capita income (10000 yuan)	0.25083885
	Proportion of fishery in agriculture	0.400473934
Industrial economy	Ratio of the marine biological industry's output value to the marine industry	0.7864
	Total profit of the marine biological industry (100 million yuan)	0.9854
	Proportion of the added value of the marine biological industry in GDP	0.3546
	Annual growth rate of the added value of the marine biological industry (%)	0.87954
Ecological resources	Mariculture (10000 HA)	1
	Sea area (10000 HA) (10000 km^2)	0.081146184
	Total output of seawater aquatic products (10000 tons)	1
	New marine reserves (10000 HA)	0.290872328
Environmental governance	Total emission of industrial waste gas (100 million standard cubic meters)	0.969443116
	Total investment in environmental pollution control (10000 yuan)	1
	Direct economic loss of ecological pollution (100 million yuan)	0.3456
	Total investment in environmental protection of industrial projects (100 million yuan)	1

Data sources: 2011 China Statistical Yearbook, 2011 China Ocean Statistical Yearbook, 2011 Shandong Statistical Yearbook, 2011 Shandong Statistical Bulletin and network statistical information, and by consulting relevant data.

Table 3: Score of the evaluation factor layer.

Factor layer	Score value	Status bar
Demographic factors	51.25	Weak sustainability
Capital	84.03	Strong sustainability
Technology	48.91	Unsustainable
Region economics	48.85	Unsustainable
Ocean economics	50.49	Weak sustainability
Industry economics	78.12	Sustainable
Ecology resources	62.27	Weak sustainability
Environmental science government	82.87	Strong sustainability

41%, and that of the method in this paper is 11%. The method in this paper always has a low demand dependence, which shows that the economic development of the marine industry in this paper is more independent of external influence.

In order to further analyze the development of the marine industry optimized by different methods, the degree of sustainable development after optimization of the above three methods is calculated, and the results are shown in Figure 4.

Table 4: Evaluation score of marine biological industry sustainable development in coastal cities of Shandong Province.

City	Score column	Status bar
Dongying city	27	Unsustainable
Qingdao	70	Sustainable
Rizhao N city	32	Unsustainable
Weihai city	51	Weak sustainability
Weifang city	55	Weak sustainability
Yantai city	61	Weak sustainability

Figure 4 shows that the degree of sustainable development of the marine industry is different under different methods. When the number of experiments is 20, the degree of sustainable development of the marine industry in the method of Zhang [11] is 69%, that of Wang et al. [17] is 79%, and that of this method is 95%. When the number of experiments is 60, the degree of sustainable development of the marine industry of Zhang [11] is 76%, that of Wang et al. [17] is 78%, and that in this method is 98.7%. The method in this paper always has a high level of sustainable development,

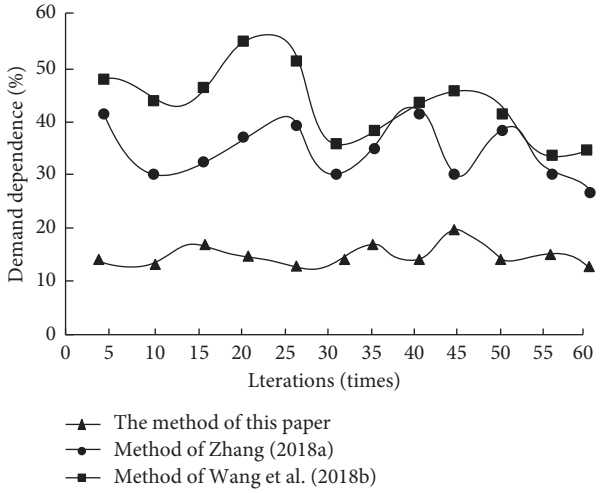

Figure 3: Requirement dependence under different methods.

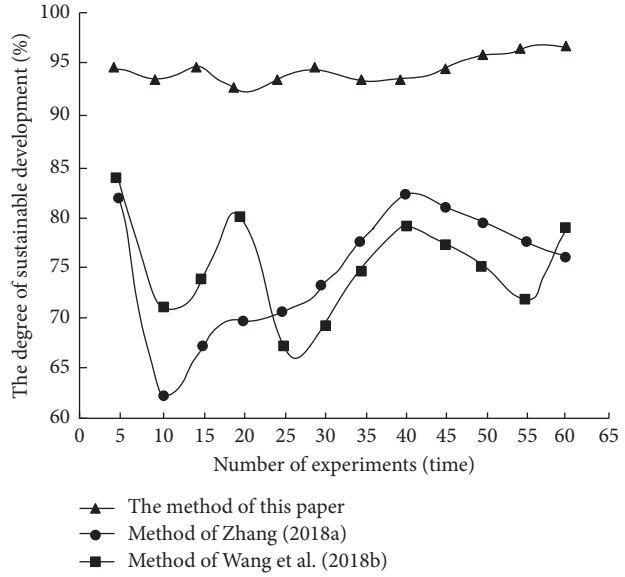

Figure 4: The degree of sustainable development under different methods.

and the score is a strong sustainable state, indicating that the sustainable state is better after the optimization of the method in this paper.

5. Conclusions

In order to analyze the impact of resource optimization and governance on the economic development of the marine industry, this paper designs a calculation method of weight quantification and evaluates the economic development of the marine industry after resource optimization through experiments; the development of the marine industry in Shandong Province is not balanced. The sustainable development ability of the marine biological industry in each coastal city of Haiti is not strong. Only Qingdao is in a state of sustainable development. Weihai, Weifang, and Yantai are in a weak sustainable state, while Dongying and Rizhao are in an unsustainable state. After the optimization of this method, the demand dependence of relevant regions is reduced, which shows that the economic development of the marine industry in this method is more independent of external influence, and when the number of experiments is 30, the demand dependence of this method is only 11%. This method always has a high level of sustainable development, and the score is a strong sustainable state, which shows that the sustainable state is better after the optimization of the method in this paper, and when the number of experiments is 60, the degree of sustainable development of the marine industry in this method can reach 98.7%. Limited by my time and energy, the research has not evaluated the economic development of the marine industry in other provinces and cities. Meanwhile, the proposed marine economic growth strategy is relatively farfetched and needs to be improved in the future.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

Recognition Method for Face Local Features Based on Fuzzy Algorithm and Intelligent Data Analysis

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Traditional recognition methods for face local features have a low recognition rate, so the recognition method for face local features based on the fuzzy algorithm and intelligent data analysis was designed. Firstly, the wavelet denoising method was used to reduce the noise of face images, and adaptive template matching was performed on the obtained images. Then, the face information was encoded, and the face features were identified to locate the face features. On this basis, the principal components of the face were analyzed to obtain the global features of the face. Finally, through the candidate set of facial local feature recognition, the extraction of face local features, and the fusion of face local features, the recognition of local face features were realized. The experimental results show that the average recognition rate of this method is 88.84% in a noise environment and 97.3% in noise-free environment. It can accurately recognize the face local features, can meet the needs of recognition of the face local features, and has certain practical application significance.

1. Introduction

With the development of pattern recognition, image processing, and machine learning, fast and effective automatic recognition and verification technology has attracted widespread attention due to its huge theoretical and practical application value. Face recognition refers to biometric recognition technology that is classified based on human face features. The technology first obtains photos containing faces through devices such as cameras. The face detection algorithm completes the collection and localization of various parts of the face, and then the collected faces are reduced in dimensions, and features are extracted to complete the recognition. Face, as one of the innate characteristics of living things, has individual uniqueness. Compared with other recognition technologies, it has the following advantages: first, it is easy to be collected. The identified individuals do not need to cooperate with the collection of images intentionally, and the user basically does not need to do any operations; secondly, there is no need to contact the captured devices; finally, face recognition has concurrency, and multiple individuals can be collected, detected, and classified simultaneously. It has been widely used in public security, banking, security inspection, and attendance.

At the same time, with the development of computer image processing technology, people have raised higher requirements for the accuracy and robustness of face recognition. For example, effective face recognition needs to be performed under some extremely harsh image acquisition conditions, and related recognition technologies will have broad application prospects in police cracking, traffic capture, and other fields. At the same time, research on face recognition methods under the condition of blurred images and face pose changes has application value in the fields of crime forensics and identity verification, so the research on recognition methods for face features has received great attention from researchers. Compared with global features, local features have the characteristics of rotation, translation, and illumination invariance and have higher accuracy and stability. However, when directly using local features for image matching, the calculation is large and it is not suitable for establishing a fast and efficient human-computer interaction system. In recent years, many scholars have

proposed improvements to the recognition of face local features, and they have improved the recognition ability of the algorithm to a certain extent. However, they all use the local size relationship between the neighbor points to describe the texture information and ignore the overall relationship between the gray value of the pixel and the center pixel in the same direction. When there are random noise points or there are changes in lighting and edges, the performance will be greatly reduced.

Therefore, the recognition method for face local features based on fuzzy algorithms and intelligent data analysis was designed to solve the problem of the low recognition rate of traditional recognition methods for face local features. Among them, the fuzzy algorithm belongs to the intelligent algorithm. When our understanding of the system model is not very deep, or objective reasons prevent us from conducting in-depth research on the system's control model, intelligent algorithms often can play a small role. At this time, a fuzzy algorithm is needed. Common fuzzy algorithms include mean blur and Gaussian blur. Intelligent data analysis refers to an analysis method that uses data analysis tools such as statistics, pattern recognition, machine learning, and data abstraction to discover knowledge from data. The purpose of intelligent data analysis is to directly or indirectly improve work efficiency. In actual use, it acts as an intelligent assistant so that workers have the right information at the right time and help them make the right decision in a limited time. Therefore, based on the advantages of fuzzy algorithms and intelligent data analysis, the two methods are combined to accurately recognize the local features of the face. In this article, the noise of the face image is removed by the wavelet filtering method to avoid the interference of noise. The LBP Operator method is used to encode the face image information. The LBP histogram is obtained by connecting the histograms to complete the feature localization. The local sensitive information of the face is recognized by the principal component analysis and the least square method; thus the recognition of the face features is realized.

2. Materials and Methods

2.1. Noise Reduction of Face Images. In order to accurately recognize face images, it is necessary to perform posture correction and noise reduction on the face images. Using wavelet denoising method, the geometric structure models of face images with different attitude features are first given [1]. Feature extraction and sample collection are performed on face models in different poses, and an affine transformation between two vector spaces with face image features is constructed in rotation coordinates [2, 3]. Among them, a new face image is reconstructed based on the pixel values corresponding to the x and y coordinates, and the face images are denoised. By training the face library and adjusting various poses of the face images to be tested, the pixel set of face images in the image set is given:

$$j(q) = \frac{\sum_{i=1} k}{W_i(n)}, \tag{1}$$

where $j(q)$ is the noise point in the pixel concentration, $\sum_{i=1} k$ is the wavelet noise reduction parameter, and $W_i(n)$ is the information of the face features.

The wavelet transform is used to filter the noise in the pixel concentration to obtain the underlying data distribution, and the image pixel feature information output after wavelet noise reduction is obtained, which is expressed as follows:

$$J(w) = \frac{\sum_c a}{W^i(x_u - x_o)}, \tag{2}$$

where $J(w)$ is the scale information of the wavelet transform, $\sum_c a$ is the projection mapping parameters of the geometric structure distribution of the face images, W^i is the diversity feature of the face pose, and x_u and x_o both represent the feature values of the face images.

Based on the noise reduction and attitude correction processing of face images, adaptive template matching is performed on the noise-reduced images, and the image segmentation method is used to block the face images. Feature information parameter extraction is performed on the background seed points of the face images according to the principal component analysis. The iterative formula for the background seed point solution is as follows:

$$W(x, y) = \frac{b}{\sum_{i=1} K + \wp}, \tag{3}$$

where $W(x, y)$ is the profile horizon data of the face position template matching center, $\sum_{i=1} K$ is the fault seed point data, $\wp$ is the face image background information, and b is the background seed point calculation parameter.

Frame scanning and information fusion are performed on continuous areas of geometric features that characterize the face images structure [4–6] and are based on linear affine subspace transformation. Under the environment of low contrast and uneven lighting, the adaptive template matching of face images is performed to build the polygon information model of the face contour distribution [7, 8]. The LGB decomposition of color features is based on the diversity of human poses, clothing colors, and other factors, and the correlation coefficients of facial contours are as follows:

$$P = \frac{q}{D(x)/\sqrt{u}}, \tag{4}$$

where P is the dimensionless quantity, $D(x)$ is the local information subspace reflecting the facial features, $\sqrt{u}$ is the image segmentation parameter, and q is the adaptive template matching parameter.

At this point, denoising of the face images is completed. Through adaptive template matching and image segmentation methods, face images are segmented to provide accurate data output basis for recognition of face local features [9–11].

2.2. Face Features Positioning

2.2.1. Face Information Encoding. After face image denoising and pose correction processing and segmentation,

accurate face feature data is output. In order to further realize feature localization, face image information needs to be encoded [12–16]. The LBP operator method is used to encode the face image information, which is mainly binary encoding using the gray value difference between the central pixel and the domain pixel. Finally, the LBP histogram is obtained by concatenating the histogram [17, 18]. Assume that the gray value of a given central pixel is P_i and the pixel value of the neighborhood is P_v. The coding rule is as follows:

$$S(P_i - P_v) = \begin{cases} 1, & P_v > P_i, \\ 0, & P_v < P_i, \\ 2, & P_v = P_i. \end{cases} \tag{5}$$

The field of the central pixel is generally taken as a 3×3 field, and a total of eight surrounding pixels are encoded with the difference ($n = 0, 1, ..., 7$). Figure 1 shows the calculation process of binary coding of a pixel.

Because the effective radius of the neighborhood is often not unique, in order to calculate a more reliable effective neighborhood point, a circular neighborhood has replaced the square area as the first choice. The LBP value of the center point encoding at a certain radius is as follows:

$$LBP_i = \sum_i q * \frac{pq}{p}, \tag{6}$$

where $\sum_i q$ is the radius of the selected neighborhood, p is the number of surrounding neighborhood points, pq is the number of neighborhood points, and LBP is the face features point encoding parameter.

Figure 2 shows the LBP operators with different radii and neighborhood points when encoding face features points.

As the number of neighborhood points increases, the types of LBP pattern values will inevitably increase sharply. If 8 neighborhood points are increased to 16, the number of binary patterns will reach 216. Although more LBP modes are accurate in describing texture details, they increase the data storage capacity and computational complexity, which reduces the efficiency of face recognition [19–21]. Therefore, the uniform mode algorithm is adopted to solve the problem of a large increase in calculation amount due to too many neighborhood points. It simplifies binary encoding and is defined by the number of changes between 0 and 1 in the encoding sequence. The calculation formula is

$$K|LBP|_i = \frac{q}{n} * \sum_i q, \tag{7}$$

where $K|LBP|_i$ represents the number of patterns in which the neighborhood points satisfy the uniform pattern condition, q/n is the measurement parameter of the uniform pattern, and $\sum_i q$ represents the uniform condition.

According to the above definitions, the encoding of face information is completed to provide a basis for the recognition of face local features.

2.2.2. Face Features Recognition. The LBP histograms of each block are connected in series to form a joint histogram of the entire face image [22–27]. The process is shown in Figure 3.

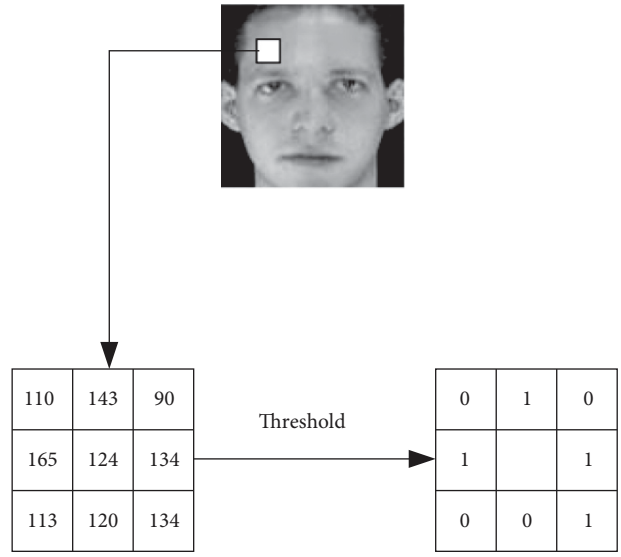

Figure 1: Encoding process of face features.

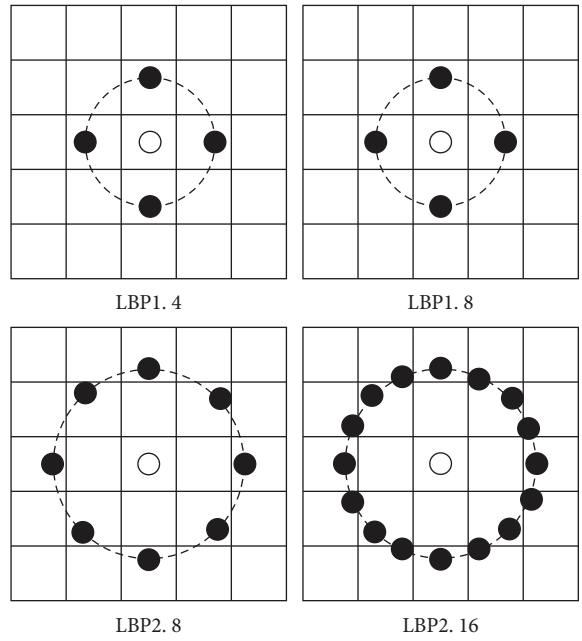

Figure 2: Encoding processes of face images based on LBP operator.

The traditional face recognition algorithm just performs simple cropping and global feature extraction before face recognition or averages the whole image into blocks. After the feature points are extracted and the histogram is obtained for stitching, although the local performance of the features is enhanced, it also brings a long processing time and redundant information [28, 29]. Therefore, based on the above-mentioned face image noise reduction processing, local sensitive information of the face is identified in order to

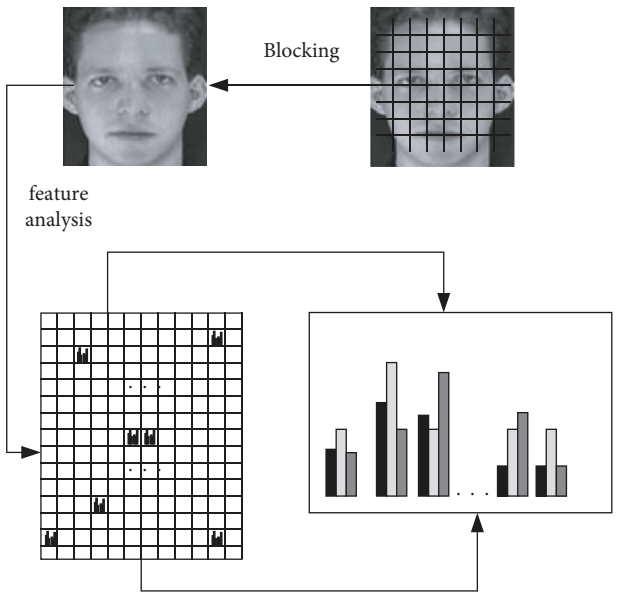

Figure 3: Concatenation of face images histograms.

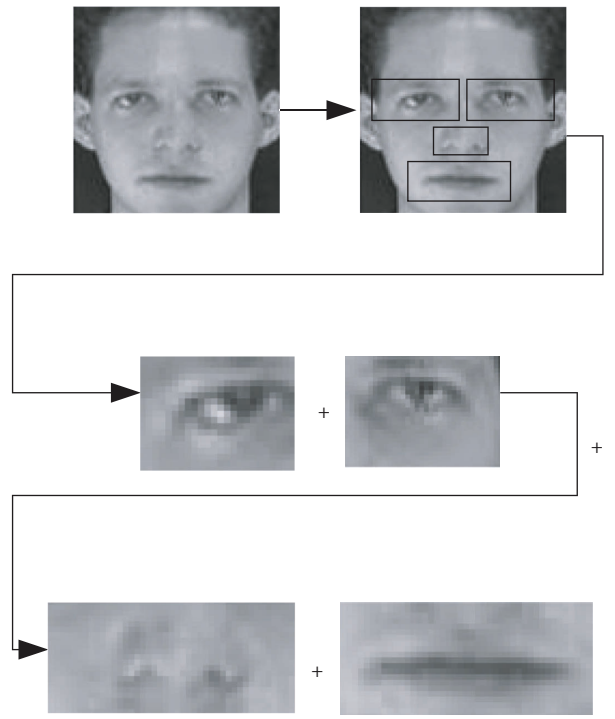

Figure 4: Positioning of face features.

locate the face features points. The most prominent features in face recognition are eyes, eyebrows, nose, mouth, and chin [30–32]. The energy differences in this part (especially eyebrow shape, eye shape, depth of nasal sulcus, nostril changes, mouth shape, chin shape, etc.) are especially obvious in various faces [33, 34]. They can become one of the important criteria for face discrimination. At the same time, in order to further reduce the complexity and redundancy of the directly preprocessed image, the sensitive parts of the face, such as eyes, eyebrows, mouth, nose, and chin, which have important discrimination characteristics, are jointly used for face recognition [35–37]. This can lay the foundation for feature point positioning. The AdaBoost method is used to locate each part of the face. The schematic diagram is shown in Figure 4.

The final calculation formula for face features is as follows:

$$LBP(i, j) = \sum_{p=0} a(h - p), \tag{8}$$

where $LBP(i, j)$ represents pixel coordinates, h and p represent gray values of adjacent pixels and center pixels, respectively, and $\sum_{p=0} a$ are the judgment parameters of face features.

According to the above-mentioned face information coding and face features point recognition, the location of the face features points is completed, providing a basis for local feature extraction.

2.3. Face Global Features. The principal component analysis of the face is to find the most orthogonal basis of face features [38–43] so that the mean square error between the transformed variable and the original variable is the smallest. The so-called "principal component" is to transform the original independent variable into another group of variables, and then some important components are used as independent variables. Finally, the least squares method is used to estimate the model parameters after selecting the principal components. In face global feature recognition, the space formed by feature vectors is called feature face space [44]. For a sample set with n face features, the covariance matrix of the face global features samples set:

$$E(X) = \frac{1}{N} * \sum_{f} a, \tag{9}$$

where $1/N$ is the corresponding eigenvalue and $\sum_f a$ is the eigenvector corresponding to the eigenvalue constituting the principal component.

Each face can be projected into the subspace of the feature face to obtain a set of coordinate coefficients, which can be used as the basis for obtaining the global features of the face. The position, scale, number, and direction of the feature vectors extracted from each face are different. Even if the same person has different expressions or different conditions, the detected feature vectors will be inconsistent. Therefore, there are many mismatches, such as the left face matching the right face and the eyes matching the nose. In the process of feature matching, some detected feature points that have a small effect on classification and recognition will play a major role in classification and recognition, such as matching hair ends, which will cause recognition errors. Therefore, the PCA method is used to extract the global features of the face, and the PCA method (principal component analysis method) mainly uses the K-L transform. K-L transform is an optimal orthogonal transform for image compression. The K-L transform can change the coordinate space, and the transformed space is called the subspace. Recognition using the PCA method is achieved by projecting

the face images that need to be recognized onto the subspace of the feature faces obtained from the training image.

The steps of PCA to obtain global features of the face are as follows:

Step 1: get the pixel matrix X of all training set images.

Step 2: get the feature matrix C_X according to the pixel matrix.

Step 3: get the covariance matrix $\sum_X$ corresponding to the feature matrix.

Step 4: find the eigenvalues and eigenvectors of $\sum_X$.

Step 5: arrange the eigenvalues in descending order and filter out o larger eigenvalues.

Step 6: orthogonalize and normalize the eigenvectors corresponding to these eigenvalues.

Step 7: combine the obtained feature vectors into columns to form the transformation matrix w, then the subspace (face global features space) is obtained. The error generated by the training output label and the actual label is backpropagated layer by layer using DBN to achieve the purpose of fine-tuning the global features of the entire face. The structure of the DBN is shown in Figure 5.

Step 8: the global feature data formula for face images is as follows:

$$C_Y = C_X * W^t. \tag{10}$$

According to the above formula, the coordinate position in the subspace is obtained. Each image in the training set corresponds to a point in the subspace, and each dimension of this point constitutes the PCA feature of the image.

Step 9: the feature data of the image to be identified is also obtained according to formula (7), and the coordinate position in the subspace is obtained so that the image to be identified is also corresponding to a point in the subspace, and the PCA feature is obtained.

2.4. Extraction and Fusion of Face Local Features

2.4.1. Candidate Set for Recognition of Face Local Features. Because there is a range when extracting face local features, the recognition rate can reach the maximum value within this range. When it is smaller than this range, with the increase of training samples, the number of extracted recognition features increases, and the recognition rate has a steady improvement process. When it is larger than this range, the recognition rate is maintained at a stable maximum, and sometimes even decreases. In other words, with the excess training samples, the recognition rate of the algorithm has not been significantly improved, but the calculation amount of the algorithm has increased. The recognition time gradually increases, which seriously affects the efficiency of the algorithm. Therefore, before the recognition of face local features, the gray features of the face

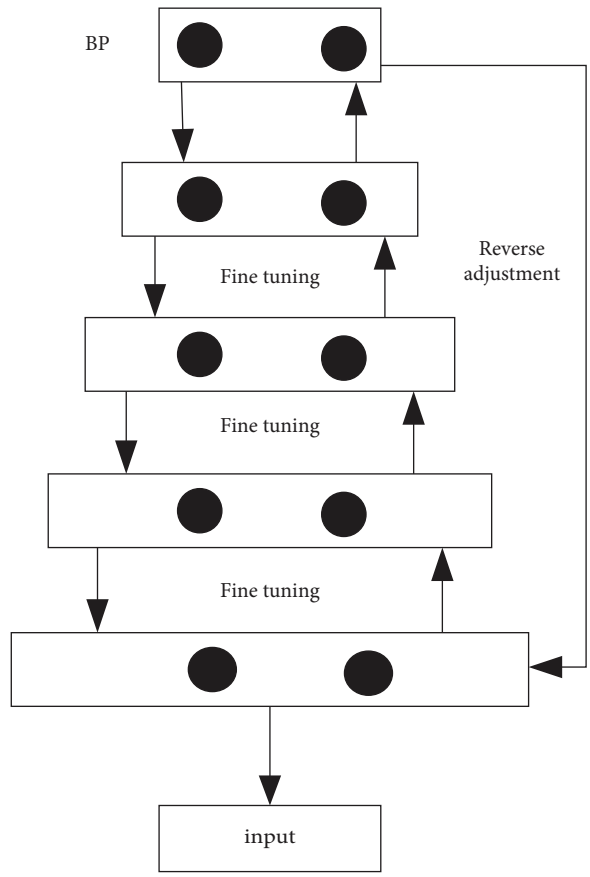

Figure 5: DBN network diagram.

images are used to simply filter the face features. The screening process is shown in Figure 6:

According to the above process, some test samples that are significantly different from the test samples and interfere with recognition are eliminated, and the training samples are controlled within a range that maximizes the recognition rate and minimizes the amount of calculation.

Assuming that the gray distribution information of the test sample is represented by the matrix $P_{m\times n}$, the similarity between the test sample and each training sample is calculated using the following formula. The calculation formula is as follows:

$$\text{dist} = \sqrt{\sum_{x=1} a\left(p(x, y)\right)}, \tag{11}$$

where dist is the image similarity threshold, $\sum_{x=1} a$ is the similarity parameter between the image and the test sample, and $p(x, y)$ is the pixel coordinates of the image.

Face samples with a distance less than the threshold are selected as candidate sets, and different numbers of candidate sets are selected as the final recognition of face local features.

2.4.2. Extraction of Face Local Features. Because the two-dimensional face images have a greater influence on the attitude angle and light irradiation, it is difficult to extract

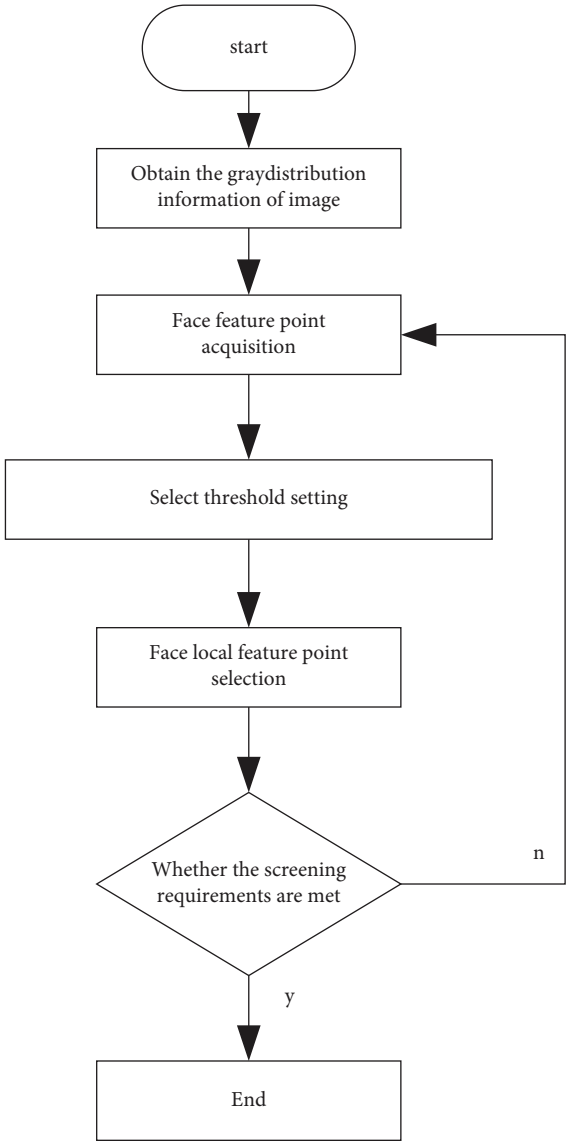

Figure 6: Screening process for face features.

features in linear space. Therefore, the attitude and illumination of the three-dimensional face model are controlled according to the spherical harmonics theory. The two-dimensional virtual image obtained by the mapping is divided into different subsets through five parameters of the change in the attitude and illumination angle. This can increase the clustering of the training samples and solve some nonlinear problems in feature extraction. Global features and local features are indispensable for face perception [45–51] and recognition, but research shows that global feature descriptions are often used as front-end input information for perception. If the person to be identified as a particularly obvious local feature, the global description will retreat to a relatively minor position. Therefore, the self-adaptive feature selection function of the human visual system is simulated to achieve the purpose of relying on the most individual local features of each person for fast face recognition.

The feature vectors of the face's left eyebrow, right eyebrow, left eye, right eye, nose, and mouth are calculated in six subregions. Assuming that each training sample set in the face images contains 3 training samples, the normalized image is expanded in rows as follows:

$$x_{i,j} = (1, 2, \ldots, n), \tag{12}$$

where $x_{i,j}$ represents the j-th sample in the i-th training sample set. A performs singular value decomposition on the overall dispersion matrix of each sample set and finds its nonzero eigenvalues and corresponding eigenvectors as follows:

$$\ni_i = \mathfrak{F}_1, \mathfrak{F}_2, \ldots, \mathfrak{F}_n. \tag{13}$$

Considering the amount of calculation, you can only choose the matrix composed of the eigenvectors corresponding to the first few eigenvalues as the projection matrix for principal component analysis and find the eigenvector of the m -th face in the i -th sample set. The calculation formula is as follows:

$$G_i = \frac{1/N}{\sum_i q.x_u}, \tag{14}$$

where G_i is the total number of face features to be identified, $1/N$ is the number of face features participating in training, and $\sum_i q$ is the distance from the q -th feature vector to the feature vector x_u.

It not only retains the information of the key feature point j itself but also contains the surrounding structure information, which shows the locality and structural topology of the face features. The distance corresponding to each feature vector in the face is sorted in descending order. A larger coefficient indicates that the local feature is more obvious.

2.4.3. Fusion of Local Face Features. Face features contribute differently to feature extraction in different situations. Therefore, according to the face features, it is weighted under different conditions, and the corresponding extracted local features are separated into the corresponding 6 local features, which are expanded into vectors on a row basis, and each vector corresponds to a subspace projection. The classification discriminant function is defined as follows:

$$H = \arg_m \min_g \left(\frac{c}{o}\right), \tag{15}$$

where (c/o) represents the discriminant function and $\arg_m \min_g$ is the distance between a set of local features of the unknown face images and the corresponding local features in the database.

Classification is to find the local features with the smallest distance between the two groups so as to obtain the lowest classification error rate. Therefore, the local feature classification is constructed by the following formula:

$$f(n) = \frac{\int_n^q v_n}{p * o}, \tag{16}$$

where $\int_n^q v_n$ is the comparison parameter of the local feature region and $p * o$ represents the weight of the face local

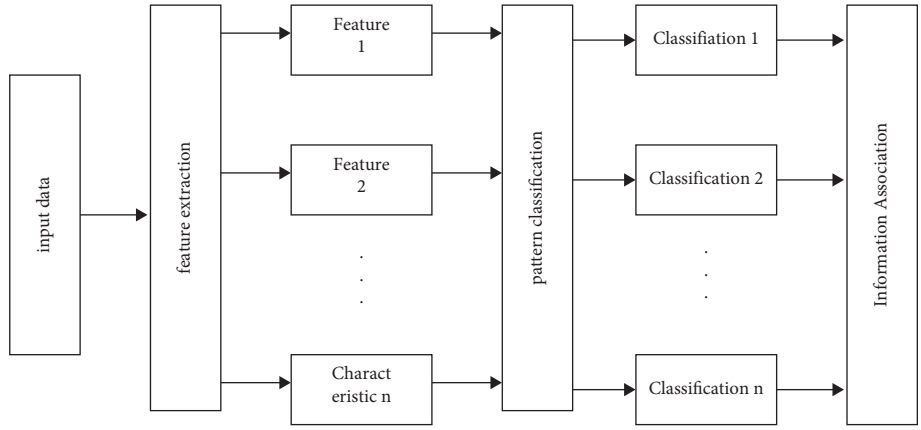

Figure 7: Decision-level fusion processes.

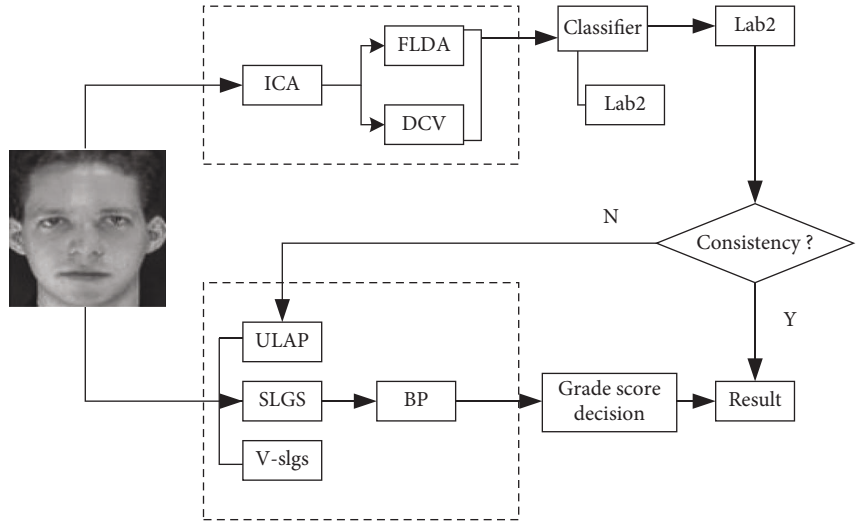

Figure 8: Recognition of face local features.

features. A larger value indicates a greater contribution of the corresponding local feature. $f(n)$ is the face features fusion factor.

On this basis, the decision-level fusion method is used to fuse face local features (Figure 7).

This method has better fault tolerance and can weaken the incomplete information and the influence of erroneous data. Firstly, the hierarchical cross-validation method is used, and the ULAP, SLGS, and V-SLGS algorithms are used to construct the base classifier. Then combined with the BP neural network [52–56], the posterior values of the samples to be classified belong to each category, and a grade score is given according to their size. Finally, the fusion scores are made for the grade scores obtained by all the base classifiers (Figure 8).

The specific face local features process is as follows:

Input: learning algorithms ULAP, SLGS, and V-SLGS, training sample set, samples to be classified

Output: the prediction category of the sample to be classified.

Define a level vector $r = \{i, q, \ldots, Q\}$, Q representing the number of categories:

First: for the given training sample dataset T, it is randomly divided into M folds using the layered cross-validation technique (each fold contains all categories, and the number of samples of each type is the same). Extract $M-1$ folds from it for training to generate a base classifier;

Second: for the m -th training $(1 \le m \le M)$, use different feature subspaces and BP neural network to construct a heterogeneous base classifier. The above process is repeated M times to build $3M$ base classifiers.

Third: initialize $R_q = 0$, and loop from $i = 1$ to Q. On the n th classifier, the target x belongs to each class and the score is $z_k = 1/(Q * b)$. After getting z_k, for the fusion of face local features, the final category of $3M$ classifiers after decision fusion is as follows:

$$c = \arg\max z_q, \quad 1 \le q \le Q. \tag{17}$$

According to the above definition, ignore the influence of other posterior probability values on recognition. All

Figure 9: Partial experimental image after adding noise or occlusion.

types of information provided by each base classifier are allowed to participate in decision-making according to a certain weight so that the information that ultimately participates in decision-making is more comprehensive, thereby obtaining more accurate recognition results.

3. Results

3.1. Experimental Samples. In order to verify the effectiveness of the above-designed recognition methods for face local features based on fuzzy algorithms and intelligent data analysis, FRGC and BU-3DFE 3D face libraries were used to generate a complete training sample set for experimental analysis. The first step is to verify the complete sample set generated. A two-dimensional virtual image is obtained through the five parameters of the change in the illumination angle. The experiment here only focuses on the horizontal offset of the face and does not consider the face's pitch and elevation. The control rules are as follows:

First: set the horizontal offset angle range of the 3D face attitude is set to [−45°, 45°].

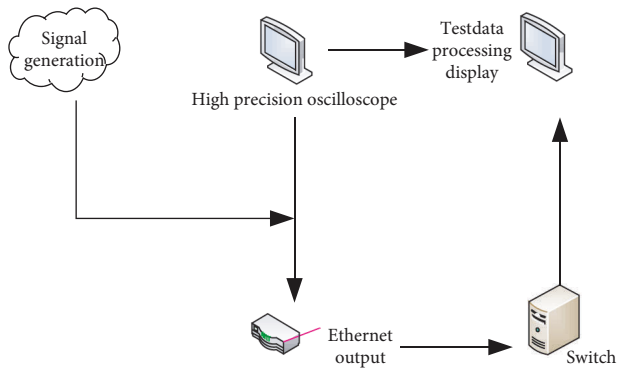

Figure 10: Experimental platform.

Table 1: Comparison of experimental results.

Face image number	Image features	Traditional method (recognition rate/%)	Designed method (recognition rate/%)
1	Adding noise	45.2	80.9
2	Adding noise	35.3	90.2
3	Adding noise	42.1	89.6
4	Adding noise	23.5	91.2
5	Adding noise	63.1	92.3
6	No noise added	70.6	95.3
7	No noise added	72.6	95.6
8	No noise added	76.3	97.4
9	No noise added	80.2	98.6
10	No noise added	70.9	99.6

Second: the light irradiation angle range is set to [0°, 60°] and the light projection angle range is set to [30°, 90°].

Third: the range of the light intensity parameter is set to [1.0, 2.0], and the step increment value is 0.25.

According to the above-mentioned generation rules, each 3D point cloud model can generate 2375 2D face virtual image samples. A total of 1600 pictures are selected to build a training set, and the design platform is trained. The maximum number of iterations is set to 5000, the initial learning rate is 0.1, and the learning rate change factor is 0.2. After the training is completed, 10 face images are randomly selected as face local recognition test samples.

At the same time, artificial noise or occlusion is added randomly, which increases the difficulty of the experiment. In the occlusion experiment, 3 out of 10 test samples were randomly added with 20% occlusion. In the noise experiment, the 30-fold random function was used to generate noise. Some samples after adding noise or occlusion are shown in Figure 9:

The image above is part of the experimental image after adding noise or occlusion. Five of the 10 images were added with noise, and the remaining 5 were not added with noise. Check the recognition of the two methods.

3.2. Experimental Platform. Windows Core i7 processor, 16 GB memory, 2.20 Hz flash memory, and 1 TB hard disk are used as the hardware configuration of the experiment. The experiment uses an ARM Cortex-M3 core microprocessor to build the hardware platform. In addition, the hardware platform also includes the Ethernet interface, the RS-456 interface, the sample value transmission interface, the GPRS wireless transmission module interface, and the field acquisition module. The specific experimental platform is shown in Figure 10:

This experiment mainly verifies the application effect of the recognition methods for face local features based on fuzzy algorithms and intelligent data analysis. In order to ensure the tightness of the experiment, the face recognition method based on machine learning is used as a comparison method, which is compared with the designed face local feature recognition method, and the recognition rate of the two methods is compared. HDGSIU simulation software was used to simulate the experimental environment, and the interference factors designed above were stored in the database, and the recognition of face local features under the influence of the interference factors was compared between the two methods. At the same time, the on-site acquisition unit collects experimental data, and the on-site test unit performs A/D conversion on the sensor signal after filtering and amplification. Then the A/D converted data is input into the database through high-speed fiber. Finally, the information in the database is sent to the Ethernet, and the host computer processes and displays the received data. In order to ensure the accuracy of the experimental results, according to the requirements of EHTFU-1/8 on the

sampled values, the sampled values are filtered to ensure the accuracy of the experimental data sampling. The calculation formula is shown as follows:

$$y(n) = \frac{1}{N} \sum_{i=m} s \times X, \tag{18}$$

where represents the number of sampling data points, $y(n)$ represents the sampling data value, X represents the average of the sampling points, and $\sum_{i=m} s$ represents the transformation function.

Through the above formula, the sampled values are processed and the experimental results are analyzed using Edifshark, a commonly used IEC589 message capture and analysis software.

3.3. Analysis of Experimental Results. After the above experimental samples and experimental platform are prepared, the experiment is performed. The comparison results between the traditional method and the designed recognition methods for face local features based on fuzzy algorithms and intelligent data analysis are shown in Table 1.

From the comparison results, it can be seen that the recognition methods for face local features based on fuzzy algorithms and intelligent data analysis are less affected by noise when identifying local features of the human face. It can be seen from the experimental comparison table that the designed method can guarantee a high recognition rate under the condition that noise is added or not. However, the traditional method is greatly affected by noise and has a low recognition rate. At the same time, in the absence of noise, the recognition rate of the traditional method is also lower than the recognition rate of the current design method. This is because the method in this article uses the wavelet denoising method to denoise the face image to avoid the interference of noise and encodes the face information to recognize the face features so that the feature location is more accurate and the analysis accuracy of the overall face features is higher, thus achieving a high-precision recognition rate.

Therefore, the above experiments prove that the designed method can improve the recognition rate of face local features. This also proves the effectiveness of the design method, which can meet the requirements of recognition of face local features.

4. Conclusions

The face recognition algorithm based on feature discriminant analysis in the intelligent environment involves many fields, such as pattern recognition, computer vision, modern signal processing, human-computer interaction, and cognitive science. It is a very challenging subject with many research contents. This research mainly addresses the low recognition rate of traditional recognition methods for face local features. The experiment proves that the designed method has a higher recognition rate than the traditional method and has certain practical application significance. It can provide reliable technical support for face recognition, visual presentation, etc. It can be considered to be applied in face collection, detection, recognition, and other directions and can be continuously adjusted in the application to gradually optimize the design method so as to improve the adaptability. Combined with this research, further research will be done on the following two aspects:

(1) When extracting multiple face features for fusion, there is a lack of a universal face database with limited scale and systematic evaluation criteria. In face recognition, which kinds of face features are selected for fusion and how to distinguish the classification capabilities, algorithm complexity, and implementability of the selected features require further research and experimental proof.

(2) There is still room for improvement in the adaptive weight selection method proposed in this article. When using experiments to explore the weights corresponding to the highest recognition rate for various face features under different sample numbers, they still contain experience components. A large number of experiments have shown that when performing face recognition based on feature fusion, the contribution of different types of face features to the recognition rate has the phenomenon of "one after another." How to form a reasonable adaptive weight selection method that allows different types of face features to participate in the representation of face images in a "competitive" manner is a question to be studied in depth.

Data Availability

The data used to support the findings of this study can be obtained from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this article.

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Research Article

Multitarget Pedestrian Tracking Algorithm Based on a Contour Template with Multiscale Stability

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In order to overcome the problems of high error rate and poor tracking effect of traditional tracking algorithms, a multitarget pedestrian tracking algorithm based on a contour template is designed in this paper. The pedestrian template is divided into several contour regions by template voting strategy and pedestrian features are classified by regional feature similarity classification. Then, the score function is selected to realize the multiobjective pedestrian feature division, and the multicontour template matching is realized according to the similarity of deformation diversity. According to the matching results, the detection and tracking of multitarget objects are realized. The experimental results show that the feature recognition accuracy of the algorithm is between 93% and 98%, the tracking error of pedestrian gravity center position is always below 5%, and the tracking time is always below 5 S in different video frame scales, which fully proves the effectiveness of the algorithm.

1. Introduction

The video image is an important way for people to understand the objective world. With the rapid development of electronic technology and Internet technology, image processing technology has attracted the attention of researchers in various fields as a convenient and practical technology. In recent years, with the popularity of smartphones equipped with high-definition cameras and video surveillance systems, people's demand for intelligent video analysis is increasing [1, 2]. We hope to use computers instead of human brains to complete complex tasks such as video classification, intelligent monitoring, and so on, in order to improve the convenience of daily life. This requires the computer to be able to understand and process such visual information, and the tracking algorithm is the most basic and important part of it. In short, the goal of tracking is to analyze and predict the motion path of the object to be measured in the video and to determine its specific position in each frame [3, 4].

Effective detection and tracking of objects in video images is a very important branch of technology in the field of modern computer vision, which has a broad development prospect in many fields such as security monitoring, logistics management, automatic navigation, military investigation, criminal suspect locking, and so on. Especially in security monitoring, military reconnaissance, criminal suspects lock, etc., of multiobjective pedestrians on the purpose of effectively detecting and tracking is the target of pedestrian-related movement data obtained, such as the movement of the target location, target track, and target's movement speed and direction and goal of the activity area, so as to realize the analysis of the moving object behavior, understand, or in order to do more advanced tasks.

In order to improve the tracking accuracy of multitarget pedestrians, many researchers have carried out a lot of research on target tracking algorithms. At present, the main algorithms used in the field of target tracking include particle filtering algorithms, correlation filtering algorithms, and so on. In addition, a multitarget tracking algorithm based on the combination of adjacent frame matching and Kalman filtering is proposed in Reference [5]. In this algorithm, the pedestrian head is detected by the AdaBoost classifier with the direction gradient histogram (HOG) as the feature; then, the pedestrian trajectory is predicted by the Kalman filter and the adjacent frame matching algorithm is used to correct the target trajectory. In the adjacent frame matching

method, the target matching problem in the tracking process is transformed into an assignment problem based on the Hungarian algorithm. Reference [6] proposed a multitarget tracking algorithm based on YOLOV3 and Kalman filtering. The algorithm uses YOLOV3 to detect the target to be tracked in the current frame and uses the Kalman filter to predict its next position and the size of the bounding box according to the position of the current target. The improved Hungarian algorithm is used to carry out data correlation and matching according to the intersection ratio of the detection frame and prediction frame and color histogram, and the tracking is completed through continuous iteration of the system to obtain the target's motion trajectory [7–9]. For the occluded target, a region-based quality assessment network is introduced, and multiframe high-quality detection images are combined to recover the occluded part and improve the tracking accuracy.

However, with the development of modern video technology and the increasing complexity of pedestrian movement background, the abovementioned traditional algorithm has the problems of a high error rate of pedestrian feature recognition and poor tracking effect. To solve this problem, a new multitarget pedestrian multiscale stable tracking algorithm is designed based on a contour template [10, 11]. The specific ideas of this paper are as follows:

First, the template voting strategy is adopted and according to the regional characteristics of pedestrian actions, the pedestrian template is divided into multiple contour areas,

Second, the feature similarity thresholds in different regions are divided by regional feature similarity classification to complete the classification of multitarget pedestrian features.

Then, the score function is selected as the matching criterion between the template and the candidate samples, and the multicontour template is matched according to the similarity of deformation diversity. Finally, the multitarget detection and tracking are realized based on the mean value.

Finally, the feature recognition effect of this method is verified by the accuracy of feature recognition, position tracking error, and tracking time.

2. Design and Matching of Contour Template

2.1. Contour Template Design. Multiscale feature areas of pedestrians mainly include the head, neck, shoulders, chest, back, abdomen, buttocks, upper limbs, and lower limbs. Different feature areas will be affected by different degrees of action.

Because the target object is different, the feature region affected by the action is also different, and the influence of different parts on the whole feature region is also different [12–15]. Therefore, a voting strategy based on multiple templates is applied in this article, according to the features of easy to affected by the action area, the human body is divided into multiple outline template sections, calculating the similarity between the template area, and implementation of the match, again USES the voting statistics majority vote for final similarity of a large area of the matching results [16, 17]. The proposed method has good robustness of occlusion and tolerance of region division, so as to avoid the problem of too much dependence on feature points to complete region division and obtain several relatively reliable region classifiers at the same time. In this paper, the multiregion contour template is divided into 9, and the partition results of the multiregion contour template are shown in Figure 1.

2.2. Multiregion Profile Template Feature Similarity Classification. The feature similarity of the multiregion contour template is to classify the features in the divided multiregion contour template according to the similarity degree and compare the similarity between the well-classified regional features and the contours of different parts of the human body in the feature database. The higher the similarity value, the more similar the image features [18–22]. The similarity of feature information in nine multiregion contour templates is calculated, and the sum of Euclidean distance squares of coordinate points corresponding to regional semantics is taken as the similarity value of the two regions. The process is as follows:

$$W = \sum_{j=1}^{N} \sqrt{\left(k\left(x_j, y_j, z_j\right) - h\left(x_j, y_j, z_j\right)^2\right)}. \tag{1}$$

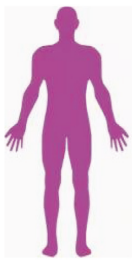
In formula (1), N is the number of templates; j is any point in the multi-region contour template; and $k(x_j, y_j, z_j)$ and $h(x_j, y_j, z_j)$ are points in the region to be tested and semantic corresponding points in the region in the feature library, respectively. The larger the similarity value is, the more similar the contour features in the two regions are. If the similarity value is greater than a certain threshold value, it is considered to be the same contour region, which is to complete the feature similarity classification of the multiregion contour template.

2.3. Contour Template Matching. The multiregion contour template was matched by feature similarity classification. Assuming that there is a point set $P = \{p_i\}_{i=1}^{m}$ corresponding to the image template image and a point set $Q = \{q_j\}_{j=1}^{n}$ corresponding to the image target, i, j, m, and n, respectively, represent the point an ordinal number of the point set and the total number of the corresponding point set, the nearest neighbor formula of the multitarget pedestrian image target in the multiregion contour template is as follows:

$$l_{mn}(q, P) = \arg\min\ D(q, p). \tag{2}$$

In formula (2), $D(q, p)$ and $l_{mn}(q, P)$, respectively, represent the distance function and the nearest neighbor of the point q in the point set P [22–27].

The purpose of calculating the feature similarity is to obtain the number of diversity of the nearest neighbor in the template image and the multi-objective pedestrian image. The calculation formula is as follows:



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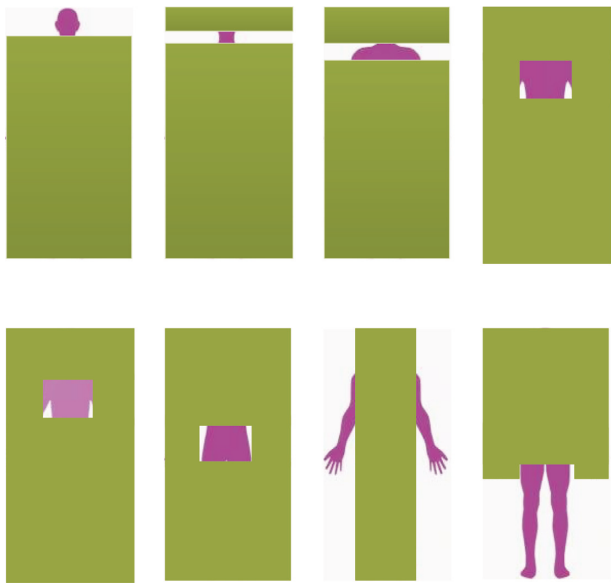

Figure 1: Multiregion contour template partitioning results.

$$\delta_{Q\longrightarrow P} = \frac{\left|l_{mn}\left(q_j, P\right) \times p_i\right|}{\min\{m, n\}}. \tag{3}$$

According to formula (3), the similarity between the multitarget pedestrian image and the multiregion contour template can be obtained, and the target deformation can be added to the above calculation to improve the matching performance of the contour template.

On this basis, A and k are used to represent the appearance model and spatial position coordinates, respectively, and the nearest neighbor formula of the appearance model in the point set P can be obtained as follows:

$$p_i = R_{mn}^{A}\left(q_j, P\right) \times k = \operatorname{argmin} d\left(q_j^{A}, p^{A}\right) \times k. \tag{4}$$

In formula (4), $d(q_i^A, p^A)$ is the model distance, and the number of nearest neighbors matching diversity of $q \in Q$ in point set P is as follows:

$$\gamma_{p_i} = q \times R_{mn}^{A}\left(q_j, P\right). \tag{5}$$

Combined with the above equation, the formula can be obtained as follows:

$$\delta = \frac{\sum_{q_j \in Q} \exp\left\{1 - \xi\left[l_{mn}^{A}\left(q_j, P\right)\right]\right\}/\gamma_{p_i} + 1}{\min\{m, n\}}. \tag{6}$$

To sum up, contour template matching can be completed through the above process.

3. Multitarget Pedestrian Multiscale Stable Tracking Algorithm Design

On the basis of the above contour template matching, a multitarget pedestrian multiscale stable tracking algorithm is designed in this study. The process is as follows.

First, the candidate region where multiscale targets may exist in each frame of the multitarget pedestrian video image is determined. Then, the abovementioned steps are repeated to obtain the final histogram of the feature probability distribution of the candidate region at a multiscale, and the construction of the candidate model is completed [27–29]. Therefore, the multiscale candidate model is obtained as follows:

$$\omega = \frac{\delta(1 + g)^{-1}}{Z}. \tag{7}$$

In formula (7), Z and g represent multiscale candidate regions and the corresponding label sets, respectively. Then, the similarity between the target model and the candidate model is calculated by using the similarity measurement method, and the maximum value of the similarity function Babbitt coefficient is selected as the mean vector of the target. This vector is the transition vector of the target from the initial position to the current position [30–33]. The search region moves continuously along the direction of the vector until the convergence condition is satisfied, and the real position of the multitarget pedestrian in the current video frame is determined, so as to achieve the goal of target tracking. The specific process is as follows:

Step 1: Read the video sequence of multiobjective pedestrians, obtain the video frame image to form the test set, and take it to the objective function F. The formula can be obtained as follows:

$$F = \frac{\omega H}{\lambda}. \tag{8}$$

In formula (8), H represents the kernel function and λ represents the target appearance model of the learned sample. Then, the inverse discrete Fourier transform is applied to $\widehat{F}$, and the position of the pedestrian target is determined according to the result. Therefore, the test set and its weight are updated in real time to adapt to the change of pedestrian target in the tracking process

$$\partial_t = \mu y + (1 - \mu)\alpha_{t-1}. \tag{9}$$

In formula (9), μ and α_{t-1} represent the learning parameters and the weight matrix of the previous video frame, respectively; μ and y represent the target template after the current frame is updated and the discrete

Fourier transform of the current frame target, respectively.

Step 2: Determine the initial frame image I_0, delimit the target area S, and determine the target center y_0.

Step 3: Build a multiscale target model with y_0 as the center, as follows:

$$q_u = \frac{I_0 \times S}{y_0}. \tag{10}$$

Step 4: Initialize the candidate targets at the current frame center y_0 and then estimate the probability of the multiscale eigenvalues of the multitarget pedestrian contour template in the candidate region.

$$z[p(y_0), q] = \sum_{u=1}^{m} \sqrt{p_u(y_0) q_u}. \tag{11}$$

Step 5: Calculate the weight w_y of each pixel in the candidate target region [34, 35].

Step 6: Move y_0 to a new position, and record the position of the new target in the candidate region as y_1. Calculate the candidate target model U with y_1 as the center and calculate as follows:

$$U_y = \sum_{u=1}^{m} \sqrt{w_y(y_1) q_u}. \tag{12}$$

Step 7: Judge whether formula (13) is true as follows:

$$z\left[w_y(y_1), q_u\right] \le z\left[w_y(y_0), q_u\right]. \tag{13}$$

If it is true, we set the target position to the appropriate area between the new position and the old position; otherwise, we proceed to the next step.

Step 8: Compare $z[w_y(y_1), q_u]$ with Kronecker delta function to obtain the following formula:

$$z\left[w_y(y_1), q_u\right] < \text{Kronecker Delta function}. \tag{14}$$

If formula (14) is true, a new target location is found, and the algorithm stops to get the real pedestrian target location in the current frame; otherwise, return to step 6 and continue to find the candidate target location that meets the conditions. After several iterations, the real position of the target in the current frame is output.

Step 9: Repeat the above process until the real position of the pedestrian target in each frame is found, so as to achieve multiscale stable target tracking. The specific multiscale stable target tracking process is shown in Figure 2.

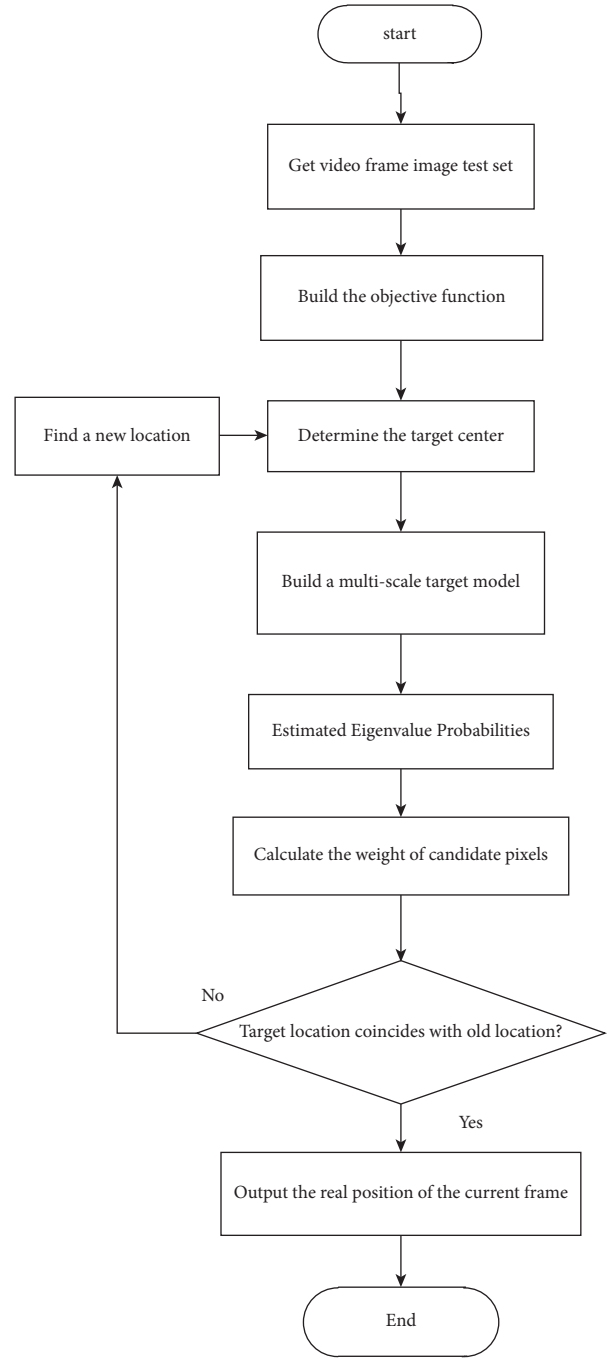

Figure 2: Flowchart of multiscale stable target tracking.

4. Experiment and Analysis

4.1. Experimental Environment Design. In order to verify the practical application performance of multitarget pedestrian multiscale stable tracking algorithm based on contour template, the following simulation experiments are designed to verify.

The experimental environment is as follows: the simulation experiment is carried out on the MATLAB platform, the operating system is windows 10, and the program development tool is Visual C++ 2008 express. The experimental database contains 500 pedestrian feature models with different postures and regions. According to the difficulty of facial feature tracking, the database can be divided into two categories as follows: the first category is facial feature videos captured from different angles, the second category is videos captured under completely arbitrary conditions, including severe occlusion, extreme lighting, and posture.

In order to avoid the singleness of the experimental results, the multitarget tracking algorithm based on the combination of adjacent frame matching and Kalman filter in reference [5] and the multitarget tracking algorithm based on yolov3 and Kalman filter in reference [6] are used as comparison algorithms to complete the performance verification with the algorithm in this paper.

4.2. Performance Index

(1) Feature recognition accuracy: this indicator is used to measure the effect of different algorithms on multiscale multitarget pedestrian feature recognition. The higher the recognition error rate is, the more accurate the algorithm can capture pedestrian features.

(2) Pedestrian barycenter position tracking error: this index is used to measure the effect of different algorithms on multiscale multitarget pedestrian feature tracking. The lower the barycenter position tracking error is, the more accurate and timely the algorithm can track and capture the pedestrian position.

(3) Tracking takes time: This index is used to verify the timeliness of different algorithms. The less the tracking time is, the more efficient the algorithm is.

4.3. Result Analysis. First, the feature recognition accuracy of the multitarget pedestrian multiscale stable tracking algorithm based on contour template, the multitarget tracking algorithm based on the combination of adjacent frame matching and Kalman filter in reference [5], and the multitarget tracking algorithm based on yolov3 and Kalman filter in reference [6] are verified. The results are shown in Figure 3.

Analysis of the results shown in Figure 3 shows that with the continuous change of frame scale, the accuracy of feature recognition of different algorithms also changes. The feature recognition accuracy of the algorithm in literature [5] is between 88% and 91%, the feature recognition accuracy of the algorithm in literature [6] is between 89.5% and 93%, and the feature recognition accuracy of the algorithm in literature [6] is slightly higher than that of the algorithm in literature [5]. The feature recognition accuracy of this algorithm is between 93% and 98%, which is significantly higher than the two contrast algorithms. With the change in video frame scale, the feature recognition accuracy of this algorithm gradually increases. Therefore, this algorithm has more application advantages, which shows that the algorithm can accurately capture the characteristics of multitarget pedestrians.

On this basis, the multitarget pedestrian multiscale stable tracking algorithm based on contour template, the multitarget tracking algorithm based on the combination of adjacent frame matching and Kalman filter in reference [5], and the application performance based on yolov3 and Kalman filter in reference [6] are verified with the tracking error of pedestrian gravity center position as the index. The results are shown in Figure 4.

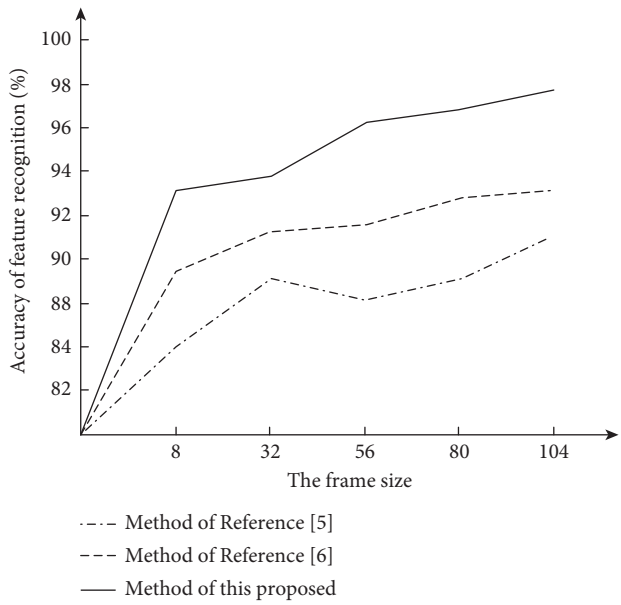

Figure 3: Comparison of feature recognition accuracy of different algorithms.

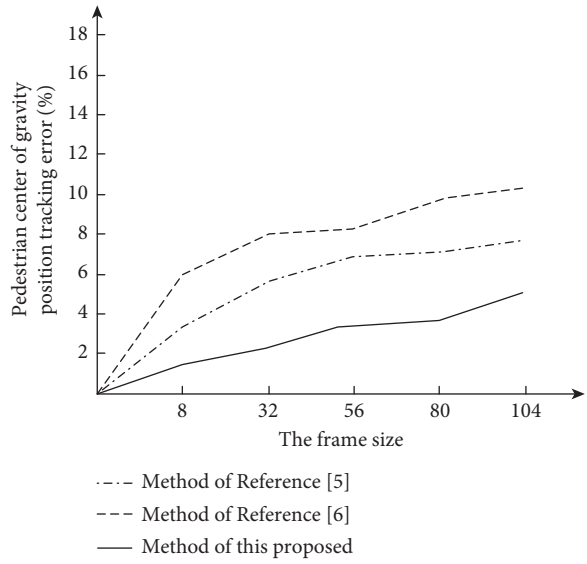

Figure 4: Comparison of pedestrian barycenter position tracking errors of different algorithms.

By analyzing the results shown in Figure 4, it can be seen that with the continuous change of frame scale, the tracking error of pedestrian gravity center position of different algorithms also increases. The tracking error of the pedestrian center of gravity position of reference [5] algorithm is always below 8%, the tracking error of the pedestrian center of gravity position of reference [6] algorithm is always below 10%, and the tracking error of pedestrian center of gravity position of reference [6] algorithm is slightly higher than that of reference [5]. However, the tracking error of the pedestrian gravity center is always below 5%, which is

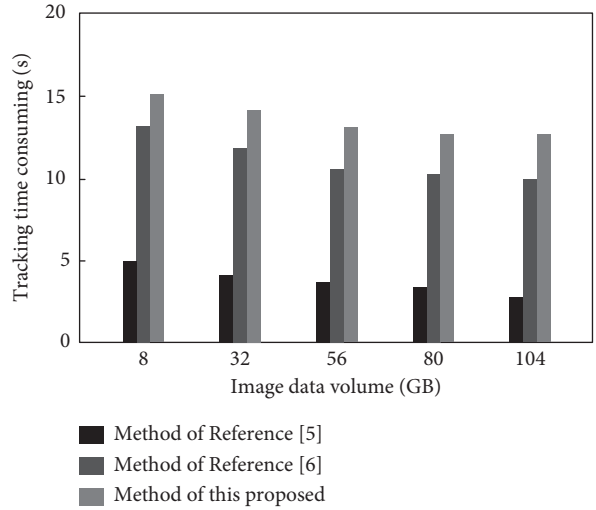

Figure 5: Comparison of tracking time of different algorithms.

Table 1: Economic benefits of the different algorithm.

Image data volume/GB	*Tracking expenses*		
	Reference [5] algorithm	Reference [6] algorithm	Methods in this paper
100	2223.7	2758.1	1086.2
200	3589.1	3456.5	1093.5
300	5432.8	4863.2	1159.3
400	6632.2	5587.3	1225.6
500	7453.8	6632.9	1318.1
600	7995.3	7642.0	1339.7

significantly lower than the two comparison algorithms. Therefore, this algorithm has more application advantages, which shows that the algorithm can accurately and timely track and capture the position of pedestrians.

Finally, taking the tracking time as the index, the application performance of multitarget pedestrian multiscale stable tracking algorithm based on contour template, multitarget tracking algorithm based on the combination of adjacent frame matching and Kalman filter in reference [5], and the application performance based on yolov3 and Kalman filter in reference [6] are verified, and the results are shown in Figure 5.

By analyzing the results shown in Figure 5, it can be seen that with the continuous change of image data, the tracking time of different algorithms also decreases. The tracking time of the reference [5] algorithm is always between 11 s and 14 s, and that of the reference [6] algorithm is always between 13 s and 15 s. The tracking time of the reference [6] algorithm is more than that of the reference [5]. The tracking time of this algorithm is always less than 5 s, which is significantly less than the two comparison algorithms. Therefore, this algorithm has more application advantages, which shows that the algorithm has stronger timeliness.

In order to further verify the effectiveness of the method in this paper, considering the economic benefits of different algorithms, the results are shown in Table 1.

Analysis of Table 1 shows that when the image data volume is 100 GB, the tracking cost of the algorithm in reference [5] is 2223.7 yuan, the tracking cost of the algorithm in reference [6] is 2758.1 yuan, and the tracking cost of the method in this paper is 1086.2 yuan. When the image data amount is 600 GB, the tracking cost of the algorithm in reference [5] is 7995.3 yuan, the tracking cost of the algorithm in reference [6] is 7642.0 yuan, and the tracking cost of the method in this paper is 1339.7 yuan. The economic cost of this method is always lower than that of other methods, which indicates that this method has better economic benefits.

5. Concluding Remarks

In this study, a multiscale pedestrian tracking algorithm based on a contour template is designed. According to the regional characteristics of pedestrian action, the pedestrian template is divided into several contour regions, and the similarity threshold is obtained by using the regional feature similarity classification. The multicontour template matching is completed, and the multitarget object detection and tracking are realized. The results are as follows:

(1) When the frame size is 56, the recognition accuracy of this algorithm can reach 96.5%, which shows that the recognition accuracy of this method is better.

(2) When the frame size is 104, the tracking error of the pedestrian gravity center is only 5%, which shows

that the tracking accuracy of the pedestrian gravity center is low.

(3) When the amount of image data is 80 GB, the tracking time of this algorithm is only 3 s, which shows that the tracking efficiency of this method is high.

(4) When the amount of image data is 600 GB, the tracking cost of this method is 1339.7 yuan, which shows that the method has good economic benefits.

To sum up, it can be proved that the algorithm has the advantages of high recognition accuracy, low tracking error, and less tracking time.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Evaluation Method of Music Teaching Effect Based on Fusion of Deep Neural Network under the Background of Big Data

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Music is an art course that is different from traditional subjects. It not only needs to teach basic music knowledge but also needs to show the timbre contained in music itself, the form of music creation, or the effects expressed by music. The teaching effect evaluation model for traditional subjects can no longer be applied to the teaching effect evaluation of music subjects. If the traditional subject teaching effect evaluation model is used to evaluate the music subject teaching effect, it will easily lead to the inaccuracy of the effect evaluation. Because there is a strong subjectivity in the evaluation of the teaching effect of music subjects, this study combines deep neural network technology to study the feasibility and accuracy of the convolutional neural network (CNN) and long short-term memory neural network (LSTM) method in the evaluation of music teaching effects. It mainly reflects the evaluation under the three characteristics of music basic knowledge, music expression effect, and music innovation effect. The research results show that the CNN and LSTM methods can better extract the three features in the evaluation of music teaching effect, and the maximum prediction error is only 2.23%. Hybrid CNN-LSTM with LSTM neural network has higher accuracy in predicting music teaching effect than single neural network technique. The linear correlation coefficients also all exceeded 0.955.

1. Introduction

Music is a relatively traditional art form that has undergone great changes over time. The art of music is mainly reflected in the timbre, loudness, and the artistic culture it conveys [1, 2]. This leads to a big difference between the teaching method of music and the teaching of traditional subjects. The teaching of traditional subjects can be displayed in the form of textbooks and PPT. It only needs to memorize the basic knowledge and the key methods of doing questions. However, music teaching is not only the memory of basic knowledge, nor is it limited to the memory of knowledge. Different students have different comprehension abilities, which can result in different musical experiences. Therefore, the teaching of music subjects is different from the teaching of traditional subjects, it is more complex than the teaching of traditional subjects [3, 4]. Likewise, the teaching of music subjects cannot simply be evaluated by means of examination papers, so it does not only involve the basic knowledge of music. The teaching of music subjects may require evaluation of instruments and timbres for effect evaluation. If it uses manual methods to evaluate the effect of music teaching, it will easily lead to the inaccuracy of the evaluation of the teaching effect. It may have a strong subjective factor in it. Because different people experience music differently. For the evaluation of the teaching effect of traditional subjects, it only needs the form of test papers or questionnaires to carry out the evaluation. Because the traditional discipline has a strong objective nature, it does not have a strong subjective nature like the music discipline. Therefore, in order to truly and effectively evaluate the teaching effect of music, an objective evaluation method is needed. The evaluation of music teaching effect mainly includes students' learning effect and students' evaluation [5]. The learning effect of students mainly includes the mastery of the basic knowledge of music, the expression of music, and the innovative effect of music [6, 7]. The students' mastery of the basic knowledge of music can be evaluated through the form of test papers or questionnaires, which is an objective effect evaluation mode. But the expressive effect

of music and the innovative effect of music are a relatively subjective form. Different evaluators have different understandings of music, which can easily lead to inaccuracy in the evaluation of music teaching effects. Finding a suitable evaluation model of music teaching effect is also the key to the success of music teaching.

Big data technology has been successfully applied in many fields of people's production and life. The application of big data technology in the effect evaluation of music teaching is also a new challenge [8, 9]. If big data technology can better guide the evaluation of music teaching effect, it will also promote the innovation and development of music discipline. The main advantage of big data technology is that it can process a large amount of complex data, whether the amount of data is huge or the data itself contain relatively complex relationships. From a big data perspective, the characteristics of any research object can be transformed into a form of data. There will be complex relationships between data with different characteristics, and these complex relationships may have relatively strong correlations or weak correlations [10, 11]. However, big data technology will map and suggest the relationship between these complex data. Since the development of big data, it already has a variety of different algorithms, which can deal with spatially related features, such as image recognition and face recognition [12]. Big data technology also includes algorithms for processing temporal features, which can better handle the temporal correlation between data. For example, it can have better applications in language recognition. It can also better deal with the characteristics related to the environment [13]. For example, reinforcement learning can achieve the correlation between the research object and the environment through reward and punishment measures [14]. In short, big data technology has been well applied in all aspects of life. Deep neural network is also a big data technology that has developed rapidly in recent years. It realizes the mapping of complex nonlinear relationships through the distribution of weights and biases. In the context of the rapid improvement of computer computing power, deep neural network technology can build deeper networks. This means that deep neural networks can handle more complex nonlinear relationships.

If the deep neural network is applied in the process of music teaching effect evaluation, it can extract the characteristics of music teaching evaluation indicators, and it can also complete the nonlinear relationship mapping between music evaluation indicators and music features. This relational mapping is based on many datasets, and it has certain commonalities. This method of evaluating the effect of music teaching is not only based on one kind of music teaching effect. This method is more objective. Deep neural network can effectively extract the characteristics of music basic knowledge, music expression effect, and music innovation effect in the process of music teaching.

This study uses deep neural network technology to study its feasibility and accuracy in the evaluation of music teaching effects. It mainly uses convolutional neural network (CNN) to extract three characteristic factors of music basic knowledge, music expression effect, and music innovation effect of music teaching. This research is mainly divided into 5 chapters. The problems existing in the evaluation of music teaching effect and the significance of the development of big data technology are introduced in Section 1. The current state of research in music teaching is investigated in Section 2. Section 3 mainly introduces the application design of deep neural network technology in music teaching effect evaluation and it also analyzes the working principle of deep neural network technology. Section 4 mainly introduces the feasibility and accuracy of the deep neural network method in the evaluation of music teaching effect. It mainly introduces the basic knowledge of music teaching, the effect of music expression, and the effect of music innovation. In Section 4, the author introduces the feasibility and accuracy of deep neural network techniques using the average error, music feature prediction box map, and music feature prediction linear correlation coefficient. Section 5 summarizes the full text.

2. Related Work

Music will develop differently in different periods of social development, and it is an important artistic feature that reflects people's production and life. The evaluation of music teaching effect is different from the teaching evaluation mode of traditional subjects. A number of researchers have presented research on teaching models of music. Chen [15] also found that the assessment of music teaching in universities and conservatories is an important part. It has analyzed the feasibility of deep learning methods and neural network methods in the evaluation of music teaching effects. It designs a compensating fuzzy neural network algorithm to study the feasibility of its application in music teaching effect evaluation. And it has verified the feasibility of the model in the actual music teaching practice. The research results show that the fuzzy compensation neural network algorithm has certain feasibility in the evaluation of music teaching effect, which has certain guiding significance for the evaluation of music teaching. Begic et al., [16] has also found that the evaluation and grading of music teaching effects are important links in music education. The evaluation of these music effects mainly includes music listening, music expression, and music learning. It surveyed many elementary school music teachers as well as music students. It found that listening to music and musical expression was the more common assessment model for music teaching in primary schools. He also pointed to student location and gender as important predictors in music teaching assessments. More teachers prefer to assess students' music teaching in the classroom, which is usually carried out by means of oral assessment. Liu [17] believed that improving the tracking and evaluation of students' learning quality of music is conducive to improving the quality of music teaching. It uses the Internet of Things technology and big data technology to design and develop a music teaching quality management system. In this way, the learning quality of students and teachers can be efficiently tracked and designed. This teaching management mode can realize the processing and storage of cloud data, which can solve the difficulties caused

by regional differences. The research results show that this teaching management mode is helpful to improve teaching quality and resource utilization, which is also a valuable teaching system for music teaching management. Espigares et al., [18] used the automatic data processing program to process and study the relevant data in music teaching. It utilizes a telematics platform as a platform for information delivery. It collects a lot of data from the music examination process of students at various schools in Spain, and it analyzes the knowledge of the musical characteristics that exist between these data using a data automation program. It then utilizes Internet technology and telematics platforms to transmit and remotely process these data. The results show that the method proposed in this study is innovative in dealing with assessment tasks in music teaching. Tejada and Morel, [19] focused on teachers and students in Spanish music universities, and it studies the assessment scheme of music teaching using information and communication technology. The main goal of this research is to improve the teaching and music technology of music teachers. It builds an integrated framework of technical teaching content. This research has been well received and highly regarded by the Conservatory of Music. This research has more guiding significance for the evaluation of music teaching. Zhe [20] combined computer technology and teaching expert system to develop an intelligent guided learning system. It can make learning less dependent on teachers, and it can improve learning autonomy. It used the intelligent guided learning system to study the teaching content and learning methods of music sight-singing subjects. It can guide students to complete the study of sight-singing subjects, and then better master the art of music knowledge. The results of the study found that the scoring recommendation system based on difficulty characteristics is the core part of resource recommendation in music teaching. Through the above literature review, it can be found that many researchers have done a lot of research on the effect of music teaching, most of them use questionnaires combined with computer processing of data. Few studies have used deep neural network techniques to process these data. This study uses deep neural network technology to extract relevant spatial and temporal features in the evaluation of music teaching effects. This study mainly adopts CNN and LSTM methods, which are different and innovative from other studies. Once the deep neural network technology designed in this study is trained, it can quickly and accurately display the characteristics of music to students, which can improve the efficiency of music classrooms.

3. Application of Deep Neural Network in Music Teaching Effect Evaluation

3.1. The Significance of Deep Neural Network Applications. This research mainly uses CNN and LSTM technology in deep neural network technology to extract relevant features in music teaching effect evaluation, these features will include spatial features and temporal features. This deep neural network technology will use the nonlinear correlation in the evaluation of music teaching effect for analysis, which

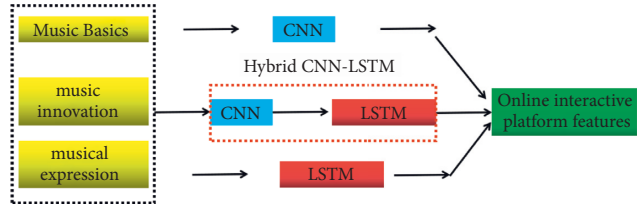

Figure 1: Scheme design of deep neural network technology in music teaching effect evaluation.

will demonstrate a certain objectivity. This will help reduce the human factor in the process of evaluating the effectiveness of music teaching. The important features in the evaluation of music teaching effect vary from person to person, so the traditional teaching evaluation model is no longer suitable for the evaluation task of music teaching effect. Deep neural networks can use a large amount of prior knowledge to evaluate unknown music teaching effects. In a word, deep neural network technology can not only help people to solve the large amount of data in the process of music teaching effect evaluation but can also map the nonlinear relationship between the relevant characteristics of music teaching effect evaluation and the evaluation level. This method only needs to collect a large amount of data for music teaching effect evaluation, and then it can use deep neural network technology to learn and test.

3.2. Design Scheme of Deep Neural Network in Music Teaching Evaluation. This research will combine the actual characteristics of music teaching effect evaluation and the advantages of deep neural network technology to design an intelligent evaluation scheme for music teaching effect evaluation. Once this kind of training is completed, it only needs to provide some relevant effect data in music teaching, and it can complete the evaluation and management of music teaching effect, which will be a fast way. At the same time, it has higher objectivity than traditional manual evaluation of music teaching effect [21]. Figure 1 shows an intelligent scheme for evaluating the effectiveness of music teaching using deep neural network technology [22]. For this scheme design, the most important thing is to collect some datasets with high accuracy. These datasets will contain data on three factors: the basic knowledge of music, the characteristics of music expression effects, and the characteristics of music innovation. These three feature data will go through the data preprocessing process before it can be input to the input layer of CNN. In the process of CNN neural network, these data will complete the extraction of spatial features using the convolution layer and pooling layer of CNN. Then, the output layer of the CNN will be converted into time series-like data. It will be input into the LSTM neural network to extract the temporal features of the music teaching effect. This is music. The expression of music has a strong correlation with time. After the LSTM neural network completes the temporal feature extraction, these data can be output. It saves the optimal weights and biases for testing. In the actual music teaching work, the teacher only provides the music-related knowledge to the deep neural network, and it

can efficiently display the characteristics of music innovation and music knowledge to the students or teachers using the computer-aided system.

The plan of music teaching effect evaluation mainly designs the three characteristics of music basic knowledge, music expression effect, and music creation effect of music teaching effect. There is a complex spatial correlation between these features and the music effect evaluation level. CNN is mainly used to extract the spatial correlation of these three features. CNN has been widely used in many fields related to image recognition, which is also a relatively mature algorithm for spatial feature extraction. Figure 2 shows the workflow of CNN for feature extraction of music teaching effect. Similar to the methods applied in other fields, CNN also mainly uses convolutional layers, pooling layers, and activation functions to complete the extraction of features related to the effect of music teaching. CNN also has a basic perceptron structure, which is a variant of the fully connected neural network. Matrix operations are performed between each factor of the fully connected neural network, which increases the parameter budget. This also leads to excessive waste of computing resources. The CNN method can use the roughness of weight sharing to reduce the amount of computation between parameters. This can reduce the utilization of computing resources, which in turn can build a deeper network structure to extract features with deeper characteristics of music teaching effects.

During the iteration and training of the CNN, the researchers will adjust the gradient descent direction of the weights and biases by adjusting the hyperparameters. Although the impact of hyperparameters on accuracy and convergence performance is relatively small relative to the dataset, however, the choice of hyperparameters is also a more critical link. Equation (1) shows the relation satisfied by the hyperparameters.

$$w' = \frac{(w + 2p - k)}{s} + 1. \tag{1}$$

Equation (2) shows the calculation method of the CNN input layer, which is one calculation method for each convolution operation. Where W and X are data in matrix form. The input data X will complete the feature extraction task through the convolution operation.

$$V = \text{conv2}\left(W, X'', \text{valis}''\right) + b. \tag{2}$$

Equation (3) shows the calculation method of the output layer of the CNN, which will perform nonlinear processing on the operations of the convolutional layer and the pooling layer, and then it can output the data.

$$Y = \phi(V). \tag{3}$$

Equation (4) shows the derivation of weights and biases in each layer of the network. Weights and biases are factors that memorize nonlinear relationships. The derivative operation is a way to find the optimal gradient descent direction. During the operation of CNN, it will involve chain derivation operations.

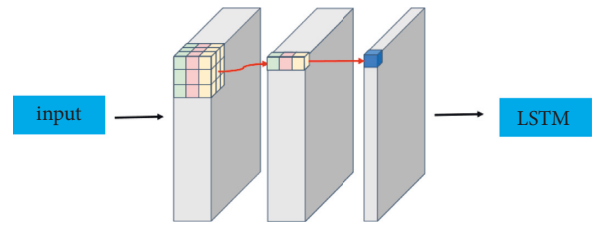

Figure 2: The workflow of CNN in extracting spatial features of music teaching effect.

$$E = \frac{1}{2}\sum_{k=1}^{m}\left[d_k - f\left(\text{netw}_k\right)\right]^2 = \frac{1}{2}\sum_{k=1}^{m}\left[d_k - f\left(\sum_{j=0}^{n}\omega_{jk}y_j\right)\right]^2$$

$$= \frac{1}{2}\sum_{k=1}^{m}\left[d_k - f\left[\left(\sum_{j=0}^{n}\omega_{jk}f\left(\sum_{j=0}^{q}u_{ij}\chi_i\right)\right)\right]\right]^2. \tag{4}$$

Equation (5) shows the method of value transfer during neural network computation. This is a recursive form of calculation. The rot180() function means to rotate the matrix 180° counterclockwise. The parameter fully represents the full convolution operation:

$$\delta^{l-1} = \text{conv2}\left(\text{rot180}\left(W^l\right), \delta^l, '\text{full}\right)\phi'\left(v^{l-1}\right). \tag{5}$$

3.3. An Introduction to the Working Principle of the Related Algorithm. LSTM neural network is used to extract temporal features in music teaching effect evaluation. The timbre expression and other features in the music teaching effect have temporal characteristics similar to speech recognition. If it is not conducive to the LSTM neural network to extract the temporal features of music teaching effects, it will lead to incomplete extraction of the features of music teaching effects. Figure 3 shows how the LSTM neural network works. In this study, the number of LSTM network layers is 5, which tries to extract the temporal features in the music teaching process as much as possible. The learning rate of the LSTM neural network is set to 0.001, which avoids falling into local minima during training.

The main reason that the LSTM method can memorize historical state information is because it has more gate structures, which can give weights to information at different times. The gate structure can selectively pass state information according to the size of the weight. Each gate structure restricts the passage of information. Equation (6) shows how the input gate is calculated. It will be responsible for selectively passing historical state information and current state information according to the weight.

$$f_t = \sigma\left(w_f \bullet [h_{t-1}, P_t] + b_f\right). \tag{6}$$

Equation (7) and (8) show how the forget gate is calculated. It will forget part of the historical information, and only part of the important historical state information will pass.

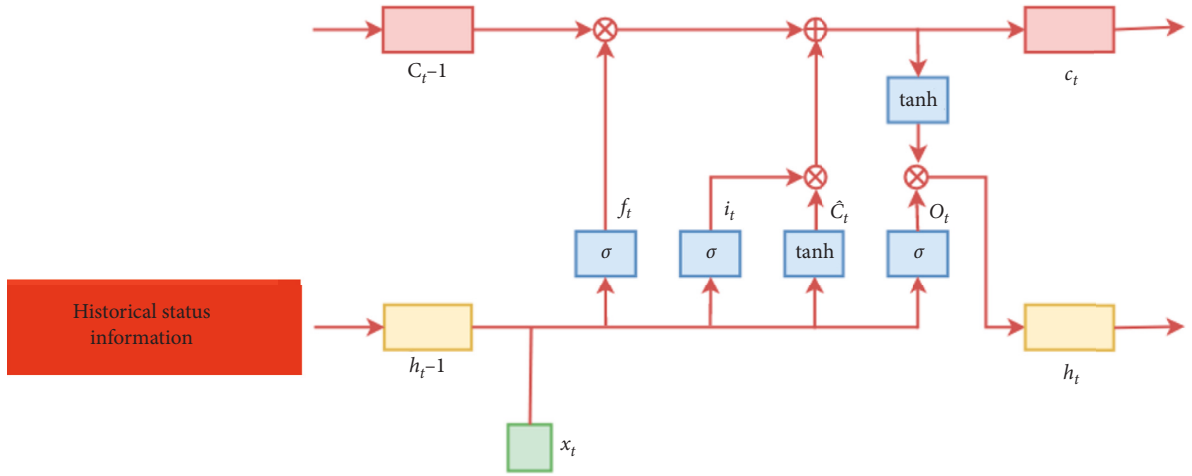

Figure 3: The working principle of LSTM in music teaching effect time feature extraction.

$$i_t = \sigma(\omega_i \bullet [h_{i-1}, P_t] + b_i), \tag{7}$$

$$\tilde{C}_t = \tan h(w_c \bullet [h_{t-1}, P_t] + b_c). \tag{8}$$

Equation (9) shows the computation of the refresh gate, which is the task responsible for updating the weights during the LSTM iteration.

$$\overrightarrow{C}_t = f_t \times \overrightarrow{C}_{t-1} + i_t \times \overrightarrow{C}_t. \tag{9}$$

Equation (10) and (11) show how the output gate of the LSTM is calculated. It also selectively inputs historical and current state information to the next neural network layer according to the size of the weight.

$$O_t = \sigma\left(w_o \bullet \left[\overrightarrow{h}_{t-1}, P_t\right] + b_o\right), \tag{10}$$

$$\overrightarrow{h}_t = O_t \times \tan h\left(\overrightarrow{C}_t\right). \tag{11}$$

4. Result Analysis and Discussion

4.1. Comparative Analysis of Prediction Errors of Different Deep Neural Networks. This research will use single CNN, single LSTM, and hybrid CNN-LSTM methods to study the accuracy and feasibility of deep neural network technology in predicting the relevant features of music teaching effect evaluation. The dataset is the first task for which this study needs to be accurate. This study selected the characteristic data of music teaching effect evaluation related to many music colleges and universities in Beijing. As the economic and political center of China, Beijing is also rich in music teaching resources, which will have more characteristics related to music teaching. This is also the requirement of the dataset, which contains the characteristics of the research object as much as possible. These data mainly include the characteristics of basic knowledge of music, the special data of music expression effect, and the characteristic data of music innovation effect. This research will predict and analyze the characteristic data of these three kinds of music teaching effects.

In order to illustrate the accuracy of the hybrid CNN-LSTM deep neural network in predicting the relevant features of music teaching effect evaluation, this study first analyzed the prediction error of a single CNN and a single LSTM neural network in predicting the characteristics of music teaching effect. Figure 4 shows the prediction errors of three features of a single CNN and a single LSTM neural network in predicting the effect of music teaching. In general, both neural network structures can meet the evaluation task of music teaching effect. Most forecast errors are within 3%. Although this error range is relatively large, it can also meet the task of evaluating the effect of music teaching. At the same time, it can also be found from Figure 4 that a single CNN method has a better prediction effect than a single LSTM structure. However, the prediction error of the characteristics of music innovation effect is relatively large, and the prediction error of the two neural networks exceeds 3%. The largest prediction error all reached 3.45%. This kind of error may have a certain deviation in the actual evaluation of music teaching effect.

The three characteristics of music teaching effect all have temporal characteristics similar to speech recognition. If only one feature extraction method is used, it is easy to lead to the incompleteness of feature extraction. It will further lead to the inaccuracy of the prediction effect for the prediction of music teaching effect evaluation. This study also organically integrates the spatial feature extraction method and the temporal feature extraction method to design a hybrid CNN-LSTM deep neural network method, which combines the advantages of the CNN and LSTM algorithms. Figure 5 shows the prediction errors of the three features of music teaching effect using the hybrid CNN-LSTM method. Overall, the prediction errors of the three features of the music teaching effect are significantly reduced compared to the single CNN and single LSTM methods. This further illustrates that the hybrid CNN-LSTM method has better feasibility and accuracy in the three feature tasks of predicting the effect of music teaching. It can also show that the

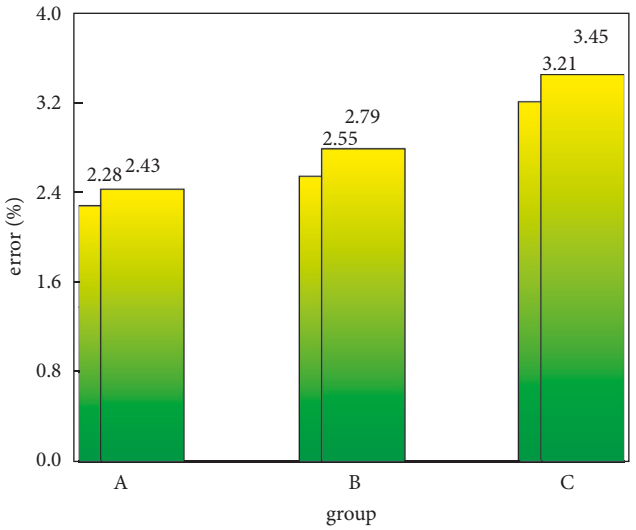

Figure 4: Prediction error of CNN and LSTM methods in predicting the characteristics of music teaching effect.

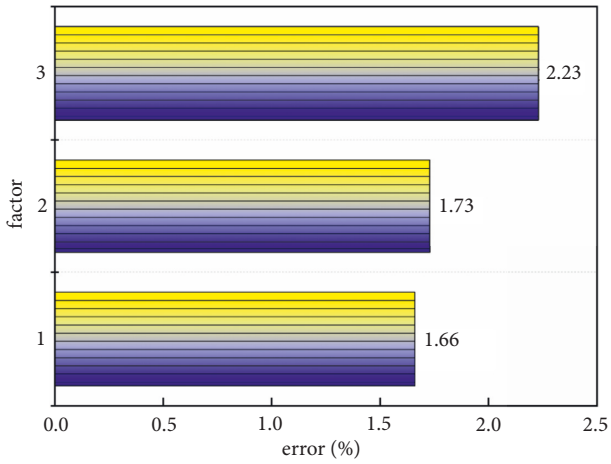

Figure 5: Prediction errors of three characteristics of music teaching effect using hybrid CNN-LSTM method.

three characteristics of music teaching effect evaluation have obvious temporal and spatial characteristics, and only using a neural network method to predict the characteristics of music teaching effect will cause certain inaccuracies. For the prediction error of the three characteristics of music teaching effect, the largest prediction error is only 2.23%. This part of the error comes from the prediction of music innovation effect. For the music emotion feature, the prediction error is only 1.73%. There is the smallest error in the characteristics of music knowledge. In the process of music teaching, this part of the error is only 1.66%. There are many fluctuations and mutations in the effect of music innovation, and the innovation effect among different students is inconsistent. It is not as easy to predict as music basics features.

4.2. Accuracy Analysis of the Hybrid CNN-LSTM Method in Predicting the Effect of Music Teaching. In this study, 30 groups of characteristic data related to the effect of music teaching were selected for accuracy analysis. Each music

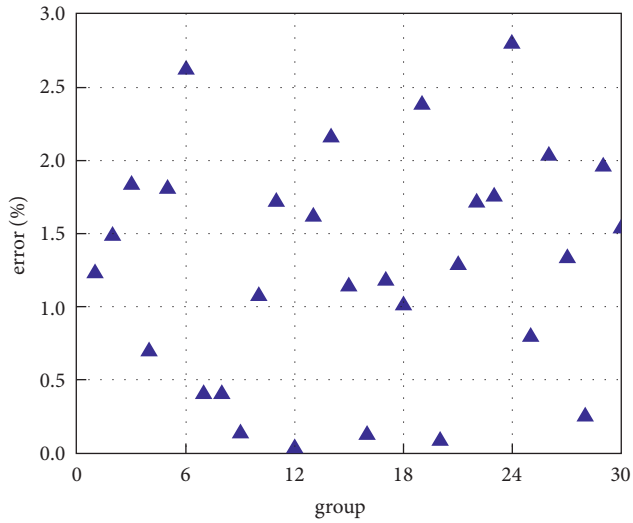

Figure 6: Prediction error distribution of music fundamentals features.

feature data will contain 30 sets of data. Figure 6 shows a scatter plot of the prediction error distribution of the music basics features in music teaching. Overall, the hybrid CNN-LSTM algorithm has high confidence in predicting music basic knowledge features. Most of the errors are mainly distributed within 2%, which is feasible for the evaluation of music teaching effect. Only a small fraction of forecast errors exceed 3%, which is an extremely small fraction of forecast errors. There is a small mutation in the characteristics of music basic knowledge in music teaching, and this part of the characteristics is almost unchanged for different music teaching. This leads to the fact that the characteristics of music basic knowledge are relatively easy to predict.

Among the three characteristics of music teaching effect involved in this study, the effect of music expression is also more difficult to predict. This is because the expressive effect of music is scored differently in different judging criteria. Figure 7 shows the distribution of the predicted linear correlation coefficients of the music expression effect characteristics of the music teaching effect. In Figure 7, in order to more accurately illustrate the effectiveness of the CNN-LSTM method in predicting the emotional features of music, it uses black lines to represent the 95% confidence interval. Most of the data points are distributed on both sides of the linear function $y = x$, and this part of the distance is also relatively close to the $y = x$ function. This shows that the predicted value of the music expression effect has a similar distribution to the actual value, which can further illustrate the accuracy and feasibility of the hybrid CNN-LSTM method in predicting the music expression effect. The linear correlation coefficient exceeding 0.95 indicates that the hybrid CNN-LSTM algorithm has certain feasibility. In this study, the linear correlation coefficients all exceed 0.955, which shows that the hybrid CNN-LSTM method has high feasibility in predicting the musical expression effect of music teaching effects.

Figure 8 shows the distribution of the predicted and actual values of the music innovation features in the music teaching effect. The blue dots represent the actual values of

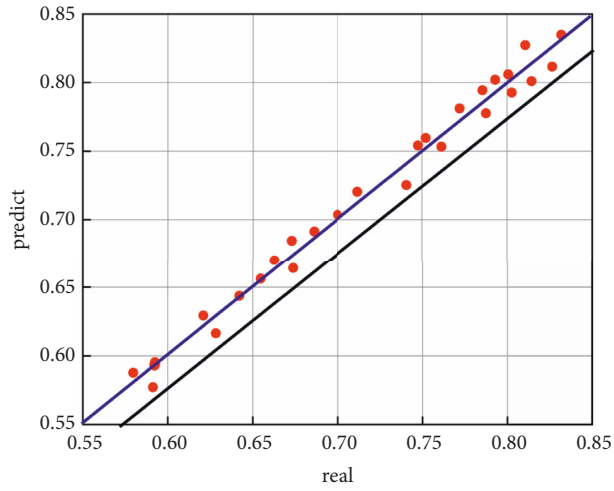

Figure 7: Predictive linear correlation coefficients of musical expression effect features.

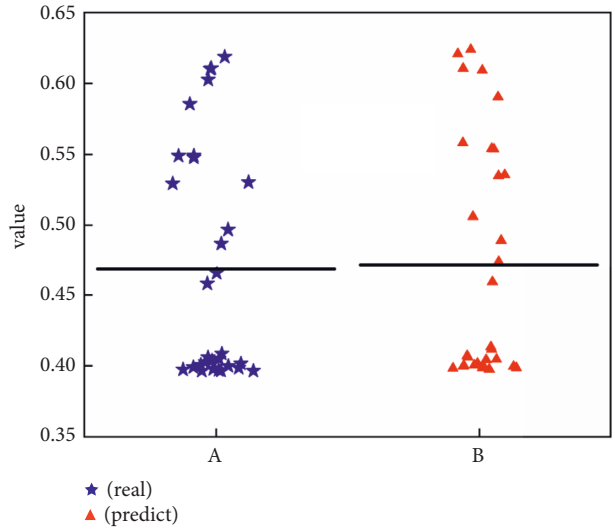

Figure 8: Numerical distribution of predicted cabinets for musical innovation effect characteristics.

the musical innovation features, while the red ones represent the predicted values of the musical innovation features. In Figure 8, the black line represents the average distribution of the music innovation effect of music teaching. For the actual value and the predicted value, it can more accurately reflect the overall situation of the music innovation characteristics. There are relatively large differences in the characteristics of music innovation in music teaching. For different music types, this will be reflected in the relatively large differences in eigenvalues. In general, the predicted value of the musical innovation feature is consistent with the actual value and distribution. This illustrates the feasibility of the hybrid CNN-LSTM algorithm in predicting musical innovation features. Although the music innovation feature is the most difficult to predict the music teaching effect feature, it can also be seen from Figure 8 that the prediction effect can satisfy the prediction task of the music innovation feature of the

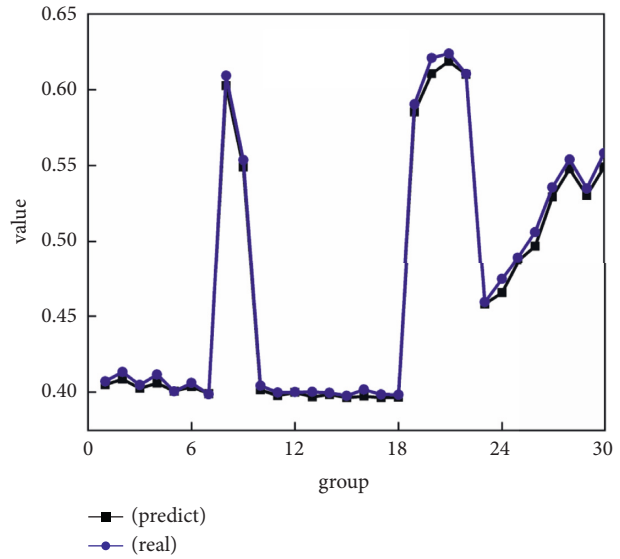

Figure 9: Predictive distribution curve of musical innovation effect characteristics.

music teaching effect. Figure 9 shows the distribution curve of the predicted value of the music innovation feature. It can be seen from the distribution of the curve that although there are relatively large fluctuations in the values of musical innovation characteristics, there are also many peaks and troughs. However, the hybrid CNN-LSTM can better capture the changing trends and numerical transformations of musical innovation features. Overall, the hybrid CNN-LSTM algorithm has achieved relatively satisfactory results. In Figure 9, the area between the blue line and the black line represents the prediction error of the music innovation feature of music teaching. It can be seen that the area of this part is relatively small for different groups.

5. Conclusions

The teaching effect of traditional subjects will be evaluated by means of examination papers or questionnaires. However, the evaluation of the teaching effect of music subjects contains more subjectivity, which makes it difficult to use the teaching evaluation mode of traditional subjects to evaluate the effect of music teaching. It is also difficult to analyze the music expression effect and music innovation effect of the teaching effect of music subject in a quantitative way, which means that the traditional teaching effect evaluation model is no longer suitable for the evaluation of music teaching effect. The deep neural network method can effectively extract the relevant features of music teaching that people cannot extract, which can establish the mapping relationship between features and time in music teaching. It can quickly help students to find suitable music information.

This study compared the feasibility and accuracy of CNN, LSTM and hybrid CNN-LSTM deep neural network techniques in the evaluation of music teaching effects. The single CNN method has higher accuracy than the single LSTM neural network method in predicting the three characteristics of music teaching effect. However, the

prediction error of these two neural network methods in predicting the music innovation effect of music teaching effect is more than 3%, which is unfavorable for the actual music teaching effect evaluation task. The prediction error of the hybrid CNN-LSTM method in predicting the three characteristics of the music teaching effect is significantly reduced, which shows the reliability and accuracy of the hybrid CNN-LSTM method in evaluating the music teaching effect. The largest prediction error is only 2.23%, which is also derived from the prediction of the effect of music innovation. The CNN method can extract the features of music teaching work, but it cannot effectively memorize the temporal relationship of music teaching features, so it cannot establish the temporal correlation in the process of music teaching. The prediction errors for the characteristics of music basic knowledge and music expression effect are both within 2%. The application of deep neural network technology in music teaching can help music learners quickly find interesting music knowledge, and it can also accurately predict relevant music teaching characteristics. This can increase student motivation.

Data Availability

The data used to support the findings of this study can be obtained from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Interface Design and Optimization Methods of Government Websites from a Flat Perspective

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Flat website design has become more and more popular in recent years due to its simplicity and elegance. Nevertheless, the current flat design thinking is mainly applied to conventional websites such as corporate websites. Recently, the increase in public demands has significantly increased the browsing frequency of government websites. To optimize the government website, this study establishes a government website design framework from the perspective of flattening. The established framework can extract flat design elements from the massive flat website design schemes in the past. Based on flat design elements, the particle swarm algorithm (PSO) algorithm in the established framework realizes the design and optimization of government websites. Subsequently, the performance of the CNN, which is used as the fitness function of the PSO algorithm, in predicting public acceptance is analyzed with a case study. The case results show that the average relative errors between the prediction results predicted by CNN and the real public acceptance in two provinces are 2.5416% and 1.4788%, respectively, which indicates that the predicted and real results are in good agreement. Moreover, the linear correlation coefficients between predicted and real public acceptance are 0.9553 and 0.9937, respectively, which further indicates that CNN is reliable as a fitness function of the PSO algorithm. Therefore, it is feasible to use the PSO algorithm to optimize the government website design scheme.

1. Introduction

Currently, with the rapid economic and social development, the government pays more attention to improving governance capacity through the transformation of government functions, thereby adapting and promoting economic development and social progress [1]. Government websites are the bridge between the public and the government [2]. Government departments generally publish relevant information such as newly adopted rules and regulations on the website to convey information to the public promptly. Moreover, the government website is a way to reflect the credibility of the government, so the design of the government website affects the public's impression of the government [3]. Besides, government websites are also a way for the public to supervise the government. The government website provides a channel for all-around supervision, such as supervision by the masses, direct supervision by subordinates and departments at the same level, and so on. Meanwhile, government websites have the effect of educating the masses and leading values. Usually, government websites are designed in strict accordance with the style of spreading positive energy and leading the frontier of the times, and it is difficult to find the emergence of negative energy information in them [4].

With the improvement of the level of social productivity and the advancement of science and technology, the public's concept of expressing their demands has become stronger, which has increased the frequency of browsing web pages [5]. So, the design optimization of government websites is significant. In the past few decades, the design thinking of web pages has undergone many iterations. In the modern

era, many statistical reports on website design show that flat website design thinking is more and more popular among people. Therefore, the flat design idea has the potential to better play the role of government websites.

Flat web design thinking abandons all decorative effects [6]. For example, shadows, perspectives, textures, gradients, and other elements that can create three-dimensional visual effects used in traditional web design are abandoned in flat web design. In addition, in the process of flat web design, all the element borders are clean and neat, without adding any feathers or shadows, making the website interface look simple and convenient [7]. Generally, a flat website design has the following advantages. First, the flat design makes the interface of the website more concise and comfortable. Based on simple elements, it is more convenient to express a lot of information and display process methods, thereby reducing the cognitive barriers of web browsers. Second, flat design allows websites to adapt to more resolutions. As the proportion of mobile phones used in people's daily life is getting higher and higher, and the resolution difference between mobile phones and computers is very large, the flat website design enables the web pages to adapt to mobile phones and computers at the same time, which greatly reduces the cost of developing multiresolution websites. Thereafter, a flat website design is very beneficial for search engine optimization. Concise design elements reduce the complexity and memory footprint of the website design, which significantly improves the loading speed of the website while reducing the load on the server. Besides, a fast website loading speed can also save time for web browsers, which can increase people's favorable opinion of the website.

Although the design idea of flat web pages has many advantages, it is currently mainly used in corporate website design. There are differences between government websites and corporate websites [8]. For example, in terms of color, the element color and background color of corporate websites will be set in different styles according to different industries, while the background color of government websites is usually more formal, such as red and blue. In terms of design purpose, in addition to listing the current important notices, the corporate website will also promote the characteristics of the company as much as possible, while the government website mainly provides services for the public around the three major themes of government affairs disclosure, online service, and government-civilian interaction, rather than purely to expand publicity efforts. In terms of layout, government websites and corporate websites have different propaganda focuses, so there are also big differences in the use and arrangement of elements such as pictures and text. Therefore, in the process of designing government websites with the idea of flattening, it is necessary not only to learn from the design style of conventional websites such as corporate websites but also to analyze the uniqueness of government websites, thereby selecting appropriate design elements and layout.

Considering that there are a large number of designed website resources on the Internet, which can provide numerous data references for the design of government websites. So, to better design government websites, this study proposes a government website design framework based on deep learning and particle swarm algorithm (PSO) from the perspective of flattening. The deep learning method applied in this study is a convolutional neural network (CNN), which can fully extract the design elements of a flat website with good results. With extracted design elements, the particle swarm algorithm, an evolutionary algorithm, can optimize the design of government websites. Finally, a high-level government website design scheme can be obtained. The CNN method can extract relevant features and content of government websites, which will help government staff to discover the relationship between some work data, which is also conducive to government staff to carry out their work efficiently. The PSO method has obvious advantages in optimizing features.

This paper is arranged as follows: In Section 1, the research background of the study is introduced, and the role of flat design ideas in current website design and the design points of government websites are also described in this section. Then, the development of related research works is described in Section 2. In Section 3, the establishment of the government website design framework and related basic theories are described. Section 4 describes case studies that analyze the effectiveness of the established framework. Section 4 shows the accuracy of CNN in predicting the relevant data and features of government websites by using the average error of relevant features of government websites, the linear correlation coefficient of predicted values, and the form of graphs. Subsequently, the feasibility and reliability of the established government website design framework are analyzed in Section 5. Finally, the conclusion of this study is drawn in Section 6.

2. Related Work

The government website is an important bridge between the government and the public, and the design and optimization of government websites are significant to improving the relationship between the government and the public and improving the efficiency of government work. Therefore, in recent years, the study on government website design has attracted the attention of many scholars.

By analyzing the design of past government websites, Lee and Lee [9] found that although the past government websites could provide basic propaganda services for the public, they were insufficient in terms of democratic appraisal. Based on this question, they propose a model for evaluating government websites and provide corresponding countermeasures for improving public participation. Thereafter, to further explore ways to improve the communication between the government and the public, Prayoga et al. [10] took the website design of a county as an example and evaluated the design of the government website from the aspects of readability and interface design friendliness. Based on the evaluation results, how government websites can better serve the public was analyzed, thereby providing a reference plan for improving the usability of government websites. From the perspective of e-government, Irawan and Hidayat [11] establish a

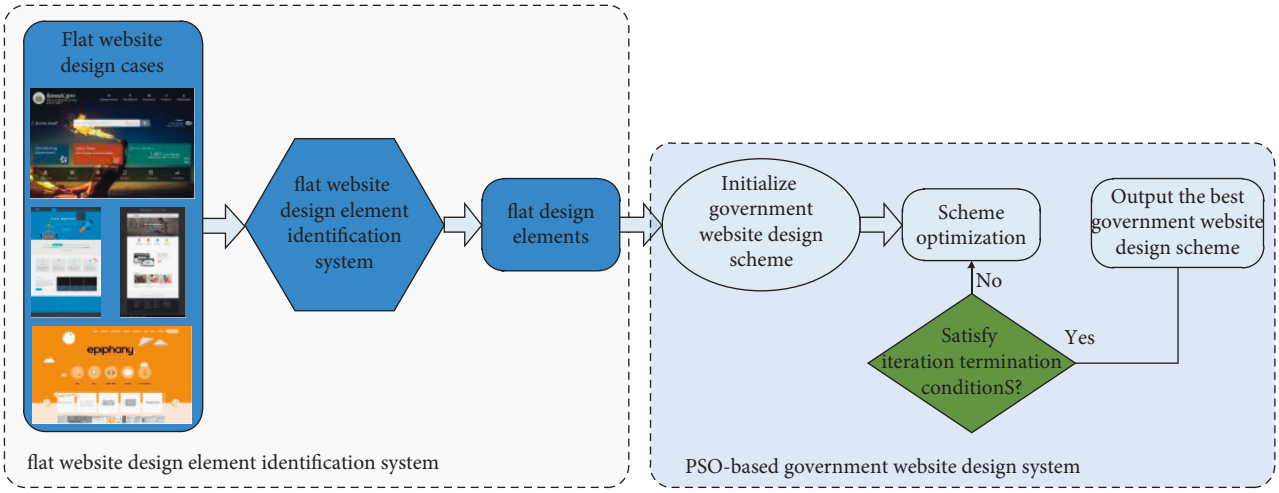

Figure 1: Schematic diagram of the established government website design framework.

comprehensive model for evaluating the usability of government websites based on richer cases. The established model assesses the factors that affect the usability of government websites and provides multiple channels for improving communication between the government and the public.

In recent years, the increased public demands have greatly increased the browsing frequency of government websites, so it is of great significance to improve the browsability of government websites. Rahayu et al. [12] analyzed the reasons that affect users' interest in visiting the website from the user's point of view. The results of the study show that the interrelationships between multiple websites and hyperlinks are important factors that affect users' interest in browsing websites. To further increase users' interest in browsing the website, Pelet and Taieb [13] analyzed the impact of website fonts and layouts on browser behavior in flat design scenarios. The results of the study show that the recognizable nature and layout friendliness of fonts in flat websites increase the interest of browsers in the website. Moreover, Cousins [14] compared the flat website design scheme and the traditional website design scheme. The comparison results show that the color scheme used by the flat website design scheme can guide users to use the website more conveniently. Based on the abovementioned analysis, flat design thinking has the potential to play a role in optimizing the design of government websites.

According to the abovementioned analysis, although the researchers tried to evaluate the usability of government websites and put forward measures to improve the communication between the government and the public, there are still deficiencies in the interface optimization of government websites. Therefore, this study tries to optimize the interface design of government websites from the perspective of flattening.

3. Methodology

From the perspective of flattening, to improve the service level of government websites, based on deep learning [15] and PSO [16], this study establishes a government website design framework. The schematic diagram of the framework is shown in Figure 1. As can be seen from Figure 1, the established design framework is divided into two parts: the flat website design element identification system and the PSO-based government website design system. Next, we briefly introduce these two parts separately.

3.1. Flat Website Design Element Identification System. To design a government website with flat thinking, the design elements used to design a flat website are required. The flat website design element identification system is to extract the design elements in the existing flat website. The structure of the flat website design element identification system built in this study is shown in Figure 2. The identification system is established based on an improved CNN, note that the applied CNN is essentially an intelligent data-driven method. With the established flat website design element identification system, numerous common flat design elements can be extracted from existing flat website design cases, thereby providing the element basis for the design of government websites.

As can be seen from Figure 2, the established flat website design element identification system is mainly divided into two subparts: feature extractor and classifier. The maximum pooling layer can further reduce the amount of parameter calculation. The information contained in government websites is relatively complex, which will generate a large number of data sets. In order to be able to accurately predict the relevant factors, this requires a max-pooling layer.

3.1.1. Feature Extractor. Feature extractors can extract implicit feature information from web design graphs. The feature extractor in this study consists of convolutional layers and pooling layers.

In deep learning, compared with other network layers, convolutional layers are better at image processing and can extract local feature information from images [17]. As indicated [18], convolutional layers have the properties of

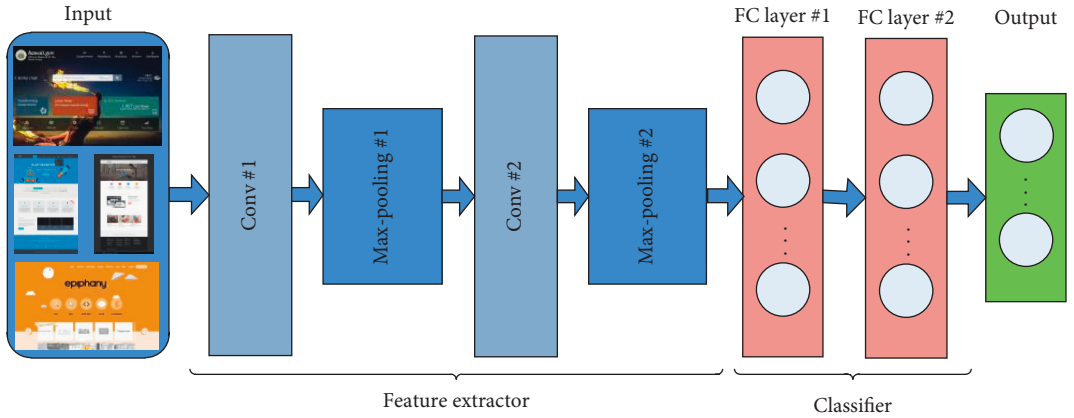

Figure 2: Structure of the flat website design element identification system.

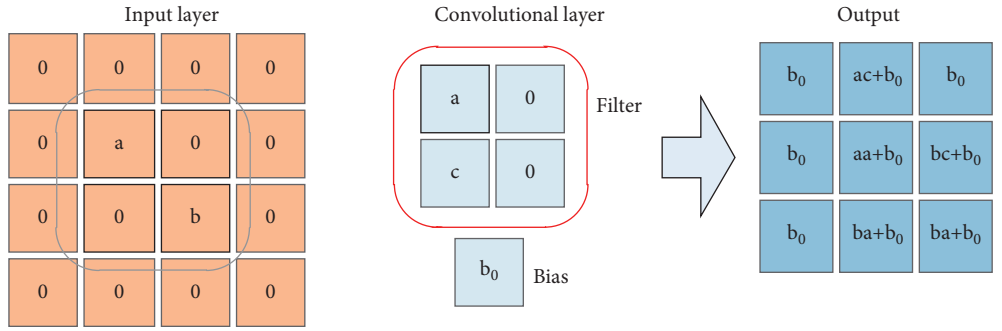

Figure 3: Process of the convolution operation.

translation invariance and inductive reasoning. In addition, the convolutional layer also has the feature of weight sharing, which makes it possible to reduce the number of trainable parameters when using the convolutional layer to build a neural network, thereby improving the training efficiency of the network to a certain extent. The operating principle of the convolutional layer is depicted in Figure 3. In order to be able to extract deeper relevant features of government websites, the number of filters selected in this study is 128, the learning rate is 0.0001, and the value of the sliding step is 2. It also contains two fully connected layers.

As shown in Figure 3, the convolution operation is the elementwise multiplication of the convolution kernel and the corresponding area in the input image. When the multiplication area scans the length and width of the input image, the output of the convolutional layer can be obtained. Based on the convolution operation, the mathematical expression of the convolution layer is as follows:

$$y = f(w * x + b), \tag{1}$$

where w and b represent the weights and biases of the network layer, respectively. F denotes the activation function. Considering that the exponential linear units (ELU) alleviate the abnormal gradient propagation problem of sigmoid and tanh, and it is closer to zero-center distribution than rectified linear units (ReLU) [19], ELU is used as the activation function in each network layer in this study. And the expression of ELU is as:

$$y = \begin{cases} \alpha(e^x - 1) & (x \le 0), \\ x & (x > 0), \end{cases} \tag{2}$$

where α is a constant, and α is set as 1 in this study.

To reduce the complexity of the network, max-pooling layers are added to the feature extractor. Although both max-pooling and average-pooling layers can reduce the number of trainable parameters of the network, compared to the average-pooling layer, the max-pooling layer preserves the maximum value of the corresponding region, thus preserving the original information of the input as much as possible, thereby improving the working performance of the network [20]. To more clearly show the working process of the max-pooling layer, the operating principle of the max-pooling layer is shown in Figure 4.

As shown in Figure 4, the size of the output image of the max-pooling layer is greatly reduced compared to the input image, which not only greatly reduces the scale of the network but also improves the generalization performance of the network by discarding part of the data. The expression of the max-pooling layer is as follows:

$$\text{pool}_{i,j,k} = \underset{\substack{(i-1)H \le p \le iH \\ (j-1)B \le q \le jB}}{\text{downsampling}}\left(V_{i,j,k}\right), \tag{3}$$

where $\text{pool}_{i,j,k}$ represents the value at the location (i, j) of the k-th output feature map of the max-pooling layer, and H and

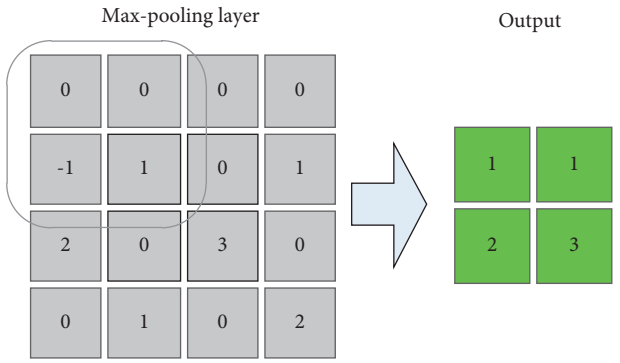

Figure 4: Operating principle of the max-pooling layer.

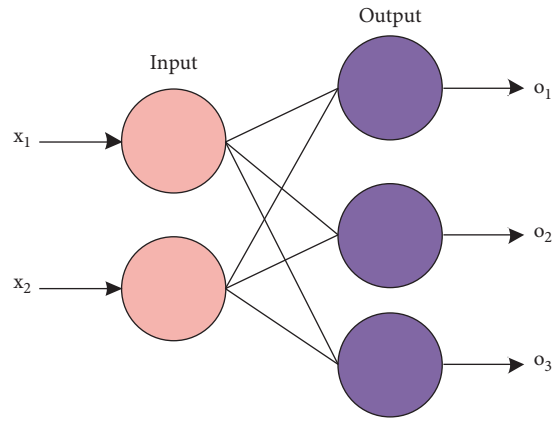

Figure 5: Schematic diagram of fully connected layers.

B are the height and width of the kernel in the max-pooling layer, respectively.

3.1.2. Classifier. With the feature extractor, the feature information hidden in the flattened website can be extracted. To obtain the design elements contained in the flattened website, it is necessary to establish a mapping relationship between the extracted feature information and multiple types of design elements. To establish such a mapping relationship, fully connected layers are adopted in this study. Since the fully connected layer realizes the classification of the extracted features, it can also be regarded as a classifier.

The schematic diagram of fully connected layers is shown in Figure 5. Based on the fully connected neurons, fully connected layers realize the classification of the extracted feature information. The mathematical expression of the fully connected layer is as follows:

$$y = f(wx + b), \tag{4}$$

where w and b represent the weights and biases of the fully connected layer, respectively. Note that although the weights in the fully connected layers have a larger number of trainable parameters compared to the convolutional layers, this is a compromise that the fully connected layers have to make to preserve as much feature information from the feature extractor as possible.

Since the process of flat website design element identification involves the classification of multiple design elements, softmax is used as the activation function in the output layer of fully connected layers [21]. The expression of softmax is as follows:

$$\text{soft max}(x_i) = \frac{\exp(x_i)}{\sum_{i=1}^{K} \exp(x_i)}. \tag{5}$$

With softmax, the value range of all output neurons can be limited to the range of (0, 1), which is closer to a form of probabilistic expression and can improve the training efficiency of the network. Besides, the sum of the values of all output neurons is 1, and the output value of each neuron in the output layer of the classifier represents the probability of the design element appearing in the flattened website.

Based on the abovementioned description, with the flat website design element identification system, common design elements can be obtained from numerous flat website design cases, thereby providing a material library for the flat design of government websites.

3.2. PSO-Based Government Website Design System. In the process of designing a flat government website, the main design points are to choose the shape of the label, the background color, the size and position of the picture, etc. This process involves the combination of multiple design elements, so this study attempts to use evolutionary algorithms to optimize the combination of design elements. PSO, an evolutionary algorithm, has the advantages of a simple algorithm and good global optimization performance compared with the genetic algorithm or artificial fish swarm algorithm. Therefore, the PSO algorithm is adopted in this study.

The specific steps of the PSO algorithm can be found in Ref. [22]. After setting the range of design elements to be selected, a government website design scheme can be obtained by randomly selecting design elements and combining them. At this point, another important step is to evaluate the level of the design scheme, that is, to construct the fitness function in the PSO algorithm. Usually, the level of government website design scheme is reflected by the acceptance of the public.

Suppose the expression of the fitness function of the PSO algorithm is as follows:

$$y = F(X), \tag{6}$$

where X and y represent government website design image and public acceptance, respectively, and F is the mapping relationship. To establish the mapping relationship F, considering the feature extraction ability of CNN for website images, CNN is applied in this study. The structure of the constructed CNN is shown in Figure 6.

Figure 6 shows that in the CNN, except for the global average-pooling layer, the structure of other layers is consistent with the structure of the feature extractor mentioned in Section 3.1.1. With the global average-pooling layer, the trainable parameters of the network are greatly reduced, which improves the training efficiency of CNN.

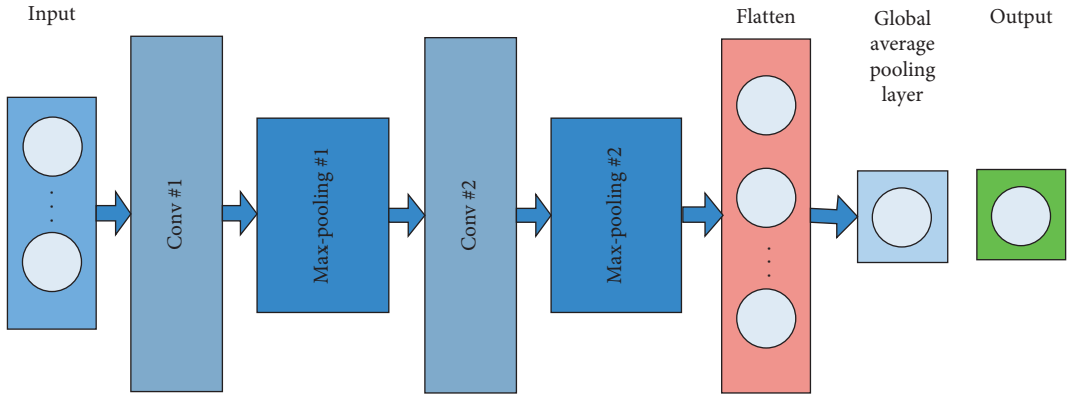

Figure 6: Structure of the constructed CNN.

Based on the abovementioned description, after setting the range of the flat design elements, with the CNN-based fitness function, the PSO algorithm can perform iterative calculations, thereby obtaining the optimized government website design scheme.

3.3. Workflow of the Government Website Design Framework. Based on the abovementioned description, the workflow of the government website design framework is depicted in Figure 7, and the detailed steps are as follows:

(i) Extraction of flat website design elements. Firstly, the established flat website design element identification system is trained with flat website design images with known design elements. Since the element recognition system is a multiclassification problem, the training loss function uses cross-entropy [23], and its expression is as follows:

$$L(\hat{\mathbf{y}}, \mathbf{y}) = -\sum_{i=1}^{K} \hat{y}_i \log(y_i). \tag{7}$$

In Equation (7), the data format of y is usually one-hot, and in addition, K represents the number of categories of labels. With the calculation in Equation (7), L can represent the comprehensive error corresponding to all samples. Then, with the trained element recognition system, flat design elements can be obtained from the massive flat website images.

(ii) Categorize flat design elements. By classifying flat design elements, an element library can be better provided for the flat design of government websites.

(iii) Government website interface design and optimization. Firstly, preset the range of flat design elements for designing government websites. Then, the government website design scheme is optimized based on the PSO algorithm. To improve the accuracy of the fitness function, it is necessary to train the CNN-based fitness function. Since the output of CNN corresponds to the public acceptance, the loss function adopted in CNN is the mean square error (MSE) [24], and its expression is as follows:

$$MSE = \frac{1}{N} \sum \left(y_{\text{pre}} - y_{\text{real}}\right)^2, \tag{8}$$

where N represents the number of samples that participate in network training. Finally, after iterative calculation, the government website design scheme corresponding to the maximum fitness function is optimal.

4. Case Study

As indicated in Section 3.3, to obtain a better government website design scheme from a flat perspective, the construction of a CNN-based fitness function is very important, which directly affects whether the website design scheme can be optimized.

To explore whether the established CNN can effectively realize the mapping relationship between the government website design scheme and public acceptance, this study takes the government website design report of a European country as an example to analyze the effectiveness of CNN.

To facilitate the analysis of the government website design report, the data in the report is divided into 15 groups according to the provinces in this study, and each group contains 200 samples. The variables of the sample are composed of (X, y), where X and y represent website images and public acceptance, respectively. To improve the training efficiency of CNN, the pixel values in the picture are normalized. Since the pixel value range of the grayscale image is [0, 255], the 0-1 normalization method is adopted here [25], and its expression is as follows:

$$\text{Norm}(X) = \frac{X - \min(X)}{\max(X) - \min(X)}, \tag{9}$$

where $\max(X)$ and $\min(X)$ represent the maximum and minimum pixel values of the image, respectively. Through the normalization operation, all pixel values in the image are in the range [0, 1], and then, the distribution of the pixel values is closer to the zero-centered distribution, which is beneficial to improving the training efficiency of networks. It should be pointed out that although the picture has been normalized, the numerical relationship of each pixel value in the picture has not changed. Besides, the value range of public acceptance is [0, 100].

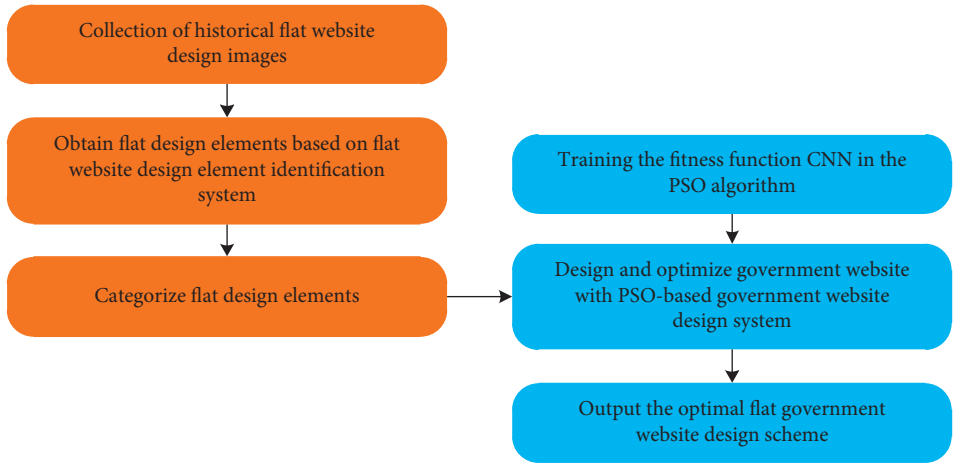

Figure 7: Workflow for the government website design framework.

In the process of exploring the accuracy of CNN in predicting popular acceptance, the 15 groups of data in the report are divided into the training, validation, and testing sets. The training set and validation set are used to train the CNN, and the testing set is used to validate the prediction performance of the CNN. Besides, the training set, validation set, and testing set contain 10, 3, and 2 groups of sample sets, respectively.

5. Results and Discussion

5.1. Effectiveness of the Established CNN. After the established CNN is trained with the training and validation sets, the performance of CNN in mapping between government website design schemes and public acceptance is evaluated via the testing set.

The testing set contains sample sets corresponding to two provinces, and the two sample sets are denoted as $P1$ and $P2$, respectively. The comparison between the prediction results of CNN and the real results on the testing set is depicted in Figure 8. As indicated in Figure 8, in the two provinces, the predicted and real public acceptance trends are very close. There is a large difference in the characteristics of public acceptance of government website content, which indicates that the data set collected in this study is relatively extensive, which helps CNN to grasp the content of different types of government websites. For some samples in province $P1$, the deviation between the predicted results and the actual results is relatively large. This may be because some samples in province $P1$ have large deviations from the samples corresponding to the training set and validation set, which makes the prediction deviation of the trained network relatively large. Although the predicted and real public acceptance in province $P1$ is greater than that in province $P2$, the deviation in province $P1$ is acceptable, so, the predicted and real results in the two provinces are in good agreement.

To more clearly present the deviation between the predicted and actual results in the two provinces, Figure 9 displays the relative error of predicted and public acceptance in the two provinces. The formula for calculating the relative error is

$$E = \text{abs}\frac{\left(y_{\text{pre}} - y_{\text{real}}\right)}{y_{\text{real}}}. \tag{10}$$

Among them, y_{pre} and y_{real} represent the predicted and real results, respectively, and abs is the operation used to calculate the absolute value. As can be seen from Figure 9(a), in province $P1$, the maximum relative error between the predicted and the real public acceptance is close to 6%, and the distribution of the relative error corresponding to the samples in this province is relatively average in the range of [0, 6%]. This shows that although the relative error corresponding to some samples exceeds 5%, on the whole, the trained network's prediction of public acceptance in province $P1$ is very stable. As shown in Figure 9(b), for province $P2$, the maximum relative error between the predicted and actual public acceptance is slightly greater than 5%. Moreover, most of the relative errors corresponding to the samples in province $P2$ are less than 3%, and even concentrated in the range of [0, 1%], which shows that the trained neural network has very good prediction performance for the samples in province P2. According to the analysis of Figures 9(a) and 9(b), the relative errors corresponding to the most of samples in the two provinces are within 5%, especially in the $P2$ province, only one sample has a relative error slightly greater than 5%. To corroborate the results of the analysis in Figure 9, the average relative error between predicted and real public acceptance in the two provinces is calculated. The comparison results of the average relative errors corresponding to the two provinces are shown in Figure 10, and the average relative errors of provinces $P1$ and $P2$ are 2.5416% and 1.4788%, respectively. The average relative error corresponding to the two provinces shows that although the average relative error of province $P1$ is nearly twice that of province $P2$, the average relative error of province $P1$ is still far less than 5%.

As indicated in Ref. [26], a relative error of 5% is acceptable in practical applications. According to the results in Figures 8–10, the public acceptance predicted by CNN has a good consistency with the real public acceptance, which indicates that the CNN-based mapping relationship between the government website design scheme and the public acceptance has good accuracy.

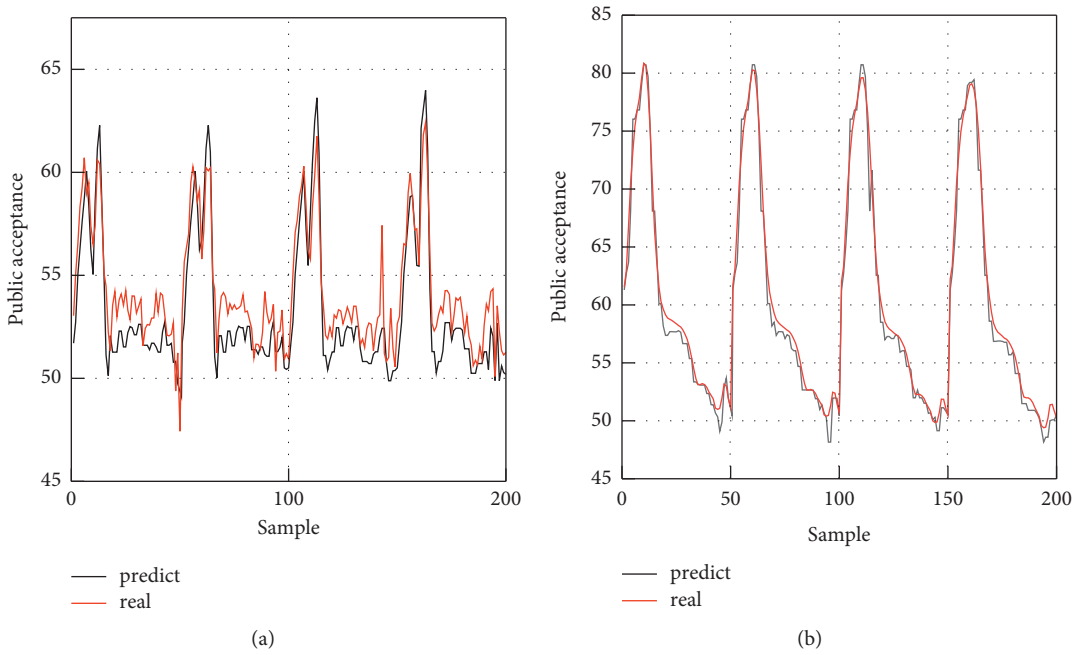

Figure 8: Comparison of the predicted and real public acceptance in two provinces: (a) province = "$P1$"; (b) province = "$P2$."

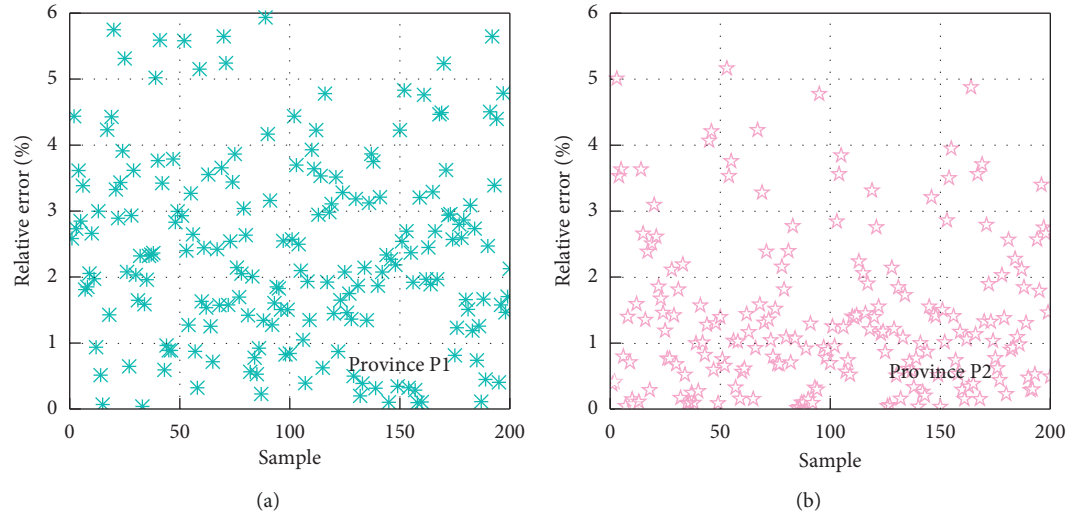

Figure 9: Relative errors between the predicted and real public acceptance in two provinces: (a) province = "$P1$;" (b) province = "$P2$."

5.2. Statistical Analysis. To further validate the effectiveness of CNN in predicting public acceptance, a statistical analysis of the prediction results of CNN is conducted in this subsection.

Firstly, the MSE between the predicted and real public acceptance is calculated, and the results are depicted in Figure 11. The calculation formula of MSE is consistent with Equation (8). As shown in Figure 11, the MSE between the predicted and real results in the two provinces is 2.9316 and 1.8695, respectively. So, the relative relationship between province $P1$ and province $P2$ is consistent from the perspective of statistical analysis and the perspective of relative error. Since the value range of public acceptance is [0, 100], it is generally considered that MSE less than 5 indicates a good agreement between the predicted and real results. Therefore, the calculation results of MSE show that CNN has a good performance in predicting public acceptance.

Secondly, a linear correlation analysis is performed between the public acceptance predicted by CNN and the real public acceptance. The correlation calculation results are depicted in Figure 12. Note that the abscissa and ordinate of the points in Figure 12 represent real public acceptance and predicted public acceptance, respectively. It can be seen from Figure 12 that although the deviation between the points in the province $P1$ and the line $y = x$ is slightly large, the corresponding relative deviation is still small, so this deviation is acceptable. In addition, for province $P2$, the corresponding points are closely around the line $y = x$, which

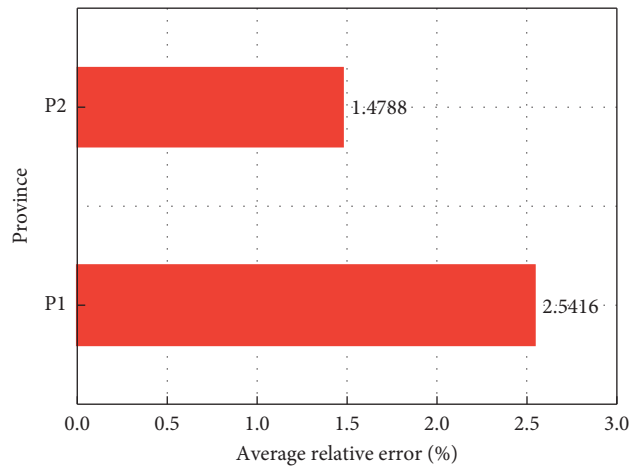

Figure 10: Average relative errors between the predicted and real public acceptance in two provinces.

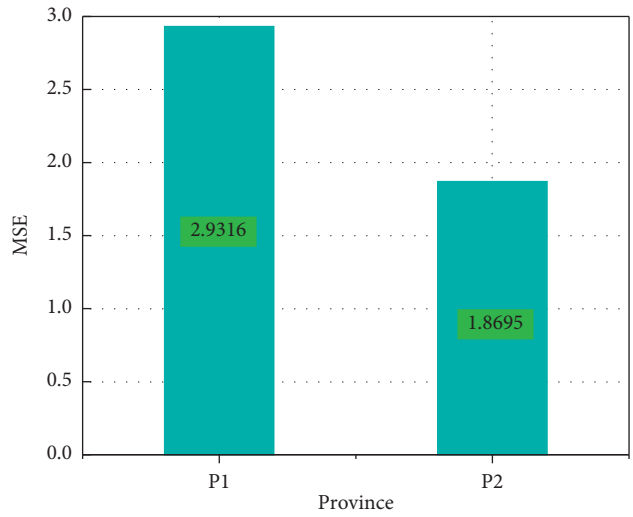

Figure 11: MSE between the predicted and real public acceptance in two provinces.

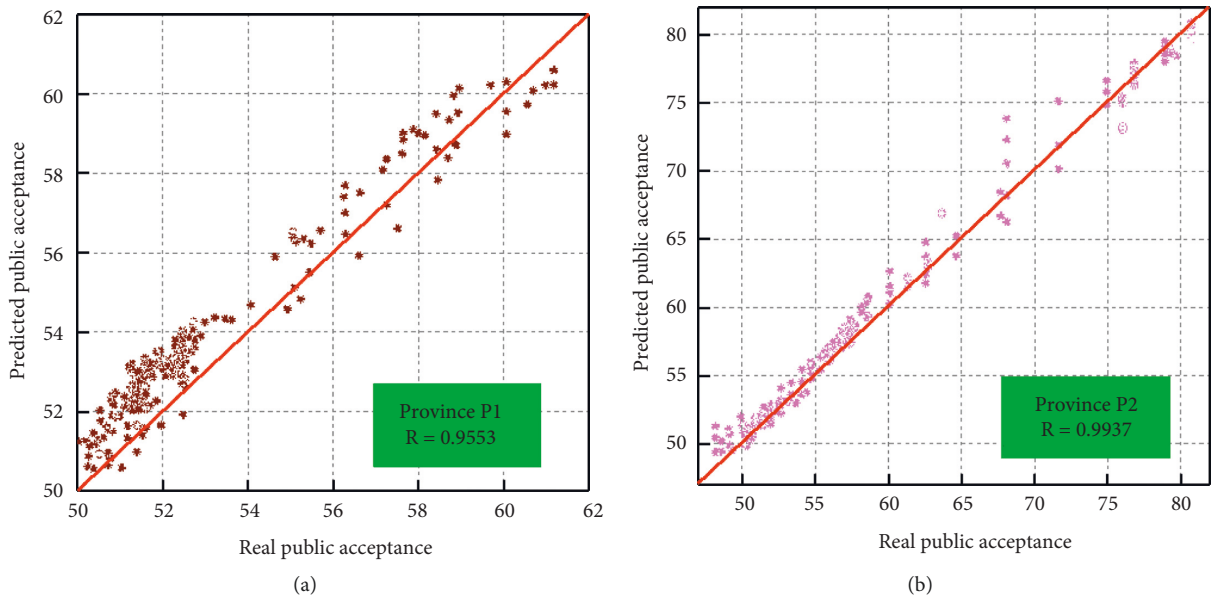

Figure 12: Linear correlation results of the predicted and real public acceptance in two provinces: (a) province = "*P*1;" (b) province = "*P*2."

shows that in province $P2$, the linear correlation between the predicted and real public acceptance is very strong. Moreover, the calculated linear correlation coefficients corresponding to the two provinces are 0.9553 and 0.9937, respectively. As indicated in reference [26], a linear correlation coefficient greater than 0.95 indicates a strong linear correlation between two variables. So, the linear correlation results further indicate a strong agreement between the predicted and real public acceptance. If the data of the public acceptance of the relevant content of the government website are distributed on both sides of $y = x$, it can be shown that CNN can better predict the characteristics of public acceptance, which also shows that the weight distribution of CNN is relatively uniform.

According to the analysis in this subsection, the results of statistical analysis are in good agreement with the relative error results, which also confirms the reliability of each other's calculation results. Therefore, with the results of statistical analysis, the accuracy of the CNN-based mapping relationship between the government website design scheme and the public acceptance is further validated.

6. Conclusions

From the perspective of flattening, a government website design framework is established in this study. The established framework can extract flat design elements from numerous flat website design schemes. Then, with the design requirements of government websites as constraints, the PSO-based algorithm is used to design and optimize government websites. With a case study, the performance of deep learning methods involved in optimizing government website design schemes is analyzed. The results revealed that:

As indicated from the calculation results on the testing set, the relative error of the predicted and real results corresponding to most of the samples in the two provinces is within 5%, especially in province $P2$, CNN shows better prediction accuracy. Moreover, the average relative errors of the predicted and real results in the two provinces are 2.5416% and 1.4788%, respectively. So, the relative error results show that the CNN-based mapping relationship between the government website design scheme and the public acceptance has good accuracy.

Statistical analysis results show that the linear correlation coefficients of the predicted and real public acceptance in the two provinces are 0.9553 and 0.9937, respectively, which further demonstrates that the CNN involved in optimizing government website design schemes has promising prediction accuracy. The CNN method can help government workers find relevant content on websites, and this method is more accurate and efficient. For cumbersome website content, it can save a lot of time and effort for government workers. The use of this method is also more convenient for the trained CNN network.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Optimal Investment-Consumption Strategy of Household Based on CEV Model

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To maintain and increase household wealth, this study studies the optimal allocation ratio of household investment and consumption. When considering venture capital, it is assumed that the theoretical price of risky asset obeys the CEV model. Our goal was to maximize the expectation of household cumulative consumption and the discounted utility of terminal wealth and to solve the optimal consumption and investment ratio using the dynamic programming principle and HJB equation. Using logarithmic utility and isoelastic power utility function with residual utility, we get the analytical solution of the household investment-consumption ratio by means of guessing and variable transformation. Finally, the influence of general parameters on the optimal ratio in the market is analyzed by numerical simulation and diagram, which is consistent with the description of actual situation. This study not only enriches portfolio theory but also provides investors with investment strategies.

1. Introduction

With the growth of economy, the household income also increases. How to reasonably invest the family's remaining wealth and realize the maintenance and appreciation of family wealth is the core issue of our research. The systematic research on household investment began in the 1960s, starting from Samuelson [1] and Fama [2]. For a continuous time, in 1969, Merton [3] studied portfolio selection under uncertainty in the life cycle, thus opening the prelude to study the dynamic portfolio optimization under continuous time. In 1971, Merton [4] proposed the continuous-time model of the optimal consumption and portfolio rules. It opens a new milestone in the methodology of dynamic portfolio selection. However, the classical Merton model and its extension [5–7] usually assume that its risk assets obey the geometric Brownian motion (GBM) model. The volatility of the price of a risky asset described by the GBM model is constant and cannot reflect the actual market situation. The CEV model, first proposed by Cox and Ross, can make up for these shortcomings. It is a natural extension of the geometric Brownian motion model [8]. For a complete financial market, the CEV model considers the relationship between the price of risky assets and the volatility, which is more in line with the requirements of the financial market [9]. The price fluctuation of risk assets described by the CEV model is stochastic, which is more suitable for practical problems. Xiao et al. [10], for the first time, will be introduced to the CEV model to determine the payment type pension (defined contribution pension) portfolio optimization problem in the study, and the optimal strategy is given under the exponential utility function. In recent years, there are a lot of literature studies on pension problems based on the CEV model [11–14] and very few literature studies on investment optimization based on the CEV model. In 2013, Chang et al. [15] pointed out that the relevant literature on the issue of investment and consumption based on the CEV model has not been widely discussed. When the CEV model is introduced into the portfolio optimization problem, it is often difficult to obtain the explicit solution of these problems. By maximizing discounted expected utility of consumption and final value wealth, Chang et al. studied the CEV model of individual optimal investment strategy. Although Yuan et al. [16] studied the family optimal investment strategy under

the CEV model, they think of it in terms of mean-variance. Later, Jia et al. [17] obtained the analytic solution of investment strategy using power function utility and exponential function utility. However, they used only an asymptotic analysis. For the portfolio optimization problem in continuous time, Pliska [18] gave the analytical solution of the optimal portfolio problem, Sundaresan and Zapatero [19] gave the optimal asset ratio, and Liu [20] derived the analytical solution of the portfolio problem in a random case. Stochastic optimal control theory is one of the effective methods to solve the problem of optimal portfolio in continuous time [21]. Summing up the above literature studies, there are not many research studies on household investment-consumption problem using the CEV model.

This research mainly focuses on the investment and consumption problems based on the CEV model. In household wealth investment, this study considers a risk-free asset and a risky asset. Assuming that the price of an asset at risk is subject to the CEV model, we aim at maximizing consumption and the expected utility of the final value of wealth with discount to acquire the optimal ratio. The innovations of this study are as follows: (1) considering both the CEV model and consumption factor in this section, the HJB equation of the corresponding value function is more difficult to solve than the equation in Gao [22]. (2) Inspired by Gao [22] and Liu [23], when a second-order nonlinear partial differential equation is transformed into a linear equation that is easy to handle, an important innovation is to assume that the structural expression of the solution of equation (25) is in the form of equation (26). It is also proved that equation (25) is equivalent to equation (29). (3) Using the method of variable transformation, the optimal consumption-consumption strategy under the exponential utility function and the equal elastic power utility function with giveaway utility function is solved. The analytic expressions of the optimal investment-consumption strategy under the two utility functions are obtained by the method of guessing.

2. Household Wealth Investment Model

We propose an investment model based on the investment and consumption decision problem under the CEV process. Assume that households have two continuously tradable financial assets in financial risk markets during an investment period [0, T]. Now, let us consider a specific risk asset based on the CEV model and a market composed of risk-free assets. At time t, the price of the risk-free asset satisfies the following random process:

$$dB_t = rB_t dt, \tag{1}$$

where r is the fixed interest rate.

At time t, let the price of the risky asset (stock) be $S(t)$, abbreviated as S_t, following the CEV model as follows:

$$\frac{dS_t}{S_t} = \mu dt + kS_t^{\beta} dW_t, \tag{2}$$

where μ represents the instantaneous return rate of the stock, which generally satisfies $\mu > \beta$. kS_t^{β} represents the instantaneous volatility, and generally, $\beta < 0$ represents the elasticity coefficient of constant variance. When $\beta = 0$, it is a general geometric Brownian motion process. $W_t\,(t \geq 0)$ is a one-dimensional standard Brownian motion, which is defined in the complete probability space (Ω, F, P) where P is the risk-neutral probability, and $F = \{F\}_t$ is a right continuous σ-algebra generated by BM W_t.

At the time of $t \in [0, T]$, let $V(t)$ denote the total additional disposable wealth of the household, and the initial household wealth is assumed to be $V_0 = V(0)$, and π_t and $1 - \pi_t$, respectively, represent the proportion of investment in risky assets and risk-free assets. The differential equation of household wealth investment can be expressed as follows:

$$\begin{aligned} dV_t &= \pi_t V_t\left(\mu\ dt + kS_t^{\beta} dW_t\right) + (1 - \pi_t)V_t r\ dt - C_t dt \\ &= [(\pi_t(\mu - r) + r)V_t - C_t]dt + \pi_t V_t k S_t^{\beta} dW_t. \end{aligned} \tag{3}$$

Let $\Gamma = \{(\pi_t, C_t)\colon 0 \leq t \leq T\}$ be the set of all feasible investment-consumption proportions. For any combination (π_t, C_t), the stochastic differential (3) has a special solution. Theoretically, investors want the ultimate wealth to have the greatest expected effect, namely, $\max_{u_t} E\{U(V_T)\}$, where $U(\cdot)$ is a concave and increasing utility function.

The target expected utility function is as follows:

$$\max_{(\pi_t, C_t) \in \Gamma} E\left[\int_0^T e^{-\delta t} U_1(C_t)\mathrm{d}t + e^{-\delta t} U_2(V_T)\right]. \tag{4}$$

The utility functions $U_1(\cdot)U_2(\cdot)$ are continuously differentiable and strictly concave utility functions on $(-\infty, +\infty)$, and δ is the discount rate. Since $U(\cdot)$ is strictly concave, there is a unique strategy (π_t, C_t) that makes (4) valid.

For a particular feedback function π, the value function can be defined as the Markov property.

Value function is as follows:

$$H(t, s, v) = \sup_{(\pi_t, C_t) \in \Gamma} E\left\{\int_0^T e^{-\delta t} U(C_t)\mathrm{d}t + e^{-\delta t} U_2(V_T) | S_t = s, V_t = v\right\}. \tag{5}$$

Boundary condition is as follows: $H(T,s,v) = e^{-\delta T}U(v)$.

The value function defined by equation (5) is the upper definite bound of the expected utility, so it reaches the optimal value under the stochastic constraint. Let us write $\pi_t = \pi$ and $C_t = c$; according to the dynamic programming principle and Itō's lemma, we obtain the following HJB equation:

$$\begin{aligned} 0 = {} & H_t + (rv - c)H_v + \mu s H_s + \frac{1}{2}k^2 s^{2\beta+2} H_{ss} \\ & + \sup_{(\pi_t, C_t)} \left\{ \frac{1}{2}\pi^2 v^2 k^2 s^{2\beta} H_{vv} + \pi\left[(\mu - r)vH_v + vk^2 s^{2\beta+1} H_{vs}\right] \right\} \\ & + e^{-\delta t}U_1(c). \end{aligned} \tag{6}$$

Boundary condition is as follows: $H(T,s,v) = U(v)$ where $H_t, H_v, H_s, H_{vv}, H_{ss}$, and H_{vs} represent the first-order and second-order partial differentials about time t, wealth v, and stock price s, respectively.

For the optimal strategy π^*, the first-order conditions lead to the following formula:

$$\pi_t^* = -\frac{(\mu - r)H_v + k^2 s^{2\beta+1} H_{vs}}{vk^2 s^{2\beta} H_{vv}}. \tag{7}$$

Similarly, for the optimal consumption strategy c^*, the first-order conditions lead to the following formula:

$$U_1'(c^*) = e^{\delta t} H_v. \tag{8}$$

Equation (7) is substituted into equation (6) of HJB to get the following formula:

$$\begin{aligned} & H_t + \mu s H_s + rv H_v + \frac{1}{2}k^2 s^{2\beta+2} H_{ss} \\ & - \frac{\left[(\mu - r)H_v + k^2 s^{2\beta+1} H_{vs}\right]^2}{2k^2 s^{2\beta} H_{vv}} - cH_v + e^{-\delta t}U_1(c) = 0. \end{aligned} \tag{9}$$

Boundary condition is as follows: $H(T,s,v) = U(v)$.

It can be seen that we turn the stochastic control problem into a problem of solving a nonlinear second-order partial differential equation. If H is solved from (9) and then substituted into equations (7) and (8), the optimal strategy π^* and optimal consumption strategy c^* can be obtained. In the following, we use the specific utility function. Here, we first select the logarithmic utility function and then the power utility function. Closed-form solutions of equation (9) are obtained by guessing solutions and variable separation methods.

3. Optimal Household Investment Strategy Based on Logarithmic Utility Function

The utility function is set as $U_1(x) = U_2(x) = \ln x$; suppose the solution of HJB equation (9) has the following form:

$$H(t,s,v) = m(t)e^{-\delta t} \ln v + n(t,s). \tag{10}$$

Boundary conditions are as follows: $m(T) = 1$ and $n(T,s) = 0$.

For simplicity, $m = m(t)$, $m_t = m'(t)$, $n = n(t,s)$, and $n_t = n'(t,s)$ are written. The first-order and second-order partial differentials of t, s, and v, respectively, are solved, and the solution results are as follows:

$$\begin{aligned} H_t &= m_t e^{-\delta t} \ln v - \delta m e^{-\delta t} \ln v + n_t; \\ H_v &= m e^{-\delta t}\frac{1}{v}, \\ H_s &= n_s; \\ H_{vv} &= -m e^{-\delta t}\frac{1}{v^2}; \\ H_{ss} &= n_{ss}; \\ H_{vs} &= 0. \end{aligned} \tag{11}$$

Because $U(c) = \ln c$, and $U_1'(c) = e^{\delta t}H_v$, with H_v in equation (10), we can get the following equation: $1/c = e^{\delta t}me^{-\delta t}(1/v)$. So, there is equation: $c = (v/m)$.

The expressions of equation (11) and c are substituted into equation (9) to get the following equation:

$$\begin{aligned} & n_t + \mu s n_s + \frac{1}{2}k^2 s^{2\beta+2} n_{ss} + \left[r + \frac{(\mu - r)^2}{2k^2 s^{2\beta}} \right] m e^{-\delta t} \\ & - e^{-\delta t}(\ln m + 1) + e^{-\delta t} \ln v\left(m_t - \delta m + 1\right) = 0. \end{aligned} \tag{12}$$

We divide (12) into the following two equations:

$$\begin{aligned} & m_t - \delta m + 1 = 0; \\ & m(T) = 1, \\ & n_t + \mu s n_s + \frac{1}{2}k^2 s^{2\beta+2} n_{ss} + \left[r + \frac{(\mu - r)^2}{2k^2 s^{2\beta}} \right] m e^{-\delta t} \\ & \quad - e^{-\delta t}(\ln m + 1) = 0, \\ & n(T,s) = 0. \end{aligned} \tag{13}$$

The first-order ordinary differential equation (12) is solved to get the following equation:

$$m(t) = m = \frac{1}{\delta} + \left(1 - \frac{1}{\delta}\right)e^{-\delta(T-t)}. \tag{14}$$

Suppose (13) has a solution of the following form:

$$n(t,s) = A(t) + B(t)y, \quad y = s^{-2\beta}. \tag{15}$$

Boundary conditions are as follows: $A(T) = 0$ and $B(T) = 0$.

For simplicity, $A = A(t)$, $A_t = A'(t)$, $B = B(t)$, and $B_t = B'(t)$ are written. The first and second partial derivatives of t, s, respectively, are solved for (15), and the results are as follows:

$$\begin{aligned} n_t &= A_t + B_t y, \\ n_s &= -2\beta B s^{-2\beta-1}, \\ n_{ss} &= 2\beta(2\beta+1)Bs^{-2\beta-2}. \end{aligned} \tag{16}$$

The above equation is substituted into (13) to get the following equation:

$$\begin{aligned} &y\left[B_t - 2\beta\mu B + \frac{(\mu-r)^2}{2k^2}e^{-\delta t}m\right] + A_t + 2\beta(2\beta+1)k^2B \\ &+ re^{-\delta t} - e^{-\delta t}(\ln m + 1) = 0. \end{aligned} \tag{17}$$

(17) is decomposed into two equations as follows:

$$\begin{aligned} &B_t - 2\beta\mu B + \frac{(\mu-r)^2}{2k^2}e^{-\delta t}m = 0; \\ &B(T) = 0, \\ &A_t + 2\beta(2\beta+1)k^2B + re^{-\delta t} - e^{-\delta t}(\ln m + 1) = 0, \\ &(T) = 0. \end{aligned} \tag{18}$$

(17) is solved to get the following equation:

$$B(t) = \frac{m(\mu-r)^2}{2k^2(\delta+2\mu\beta)}e^{-\delta T}\left[e^{\delta(T-t)} - e^{-2\mu\beta(T-t)}\right]. \tag{19}$$

$B(t)$ is substituted into (18), and it is solved to get the following equation:

$$A(t) = \frac{r - \ln m - 1}{2\beta(2\beta+1)k^2B(t) - \delta}\left[e^{\left[2\beta(2\beta+1)k^2B(t)-\delta\right](T=t)} - e^{-\delta t}\right]. \tag{20}$$

The following conclusion is obtained from the above solution process.

Theorem 1. *If the utility function $U_1(x) = U_2(x) = \ln x$, then the solution of HJB equation (9) has the following form:*

$$H(t,s,v) = \frac{1}{\delta}\left[1 - e^{-\delta(T-t)}\right]e^{-\delta t}\ln v + A(t) + B(t)s^{-2\beta}, \tag{21}$$

where $A(t) = r - \ln(m - 1/2\beta(2\beta+1)k^2B(t) - \delta)$ $[e^{[2\beta(2\beta+1)k^2B(t)-\delta](T=t)} - e^{-\delta t}]$, *and*

$$B(t) = \frac{m(\mu-r)^2}{2k^2(\delta+2\mu\beta)}e^{-\delta T}\left[e^{\delta(T-t)} - e^{-2\mu\beta(T-t)}\right]. \tag{22}$$

Theorem 2. *Under the logarithmic utility function, the optimal investment ratio and optimal consumption ratio in the stocks of risky assets are listed as follows:*

$$\begin{aligned} \pi_t^* &= M(\sigma_t), \\ C_t^* &= \frac{v}{m} = \frac{v}{m(t)}. \end{aligned} \tag{23}$$

$M(\sigma_t) = (\mu - r)/\sigma_t^2$, $\sigma_t = kS_t^\beta$, and $m(t) = (1/\delta) + (1 - (1/\delta))e^{-\delta(T-t)}$ are written.

Proof. From equation (10), we can get the following:

$$\frac{H_v}{H_{vv}} = \frac{me^{-\delta t}(1/v)}{-me^{-\delta t}\left(1/v^2\right)} = -v, \quad \frac{H_{vs}}{H_{vv}} = 0. \tag{24}$$

Substituting the above equation into equations (7) and (8), we can get the optimal investment ratio π_t^* and the optimal consumption ratio C_t^*.

$$\begin{aligned} \pi_t^* &= -\frac{\mu - r}{vk^2s^{2\beta}}\frac{H_v}{H_{vv}} - \frac{s}{v}\frac{H_{vs}}{H_{vv}} \\ &= \frac{\mu - r}{k^2s^{2\beta}} \\ C_t^* &= \frac{v}{m} \\ &= \frac{v}{m(t)}. \end{aligned} \tag{25}$$

□

4. Optimal Household Investment Strategy Based on Equal Elastic Power Utility Function

For the objective function (4), where $U_2(V_T)$ has retention utility, isoelastic power utility function is defined as follows:

$$\begin{aligned} &U(\mathrm{v}) = \phi^\gamma\frac{v^{1-\gamma}}{1-\gamma}, \\ &U(c) = \frac{c^{1-\gamma}}{1-\gamma}, \quad \text{where } \gamma > 0 \text{ also } U(V_T) = \phi^\gamma\frac{V_T^{1-\gamma}}{1-\gamma}, \end{aligned} \tag{26}$$

where $\phi = \phi(v)$ is a weighting adjustment factor for the bequest value function. Its coefficient is the utility function of constant relative risk aversion (CRRA). Now, it is assumed that the solution form of the objective function $H(t,s,v)$ is as follows:

$$H(t,s,v) = e^{-\delta t}g(t,s)\frac{v^{1-\gamma}}{1-\gamma}. \tag{27}$$

Boundary condition is as follows: $g(T,s) = \phi^\gamma$.

For simplicity, $g(t,s) = g$ is written. The first-order and second-order partial differentials of t, s, and v are solved, respectively. The results are as follows:

$$
\begin{aligned}
H_t &= e^{-\delta t} g_t \frac{v^{1-\gamma}}{1-\gamma} - \delta e^{-\delta t} g \frac{v^{1-\gamma}}{1-\gamma};\\
H_v &= g e^{-\delta t} v^{-\gamma};\\
H_s &= e^{-\delta t} g_s \frac{v^{1-\gamma}}{1-\gamma};\\
H_{vv} &= -\gamma e^{-\delta t} g v^{-\gamma-1};\\
H_{ss} &= e^{-\delta t} g_{ss} \frac{v^{1-\gamma}}{1-\gamma};\\
H_{sv} &= e^{-\delta t} g_s v^{-\gamma}.
\end{aligned}
\tag{28}
$$

Because $U(c) = c^{1-\gamma}/(1-\gamma)$ and $U_1'(c) = c^{-\gamma}$, with the equation (8) $U_1'(c) = e^{\delta t} H_v$ and the equation in H_v, we have the equation $e^{\delta t} H_v = e^{\delta t} e^{-\delta t} g v^{-\gamma} = c^{-\gamma}$. So, $c = g^{-(1/\gamma)} v$.

The expressions of (28) and c are substituted into (9) and arranged as follows:

$$
\left\{ g_t - \delta g + \mu s g_s + r(1-\gamma) g + \frac{1}{2} k^2 s^{2\beta+2} g_{ss} + \frac{(1-\gamma)(\mu-r)^2}{2\gamma k^2 s^{2\beta}} g + \frac{k^2 s^{2\beta}(1-\gamma)}{2\gamma} \frac{g_s^2}{g} + \frac{1}{\gamma}(\mu-r)(1-\gamma) s g_s + \gamma g^{(\gamma-1)/\gamma} \right\} \frac{v^{1-\gamma}}{1-\gamma} e^{-\delta t} = 0.
\tag{29}
$$

The dependence on v is removed, and you get the following equation:

$$
\begin{aligned}
& g_t - \delta g + \mu s g_s + r(1-\gamma) g + \frac{1}{2} k^2 s^{2\beta+2} g_{ss}\\
& + \frac{(1-\gamma)(\mu-r)^2}{2\gamma k^2 s^{2\beta}} g + \frac{k^2 s^{2\beta}(1-\gamma)}{2\gamma} \frac{g_s^2}{g}\\
& + \frac{1}{\gamma}(\mu-r)(1-\gamma) s g_s + \gamma g^{(\gamma-1)/\gamma} = 0.
\end{aligned}
\tag{30}
$$

Based on the inspiration of the method in Gao [21], we will use the following power transformation and variable transformation methods.

Let $g(t,s) = h(t,y)$, and $y = s^{-2\beta}$.

For simplicity, $g(t,s) = g$ is written, and the first and second partial derivatives of t and s are solved, respectively. The results are as follows:

$$
\begin{aligned}
g_t &= h_t,\\
g_s &= -2\beta s^{-2\beta-1} h_y,\\
g_{ss} &= 2\beta(2\beta+1) s^{-2\beta-2} h_y + 4\beta^2 s^{-4\beta-2} h_{yy}.
\end{aligned}
\tag{31}
$$

Substituting the expression in equation (31) into (30), the following equation is obtained:

$$
\begin{aligned}
& h_t + [r(1-\gamma) - \delta] h - 2\beta\mu y h_y + \beta(2\beta+1) k^2 h_y + \frac{(\mu-r)^2}{2k^2} \frac{1-\gamma}{\gamma} y h\\
& + 2\beta^2 k^2 y h_{yy} + 2\beta^2 k^2 \frac{1-\gamma}{\gamma} y \frac{h_y^2}{h} - 2\beta(\mu-r) \frac{1-\gamma}{\gamma} y h_y + \gamma h^{1-(1/\gamma)} = 0.
\end{aligned}
\tag{32}
$$

Boundary condition is as follows : $h(T,y) = \phi^\gamma$.

Let $h(t,y) = [f(t,y)]^\gamma$, using the method of variable transformation, and then, $h(T,y) = [f(T,y)]^\gamma = \phi^\gamma$. So, $f(T,y) = \phi$. For simplicity, $f(t,s) = f$ is written. The first and second partial derivatives of t and y are solved, respectively. The results are as follows:

$$
\begin{aligned}
h_t &= \gamma f^{\gamma-1} f_t,\\
h_y &= \gamma f^{\gamma-1} f_y,\\
h_{yy} &= \gamma(\gamma-1) f^{\gamma-2} f_y^2 + \gamma f^{\gamma-1} f_{yy}.
\end{aligned}
\tag{33}
$$

Substituting the expression in equation (33) into equation (32), we get the following equation:

$$\gamma f^{\gamma-1}\left[\begin{array}{l} f_t+\dfrac{r(1-\gamma)-\delta}{\gamma}f-2\beta\mu y f_y+\beta(2\beta+1)k^2 f_y+2\beta^2k^2 y f_{yy} \\ \\ \quad +\dfrac{(\mu-r)^2}{2k^2}\dfrac{1-\gamma}{\gamma^2}yf-2\beta(\mu-r)\dfrac{1-\gamma}{\gamma}yf_y+1 \end{array}\right]=0, \tag{34}$$

which simplifies to the following partial differential equation:

$$\begin{aligned} f_t+\frac{1}{\gamma}[r(1-\gamma)-\delta]f-2\beta\mu y f_y+\beta(2\beta+1)k^2 f_y+2\beta^2k^2 y f_{yy} \\ +\frac{(\mu-r)^2}{2k^2}\frac{1-\gamma}{\gamma^2}yf-2\beta(\mu-r)\frac{1-\gamma}{\gamma}yf_y+1=0. \end{aligned} \tag{35}$$

Boundary condition is as follows: $f(T,y)=\phi$.

Notice that equation (35) has changed into a linear second-order partial differential equation, which is still difficult to deal. Based on the inspiration of the method in Liu [22], we solve the solution of (35).

Theorem 3. *Assume that* $f(t,y)=\int_t^T \overline{f}(u,y)du+\phi\overline{f}(u,y)$ *is a solution to (25), and it can be proved that* $\overline{f}(u,y)$ *satisfies the following equation:*

$$\begin{aligned} &\overline{f}_t+\left[\frac{1}{\gamma}(r(1-\gamma)-\delta)+\frac{(\mu-r)^2}{2k^2}\frac{1-\gamma}{\gamma^2}y\right]\overline{f} \\ &-\left[2\beta\mu+2\beta(\mu-r)\frac{1-\gamma}{\gamma}\right]y\overline{f}+\beta(2\beta+1)k^2\overline{f}_y \\ &+2\beta^2k^2y\overline{f}_{yy}=0. \end{aligned} \tag{36}$$

Boundary condition is as follows: $\overline{f}(t,y)=1$.

Proof. The following differential operator is defined:

$$\begin{aligned} \nabla f(t,y)&=2\beta^2k^2y\overline{f}_{yy}+\beta(2\beta+1)k^2\overline{f}_y \\ &+\left[\frac{1}{\gamma}(r(1-\gamma)-\delta)+\frac{(\mu-r)^2}{2k^2}\frac{1-\gamma}{\gamma^2}y\right]\overline{f} \\ &-\left[2\beta\mu+2\beta(\mu-r)\frac{1-\gamma}{\gamma}\right]y\overline{f}_y. \end{aligned} \tag{37}$$

Equation (35) can then be rewritten in the form as follows:

$$\begin{aligned} &\frac{\partial f(t,y)}{\partial t}+\nabla f(t,y)+1=0,\quad f(T,y)=\phi \\ &\frac{\partial f(t,y)}{\partial t}=-\overline{f}(t,y)+\phi\frac{\partial\overline{f}(t,y)}{\partial t} \\ &=\left[\int_t^T\frac{\partial\overline{f}(t,y)}{\partial u}du-\overline{f}(T,y)\right]+\phi\frac{\partial\overline{f}(t,y)}{\partial t}. \end{aligned} \tag{38}$$

The operator of equation (26) is obtained as follows:

$$\nabla f(t,y)=\int_t^T\nabla\overline{f}(u,y)\mathrm{d}u+\phi\nabla\overline{f}(t,y). \tag{39}$$

(30) and (31) are substituted into equation (29) to obtain the following equation:

$$\left[\int_t^T\left(\frac{\partial\overline{f}(t,y)}{\partial u}+\nabla\overline{f}(u,y)\right)\mathrm{d}u\right]+\phi\left[\frac{\partial\overline{f}(t,y)}{\partial t}+\nabla\overline{f}(u,y)\right]-\overline{f}(T,y)+1=0. \tag{40}$$

Since $\overline{f}(T,y)=1$, the above equation can be written in the following form:

$$\frac{\partial\overline{f}(t,y)}{\partial t}+\nabla\overline{f}(u,y)=0,\quad \overline{f}(T,y)=1. \tag{41}$$

Theorem 3 is proved. For equation (27), the form of the guessing solution is as follows:

$$\overline{f}(t,y)=e^{A(t)+B(t)y},\quad A(T)=0,\ B(T)=0. \tag{42}$$

(42) is substituted into (36), and the following equation is obtained:

$$y\left[B_t+2\beta^2k^2B^2-\left(2\beta\mu+2\beta(\mu-r)\frac{1-\gamma}{\gamma}\right)B+\frac{(\mu-r)^2(1-\gamma)}{2k^2\gamma^2}\right]+A_t+\beta(2\beta+1)k^2B+\frac{1}{\gamma}(r(1-\gamma)-\delta)=0. \tag{43}$$

To eliminate the dependence on y, (43) is decomposed into two equations as follows:

$$B_t+2\beta^2k^2B^2-\left(2\beta\mu+2\beta(\mu-r)\frac{1-\gamma}{\gamma}\right)B+\frac{(\mu-r)^2(1-\gamma)}{2k^2\gamma^2}=0,\quad B(T)=0,$$
$$A_t+\beta(2\beta+1)k^2B+\frac{1}{\gamma}(r(1-\gamma)-\delta)=0,\quad A(T)=0. \tag{44}$$

The method of solving equations (35) and (36) is the same as that of Gao [22]. First, (35) is solved. The process is as follows.

$a=2\beta^2$, $b=2\beta[\mu+(\mu-r)1-\gamma/\gamma]$, and $c=-((\mu-r)^2(1-\gamma)/2\gamma^2)$ are set. Then, equation (35) can be changed into the following form:

$$\frac{\mathrm{d}B(t)}{\mathrm{d}t}=ak^2B^2(t)+bB(t)+\frac{c}{k^2},\quad B(T)=0. \tag{45}$$

Both sides of (45) are integrated with respect to t to get the following equation:

$$\frac{1}{ak^2(m_1-m_2)}\int\frac{1}{B(t)-m_1}-\frac{1}{B(t)-m_2}\mathrm{d}B(t)=t+c_1, \tag{46}$$

where c_1 is a constant and m_1 and m_2 are the solutions of the quadratic equation.

$$ak^2m^2+bm+\frac{c}{k^2}=0, \tag{47}$$

where $m_{1,2}=[\gamma\mu+(\mu-r)(1-\gamma)]\pm(\sqrt{[\gamma\mu+(\mu-r)(1-\gamma)]^2-(\mu-r)^2(1-\gamma)}/2\beta\gamma k^2)$.

Considering the boundary condition $B(T)=0$, the solution of (45) is as follows:

$$B(t)=\frac{m_1-m_1e^{ak^2(m_1-m_2)(t-T)}}{1-m_1/m_2e^{ak^2(m_1-m_2)(t-T)}}. \tag{48}$$

$\lambda_{1,2}=[\gamma\mu+(\mu-r)(1-\gamma)]\pm(\sqrt{[\gamma\mu+(\mu-r)(1-\gamma)]^2-(\mu-r)^2(1-\gamma)}/2\beta\gamma)$ is defined.

Then, (48) can be rewritten, so the solution of equation (35) is listed as follows:

$$B(t)=k^{-2}I(t), \tag{49}$$

where $I(t)=\lambda_1\lambda_2(1-e^{2\beta^2(\lambda_1-\lambda_2)(T-t)})/(\lambda_2-\lambda_1 e^{2\beta^2(\lambda_1-\lambda_2)(T-t)})$.

(44) is solved, which can be obtained directly from (44).

$$dA(t)=-\left[\beta(2\beta+1)I(t)+\frac{r(1-\gamma)-\delta}{\gamma}\right]dt. \tag{50}$$

Both sides of $I(t)$ are differentiated to get the following equation:

$$\int I(t)\mathrm{d}t=\lambda_1t+\frac{1}{2\beta^2}\ln\left(\lambda_2-\lambda_1e^{2\beta^2(\lambda_1-\lambda_2)(T-t)}\right)+c_2. \tag{51}$$

On differentiating both sides of (51), the solution of (44) can be obtained from (42) and the boundary condition $A(T)=0$ as follows:

$$A(t)=\left[\lambda_1\beta(2\beta+1)k^2+\frac{1}{\gamma}(r(1-\gamma)-\delta)\right](T-t)+\frac{2\beta+1}{2\beta}\ln\left(\frac{\lambda_2-\lambda_1}{\lambda_2-\lambda_1e^{2\beta^2(\lambda_1-\lambda_2)(T-t)}}\right). \tag{52}$$

□

Theorem 4. *If the utility function is $u(v)=\phi^\gamma(v^{1-\gamma}/1-\gamma)$, $v(c)=(c^{1-\gamma}/1-\gamma)$, $\gamma>0,\gamma\neq1$, then the optimal investment and consumption strategy of problem (5) are listed as follows:*

$$\pi_t^*=\frac{\mu-r}{\gamma k^2s^{2\beta}}-\frac{2\beta}{s^{2\beta}}\frac{f_y}{f},$$
$$c_t^*=\frac{v}{f}, \tag{53}$$

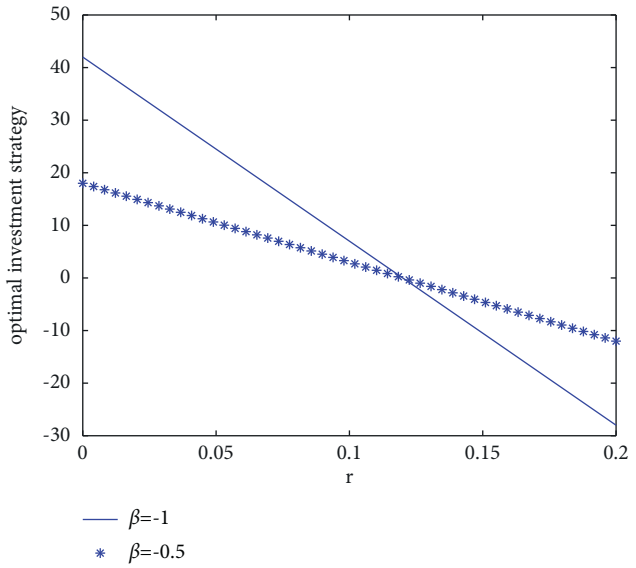

Figure 1: Effect of r on optimal investment ratio π_t^*.

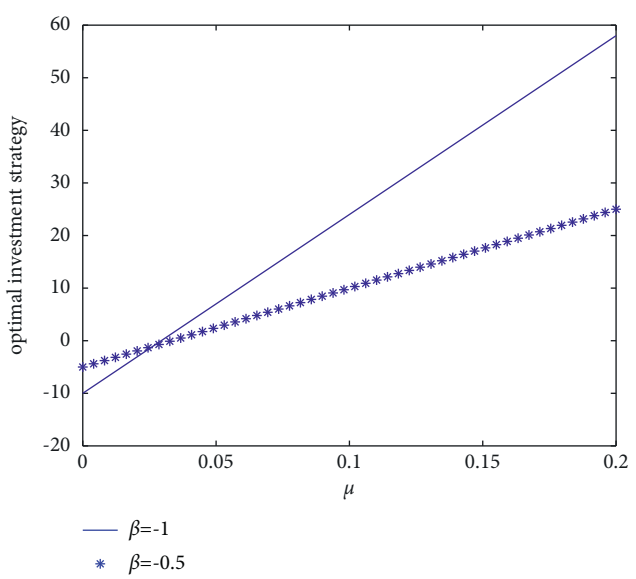

Figure 2: Influence of μ on optimal investment ratio π_t^*.

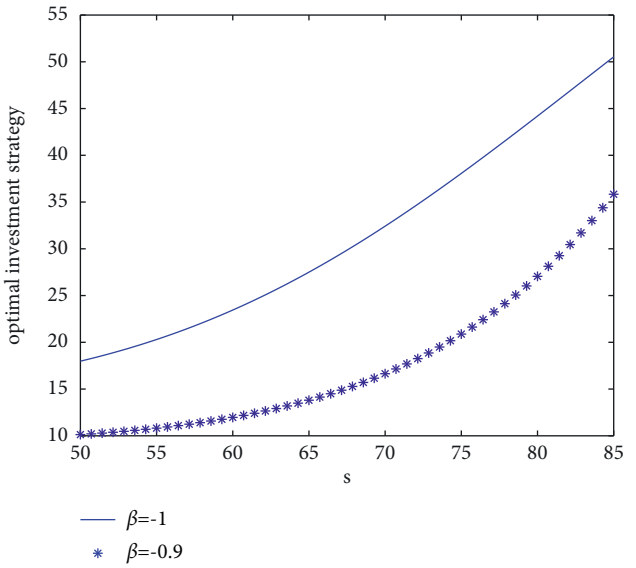

Figure 3: Influence of S on optimal investment ratio π_t^*.

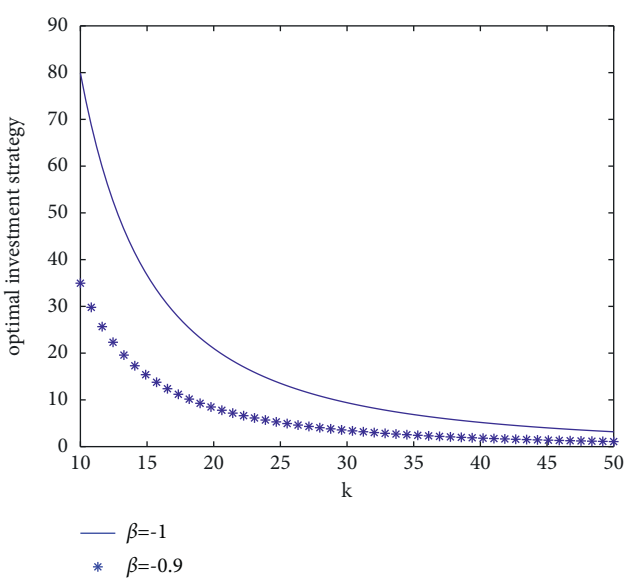

Figure 4: Influence of k on optimal investment ratio π_t^*.

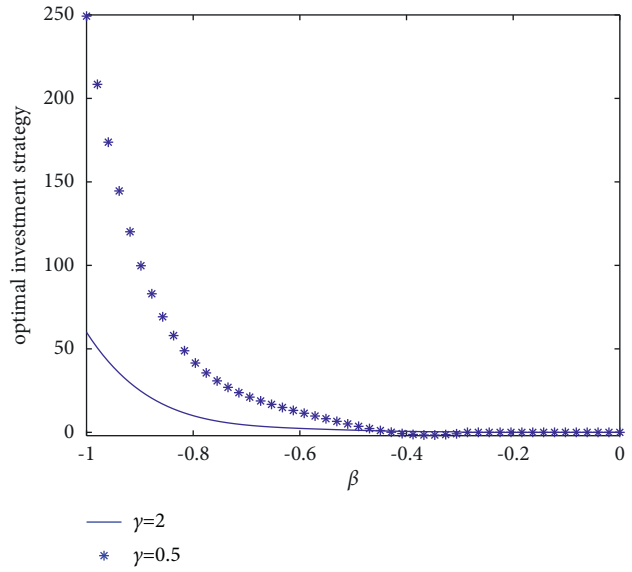

Figure 5: Influence of β on optimal investment ratio π_t^*.

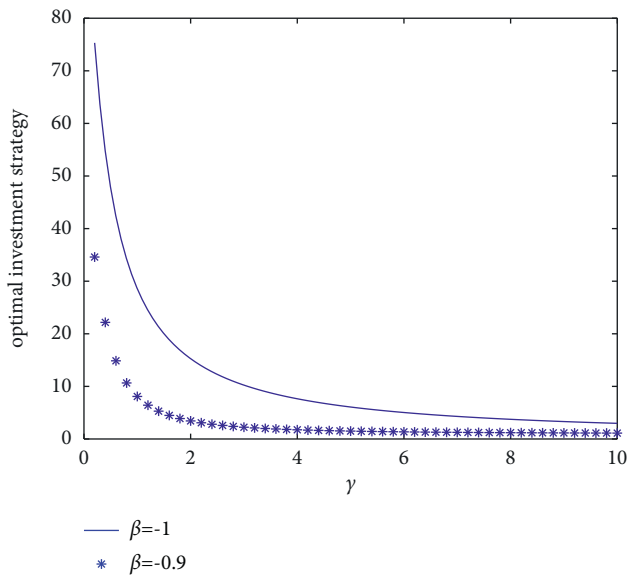

Figure 6: Influence of γ on optimal investment ratio π_t^*.

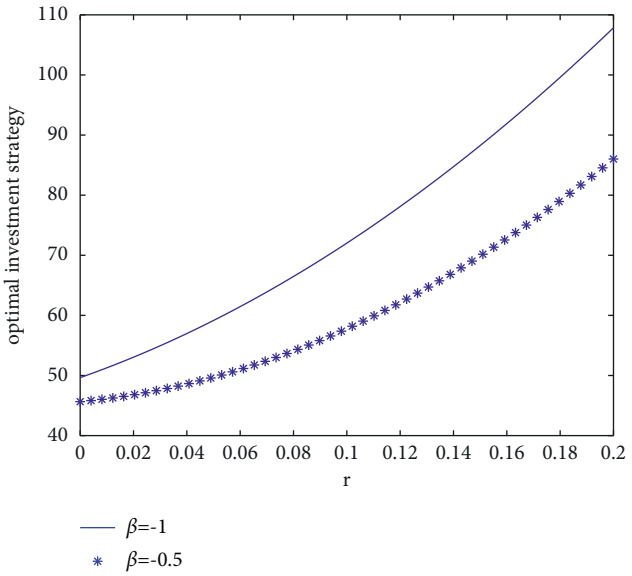

Figure 7: Influence of r on optimal consumption ratio C_t^*.

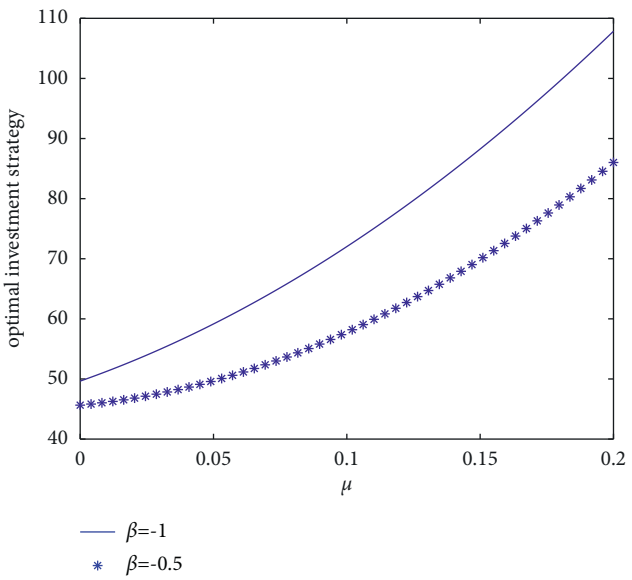

Figure 8: Influence of μ on optimal consumption ratio C_t^*.

where $f = f(t,y) = \int_t^T e^{A(u)+B(u)y}du + \phi e^{A(t)+B(t)y}$, *and* $y = s^{-2\beta}$, $A(t)$ *and* $B(t)$ *are given by equations (49) and (52).*

Proof. Following equations can be obtained from equation (7):

$$\begin{aligned}\pi_t^* &= -\frac{\mu - r}{\nu k^2 s^{2\beta}}\frac{H_\nu}{H_{\nu\nu}} - \frac{s}{\nu}\frac{H_{\nu s}}{H_{\nu\nu}}\\ &= \frac{\mu - r}{\gamma k^2 s^{2\beta}} - \frac{s g_s}{\gamma g} \text{ (According to Equation (20))}\\ &= \frac{\mu - r}{\gamma k^2 s^{2\beta}} - \frac{2\beta s^{-2\beta} h_y}{\gamma h} \text{ (According to Equation (22))}\\ &= \frac{\mu - r}{\gamma k^2 s^{2\beta}} - \frac{2\beta}{\gamma s^{2\beta}}\frac{\gamma f^{\gamma-1} f_y}{f^\gamma} \text{ (According to Equation (24))}\\ &= \frac{\mu - r}{\gamma k^2 s^{2\beta}} - \frac{2\beta}{s^{2\beta}}\frac{f_y}{f}.\end{aligned} \tag{54}$$

Because $U(c) = c^{1-\gamma}/(1-\gamma)$ and $U_1'(c) = c^{-\gamma}$, according to (8): $U_1'(c) = e^{\delta t}H_\nu$ and the equation in H_ν, we have the equation $e^{\delta t}H_\nu = e^{\delta t}e^{-\delta t}g\nu^{-\gamma} = c^{-\gamma}$. Therefore, $c = g^{-1/\gamma}\nu$. Then, by $g = h(t,y)$ and $h(t,y) = [f(t,y)]^{1/\gamma}$, the optimal ratio is obtained as follows:

$$c_t^* = \frac{\nu}{f}. \tag{55}$$

So far, Theorem 4 is proved.

Special cases are discussed as follows.

(1) When $\gamma \longrightarrow 1$, the optimal investment and consumption problem (5) of the optimal strategy are as follows:

$$\pi_t^* = \frac{\mu - r}{k^2 s^{2\beta}}, \tag{56}$$

$$\begin{aligned}c_t^* &= \frac{\nu}{f}\\ &= \frac{\nu}{\phi e^{-\delta(T-t)} + \left(1/\delta\left(1 - e^{-\delta(T-t)}\right)\right)}.\end{aligned} \tag{57}$$

It shows that when $\phi = 1$, $U_1(x) = U_2(x)$ is power utility function, and $\gamma \longrightarrow 1$ power utility function degenerates into an exponential utility function. We know from (56) and (57) that the result is exactly the optimal ratio under the exponential utility function.

(2) If $\beta \longrightarrow 0$, the CEV model degenerates to GBM model.

Equations (35) and (36) are simplified as follows:

$$B_t + \frac{(\mu - r)^2(1-\gamma)}{2k^2\gamma^2} = 0, \quad B(T) = 0, \tag{58}$$

$$A_t + \frac{1}{\gamma}(r(1-\gamma) - \delta) = 0, \quad A(T) = 0. \tag{59}$$

(58) and (59), respectively, are solved to get the following results:

$$\begin{aligned}A(t) &= \frac{r(1-\gamma) - \delta}{\gamma}(T - t),\\ B(t) &= \frac{(\mu - r)^2(1-\gamma)}{2\gamma^2 k^2}(T - t).\end{aligned} \tag{60}$$

Assume $D = ((\mu - r)^2(1-\gamma)/2\gamma^2k^2) + r(1-\gamma) - \delta/\gamma$. Then,

$$f(t,y) = f(t) = \frac{1}{D}\left(e^{D(T-t)} - 1\right) + \phi e^{D(T-t)}. \tag{61}$$

It can be known from (61) that $f_y/f = 0$, and then, (44) and (45) degenerate into $\pi_t^* = \mu - r/\gamma k^2$ and $c_t^* = \nu/f$, where f is given by equation (50).

It shows that if the CEV model degenerates into the GBM model, the optimal investment ratio is only affected by the risk aversion coefficient.

(3) When $\phi = 0$, it means there is no retention utility. Assuming that the general form of the residual function is $B(V(T),T) = G(T)\ (V(T))^{1-\gamma}/\ (1-\gamma)$, in this study $G(t) = \phi^\gamma$.So, when there is no bequest, there is $B(V(T),T) = 0 \Leftrightarrow \phi = 0$.

When $\phi = 1$, $B(V(t),t) = (V(t))^{1-\gamma}/(1-\gamma)$; that is, it is the ordinary power utility function. In this case, (44) and (45) are the optimal investment-consumption ratio under the general power utility function. □

5. The Numerical Simulation Analysis

Suppose there are two forms of assets in the financial market. One is bank deposits or bonds, and the other is stocks. Referring to the estimation of Hong Kong stock option market by Yuen et al. [24], the parameter values are set as follows: $r = 0.03$, $\mu = 0.12$, $k = 16.16$, $\beta = -1$, and $S_0 = 67$. With reference to Chang et al. [15], $\delta = 0.1$, $\gamma = 3$ ($\gamma = 5$), and $V_0 = 100$ are set. Without loss of generality, let $\phi = 1$, $t \in [0,T]$, and $T = 5$.

(1) From Figure 1, we can see the influence of risk-free interest rate r on the optimal ratio π_t^*. As can be seen from Figure 1, the optimal ratio π_t^* is negatively correlated with the risk-free interest rate r; that is, when the deposit interest rate rises, investors are more willing to deposit or buy bonds and reduce the proportion of buying stocks. This phenomenon echoes the intuition.

(2) From Figure 2, we can see the effect of the expected instantaneous rate μ of return of a risky asset on the optimal ratio π_t^*. The optimal investment strategy π_t^* is positively correlated with the expected instantaneous rate μ. That is, when stocks have a high yield, people are always willing to put more money into stocks in order to get more yield.

(3) From Figure 3, we can see the influence of stock price S on the optimal investment ratio π_t^*. As can be seen from Figure 3, π_t^* is positively correlated with the price S of risky assets. Under the CEV model, when the stock price increases, the instantaneous volatility of the stock price ks_t^β becomes smaller, and the investment risk accordingly decreases. Household investors are more likely to invest in stocks with high returns and relatively low risk in order to earn more wealth.

(4) From Figure 4, we can see the influence of k on the optimal investment ratio π_t^*. As can be seen from Figure 4, the optimal investment strategy π_t^* is negatively correlated with k. Under the CEV model, the higher the value of k, the higher the instantaneous volatility ks_t^β of the stock price will be, and the higher the investment risk will be. As a result, investors will reduce their exposure to stocks.

(5) From Figure 5, we can see the influence of β on the optimal ratio π_t^*. As can be seen from Figure 5, the optimal investment ratio π_t^* is negatively correlated with the constant elasticity coefficient β. Under the CEV model, generally $\beta < 0$, when the constant elastic coefficient β increases slightly, the instantaneous volatility ks_t^β of the stock price becomes larger and larger, which leads to higher investment risks. We can also draw the conclusion that the amount of assets that household investors invest in stocks under the CEV model is more than that under the GBM model.

(6) From Figure 6, we can see the influence of the risk aversion coefficient γ on π_t^*. Figure 6 also shows that the optimal ratio π_t^* is negatively correlated with the risk aversion coefficient γ. In fact, under the power utility function, the greater the risk aversion coefficient γ is, the more risk aversion household investors will have, so they are unwilling to invest more in stocks with high risks. This situation is consistent with the reality.

(7) Figure 7 shows the effect of risk-free interest rate r on C_t^*. As can be seen from Figure 7, optimal consumption C_t^* is positively correlated with risk-free interest rate r. In other words, when the deposit interest rate rises, investors are more willing to deposit or buy bonds and less to buy stocks, but the overall expectation of wealth increases, so investors are willing to spend more.

(7) Figure 8 shows the effect of the expected instantaneous rate μ on C_t^*. Intuitively, there is a positive correlation between optimal consumption and μ. That is, when the return rate of stocks is high, the share of wealth invested in stocks will increase, so will the overall expected return, and people will increase consumption. This phenomenon is verified by Figure 8.

As for the factors that affect the consumption strategy, we draw a conclusion that all the factors that can cause the increase in the total expected income can cause the increase in consumption.

6. Summary

The research of this study makes rational investment of household wealth to achieve the maximization of investment-consumption utility. We assume that there are two types of assets in the household financial market, namely, risk-free assets and risky assets, in which it is assumed that the price of risky assets obeys the CEV model. Firstly, we obtain the HJB equation by dynamic programming method. Secondly, we select specific utility functions, such as logarithmic utility function and power utility function, and apply variable transformation method to obtain the display solution, that is, optimal ratio. Finally, the effects of market general parameters on optimal ratio are analyzed by numerical simulation and graphical results, and the results are consistent with the actual situation. In further research, we will consider more factors, such as transaction costs and borrowing.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Cost Accounting Algorithm of Environmental Pollution Control Based on Discrete Probability

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Aiming at the problems of high error rate and long time of traditional environmental pollution control cost accounting algorithm, a cost accounting algorithm of environmental pollution control based on discrete probability was designed. Firstly, the cost of environmental pollution is classified and the monetization function of environmental pollution cost is constructed. Then, the cost accounting index system of environmental pollution control is established, and the cost function of environmental pollution control is constructed. Finally, a discrete probability model is used to optimize the cost function, and the optimized cost function is used to design the environmental pollution control cost accounting algorithm. The experimental results show that the proposed algorithm can quickly converge to the optimum within 70 iterations, the accounting error rate is between -0.2% and 1.3%, and the accounting time is always less than 0.4 s. It has good convergence and can accurately calculate the cost of ecological environmental pollution control.

1. Introduction

Since the 1960s, the change of the natural environment has gradually posed a more and more serious threat to human survival. Among the environmental problems, environmental pollution is the most concerned and has the greatest impact on people's daily life [1]. Since the 1970s, economists have focused their research vision on the field of environmental pollution in environmental problems, creating a new direction of research, namely, the cost of environmental pollution control [2, 3]. Environmental treatment cost refers to the operation cost of environmental pollution control, including depreciation cost of fixed assets, maintenance cost, labor cost, electricity cost, and consumption of various materials in the process of treatment. But so far, there is no perfect method for the cost accounting of environmental pollution control, so the research on the calculation algorithm of environmental pollution control cost has been studied great concern.

In [4], a cost accounting algorithm for environmental pollution control based on activity-based costing method was proposed by analyzing the composition of treatment cost. According to the actual needs of the algorithm, through the establishment of resource cost database, activity-based cost database, and cost driver evaluation and allocation, the algorithm process of environmental pollution control cost accounting is designed, and the management cost allocation model is further proposed, in order to provide the basis for the cost management of environmental pollution control. However, the design of the algorithm is too simple and the factors considered are less, which lead to the increase of the error rate of environmental pollution control cost accounting, and the actual application effect is poor. In [5], in order to improve the scientificity, rationality, and practicability of the cost accounting process of environmental pollution control, a multiattribute analysis-based cost accounting algorithm for environmental pollution control was proposed. Firstly, the algorithm makes multiattribute analysis on the environmental pollution control projects and indirect cost objects and then designs the cost accounting algorithm of environmental pollution control by combining qualitative and quantitative methods according to the actual situation and historical data. Through the coordinated control of multiattribute and weight, the accurate

accounting of environmental pollution control cost can be realized. However, the method is too complex and has a kernel and the calculation time is long. In [6], in order to quickly and accurately obtain the best scheme for environmental pollution control, a cost accounting algorithm for environmental pollution control based on BP neural network was designed. This method takes the efficiency and quality of pollution treatment as constraints, constructs the cost of environmental pollution control as the objective function, and designs the cost accounting algorithm of pollution control by combining multiple linear regression and BP neural network according to the results of the objective function. However, this method has many problems such as long calculation time and high error rate, so the practical application effect is not good.

In order to solve the problems of the above algorithm, this paper designs an environmental pollution control cost accounting algorithm based on discrete probability, in order to improve the efficiency of environmental pollution control cost accounting and reduce the accounting error. The specific research ideas of this paper are as follows.

Firstly, the connotation and classification of environmental pollution cost are clarified, and the monetization function of environmental pollution cost is constructed.

Secondly, the cost accounting index system of environmental pollution control is established and the cost function of environmental pollution control is constructed.

Then, the cost function is optimized by the discrete probability model, and the optimized cost function is used to design the environmental pollution control cost accounting algorithm.

Finally, the convergence, accounting error rate, and calculation time of the environmental pollution control cost accounting algorithm are used as experimental indicators to verify the experimental results.

2. Design of Cost Accounting Algorithm for Environmental Pollution Control

2.1. Connotation and Classification of Environmental Pollution Cost

2.1.1. Connotation of Environmental Pollution Cost. The cost of environmental pollution refers to the cost loss caused by the reduction of the value of the environment due to unreasonable human activities. Generally, the cost of environmental pollution can be divided into environmental recession cost and environmental prevention and control expenditure cost. The cost of environmental degradation mainly refers to the loss cost caused by the decline of the quality and value of environmental resources caused by unreasonable human activities, and the expenditure cost of environmental prevention and control refers to the expenditure spent to enhance the quality value of declined environmental resources [7].

2.1.2. Cost Classification of Environmental Pollution

(1) Classification according to different production links is as follows:

The cost of environmental pollution can be divided into preparation stage, production stage, and maintenance stage. The cost of environmental pollution in preparation stage refers to the cost of avoiding environmental pollution before production [8]. Specifically, it includes the installation and commissioning of environmental protection facilities, the publicity and education of environmental protection concept, the measurement of geographical and geomorphic environment in surrounding areas, etc. The cost of environmental pollution in the production stage refers to the cost of environmental loss in the production process; for example, a large amount of sewage and waste will be discharged in the production process, which belongs to the environmental pollution cost in the process of maintenance after the completion of the production process and the expenditure for environmental protection work; that is, the pollution department or enterprise will repurify the waste gas and sewage generated by itself, so the cost generated belongs to the category of recycling cost [9].

(2) Classification by expenditure purpose is as follows:

Environmental pollution cost can be divided into energy conservation and emission reduction cost, protection cost, technology research cost, public activity cost, and other environmental protection expenditures according to different expenditure purposes. The cost of energy conservation and emission reduction refers to the expenditure for saving energy and reducing pollutant emissions in production, such as the introduction of environmental protection industrial equipment and production lines and the operating costs of various green systems. The protection cost refers to the protection expenses invested to prevent environmental pollution in the whole development process, such as the purchase of environmental protection facilities and the publicity of environmental protection ideas. The cost of technology research mainly refers to the cost of strengthening environmental protection, such as the cost of improving the technological process and the research and development of environmental protection technology [10]. The cost of public activities refers to the cost of social environmental protection activities taken for social public welfare, such as the sponsorship provided for the activities of some environmental protection organizations, which belong to the public welfare expenditure cost. Other environmental protection expenditures refer to the cost consumption of environmental protection nature in addition to the costs listed above. This includes various fines and environmental taxes collected and paid by government agencies for environmental pollution enterprises.

(3) Classification according to the length of amortization time is as follows:

The cost of environmental pollution is divided into long-term environmental pollution cost and short-term environmental pollution cost according to the length of amortization time. The long-term environmental pollution cost refers to the various expenses that need to be paid continuously for the prevention and control of environmental pollution in a relatively long period of time, such as the various sewage charges paid to the environmental protection department on a regular basis. The short-term environmental pollution cost expenditure refers to the expenses that need to be paid at one time in order to prevent and control environmental pollution at a certain time point, such as the need for coal mining enterprises to obtain coal mining rights, the cost of one-time expenditure, and the expenditure of establishing sewage treatment plant [11].

2.2. Construction of Environmental Pollutant Cost Monetization Function. Generally, the cost calculation procedure of environmental pollutants is complicated. The procedure of cost calculation should be strictly selected from the selection of initial calculation items, the establishment of calculation method, and currency conversion. Generally speaking, the general steps of environmental pollutant cost monetization function can be divided into the following three steps:

(1) Determine the impact factors and calculate the project:

Determining the influencing factors and calculation items of environmental pollutant cost is the premise of environmental pollutant cost monetization. Only when the impact factors and calculation items are clearly understood can we grasp the key points and have a definite target [12]. There are many kinds of environmental problems in various regions, but the environmental pollution problems in specific areas have their own priorities, which cannot be copied. Therefore, the calculation of the cost of environmental pollutants should grasp the main characteristics according to their respective economic and social characteristics and environmental problems. It is not necessary to calculate everything; otherwise, the work will be twice as good as half.

(2) Establish the reaction relationship between environmental pollution and physical loss and calculate the loss:

After defining the impact factors and calculating the project, the specific loss can be measured according to the environmental pollution status. The state of environmental pollution can be expressed by the concentration of environmental pollutants or other indicators. Therefore, it is important to establish the reaction relationship between the concentration of environmental pollutants and other expressed quantities and physical loss [13]. According to the main ways of environmental pollution affecting physical objects, it can be summarized into three types of paths: chain path, that is, the destruction of certain environmental pollution on the physical impact can be transmitted according to the chain of causality; the fan path, that is, a certain environmental pollution hazard can cause multiple negative effects in a fan-shaped manner; the network path, that is, all kinds of environmental damage can cause comprehensive effects in the form of network. It is helpful to construct the cost loss response relationship by defining the impact form of environmental hazards. From the perspective of the whole influence path, the chain path shows the connection relationship, the fan path shows the combination relationship, and the network influence shows the cross relationship [14]. The functional relationship between the state of environmental damage and various physical hazards can be expressed by the following formula:

$$F_{ij} = \left(D_i, S_i, T_j, \partial_{ij}\right). \tag{1}$$

In the above formula, F_{ij} represents the loss of j-th category physical object caused by i-th category environmental damage, D_i represents the magnitude under i-th category environmental pollution, S_i represents the class i environmental standard, T_j represents the magnitude under j-th category physical condition, and ∂_{ij} represents the calculation parameter of j-th category physical loss caused by i-th category environmental pollution.

In this exposure response function, D_i, S_i, and T_j are known quantities, while parameter ∂_{ij} is unknown. The value of ∂_{ij} is mainly determined by three factors. Firstly, ∂_{ij} depends on the separability of environmental pollution factors, such as the emission of sulfur dioxide gas in the air, which increases the incidence rate of human respiratory diseases. The loss and harm caused by sulfur dioxide can be separated from the environmental impact of human health. Secondly, ∂_{ij} depends on the testability after separation from the state of environmental damage. The more measurable ∂_{ij} is, the more specific and easier it is to calculate. Otherwise, ∂_{ij} is fuzzy. Thirdly, ∂_{ij} depends on the function type of environmental pollution exposure response relationship. If a function is expressed in terms of power function, exponential function, and linear type, then their ∂_{ij} values and meanings are different.

To sum up, in order to construct the reaction relationship of environmental pollutants, it is necessary to separate the influencing factors of environmental pollution and have measurability, so as to accurately calculate and process them through the reaction relationship of environmental pollutants [15].

(3) Constructing monetization function:

When the loss of physical quantity is calculated and processed, the loss is converted into monetary loss

according to relevant regulations. As the loss of physical quantity often involves multiple value losses, the process of converting the loss of physical quantity into monetary loss is more complicated. For example, air pollution will not only cause the loss of human health but also cause the loss of crop yield and quality and also cause serious loss of forest damage [16–20]. In addition, some environmental pollution will not only cause losses to human society but also damage the natural environment. The impact path of these losses of physical quantity is different: some belong to direct influence, some belong to indirect influence, some belong to selection value, and some belong to existence value, so their monetization path is also different. In a general sense, the monetization function of the loss of physical quantity into monetary loss can be expressed by the following formula:

$$M_{jk} = \left(F_{ij}, P_{jk}\right). \tag{2}$$

In the above formula, M_{jk} represents the quasi monetization loss caused by the loss of physical quantity of the j-th category, and P_{jk} represents the price of the k-th type of monetary loss caused by the j-th type of physical quantity loss.

Through this monetization function, we can express the characteristics of multiple value losses of the same kind of physical quantity loss. In formula (2), how to establish price P_{jk} under market conditions becomes the primary task. In ecological economics and environmental economics, direct loss can be calculated directly by market price, indirect loss can be calculated indirectly by shadow price or alternative price, and some existence loss can be calculated according to willingness to pay price. From the initial market price method to the final price method of willingness to pay, the influence of objective factors on price P_{jk} gradually decreases, while the degree of subjective factors gradually increases. Therefore, the rationality of price P_{jk} in monetization function mainly depends on the rationality of subjective will. In the process of monetization of physical loss, different measurement methods often lead to different errors. In general, the debate on the error caused by the market price method is relatively small, but the dispute caused by the alternative price method and shadow price method is larger. According to the price method of willingness to pay, the debate is the most intense, mainly because the price method of willingness to pay is most affected by subjective factors [21–24]. Therefore, in order to accurately calculate the monetary value of physical loss, it is the most important to select the appropriate environmental pollutant cost monetization function.

2.3. Design of Environmental Pollution Control Cost Accounting Algorithm Based on Discrete Probability. According to the above analysis, in order to reflect the corresponding relationship between resources and environment changes and governance costs, the cost accounting index system is established. The results are shown in Table 1.

2.3.1. Cost of Pollution Control. The cost of pollution prevention and control refers to the cost of purchasing and installing environmental protection equipment and the follow-up maintenance cost of the equipment due to the pollutant emission limit policy formulated by the national environmental protection department. The installed environmental protection equipment mainly includes dust removal equipment, desulfurization equipment, denitration equipment, wastewater treatment system, etc. [25–28]. The calculation formula of pollution control cost is as follows:

$$C_d = C_f + C_r. \tag{3}$$

In the above formula, C_d is the cost of pollution prevention and control, C_f is the purchase and installation cost of environmental protection equipment, and C_r is the maintenance cost of environmental protection equipment.

(a) Purchase and installation cost of environmental protection equipment:

Equipment purchase and installation cost mainly includes environmental protection equipment installation design cost, environmental protection equipment construction cost, and unforeseen cost, while environmental protection equipment construction cost includes environmental protection equipment purchase cost, equipment civil engineering cost, equipment installation cost, and construction cycle interest [29–31]. The calculation formula for the purchase and installation cost of environmental protection equipment is as follows:

$$C_f = f_0 \cdot H_{CRF}. \tag{4}$$

In the above formula, f_0 is the sum of the purchase and installation amount of environmental protection equipment in the power plant and the interest in the construction period, and H_{CRF} is the fund recovery coefficient. The calculation formula of fund recovery coefficient H_{CRF} is as follows:

$$H_{CRF} = i \times \frac{(1+i)^n}{(1+i)^n - 1}. \tag{5}$$

In the above formula, n is the service life of the equipment, and i is the social discount rate or benchmark rate of return.

(b) Maintenance cost of environmental protection equipment:

After the environmental protection equipment is completed and put into operation, while reducing the emission of various pollutants, there will be certain maintenance costs, and this part of the cost also accounts for a certain proportion. Operation and maintenance costs mainly include [32–34] the cost of raw materials, such as raw materials of the plant, water consumption, fuel consumption, and

Table 1: Cost accounting index system.

Criterion layer		Index layer	
		Physical measurement index	Monetary value accounting indicators
Cost of environmental pollution control	Water pollution	Discharge of water pollutants	Cost of water pollution control
	Air pollution	Emission of air pollutants	Cost of air pollution control
	Solid waste pollution	Discharge of solid waste pollutants	Cost of solid waste pollution control
Cost of pollution control	Purchase cost	Purchase of environmental protection equipment	Purchase cost and installation cost of environmental protection equipment
	Maintenance cost	Maintenance cost of environmental protection equipment	Labor and other costs of environmental protection equipment maintenance

auxiliary power consumption; labor costs, including wages and bonuses paid to operation and maintenance personnel of environmental protection equipment [35–38]; maintenance cost, including the maintenance cost of various environmental protection equipment and the depreciation cost of each environmental protection equipment [39–41]. The maintenance cost of environmental protection equipment can be expressed by the following formula:

$$C_r = \sum_{i=1}^{n} r_i. \tag{6}$$

In the above formula, r_i is the maintenance cost of the i-th environmental protection equipment in the power plant.

2.3.2. Pollution Loss Cost

(a) Air pollutants:

Gas pollutants can be divided into two categories, namely, natural pollutants and man-made pollutants. Pollution is often caused by man-made pollutants, which mainly come from fuel combustion and large-scale industrial and mining enterprises [42].

Particulate matter refers to the atmospheric liquid; solid matter, also known as dust; sulfur oxide, which refers to the general term of sulfur oxides, including sulfur dioxide, sulfur trioxide, sulfur trioxide, and sulfur monoxide; carbon oxides, mainly including carbon dioxide and carbon monoxide; nitrogen oxide, which refers to the general term of nitrogen oxides, including nitrous oxide, nitric oxide, nitrogen dioxide, and nitrogen trioxide.

Hydrocarbon: it is a kind of compound formed by carbon and hydrogen, such as methane, ethane, and other hydrocarbon gases, and other harmful substances, such as heavy metals, fluorine-containing gases, and chlorine gases.

The calculation of emission cost of gaseous pollutants is shown in

$$G_a = \sum_{i=1}^{n} (F_{ei} \cdot G_i). \tag{7}$$

In the above formula, G_a is the emission cost of gas pollutants, F_{ei} is the charging standard of the i-th gas pollutant emission, and G_i is the total emission amount of the i-th gas pollutant.

(b) Solid pollutants:

Solid waste includes industrial solid waste and municipal solid waste. Agricultural solid waste causes relatively small environmental losses, so it is not considered. According to the types of industrial solid waste, it can be divided into seven categories: hazardous waste, coal gangue, tailings, smelting slag, fly ash, slag, and other wastes. Other wastes include industrial waste, sludge, and dust removed during fuel combustion. Coal gangue, tailings, smelting waste slag, fly ash, slag, and other wastes are classified as general industrial solid waste. Urban domestic waste is mainly divided into three categories: household garbage, street cleaning waste, and group waste. Among them, the quantity of domestic waste is the first, and its composition is the most complex, and its composition is affected by time and season. Street cleaning garbage comes from the cleaning of roads, streets, and alleys. Group waste refers to the waste generated in the production and work process of organs, groups, schools, factories, and the tertiary industry. The total cost calculation formula of solid pollutants is as follows:

$$G_e = F_{ei} + G_{ei} + E_{ei}. \tag{8}$$

In the above formula, G_e is the total cost of solid pollutants, F_{ei} is the cost of pollutant treatment, G_{ei} is the cost of treatment and storage of waste, and E_{ei} is the cost of treatment of discharged waste.

The calculation formula of F_{ei} is as follows:

$$F_{ei} = F_{eij} + F_{eik}. \tag{9}$$

In the above formula, F_{eij} represents the virtual treatment cost for the disposal of storage waste, and F_{eik} represents the treatment cost for the disposal of discharged waste.

The calculation formula of G_{ei} is as follows:

$$G_{ei} = g_i \times \left(g_j - g_k\right), \tag{10}$$

In the above formula, g_i is storage, g_j is disposal unit governance cost, and g_k is storage unit governance cost.

The calculation formula of E_{ei} is as follows:

$$E_{ei} = e_k \times e_i. \tag{11}$$

In the above formula, e_k is the amount of waste discharged and e_i is the unit treatment cost of discharged waste.

(c) Water pollution:

At present, about one-third of water pollutants in China come from industry, agriculture, tertiary industry, and residents' life. The wastewater quality and pollutant content of different industries are quite different. Even in the same industry, due to the different products, raw materials and auxiliary materials, process routes, and treatment methods, the wastewater quality is also quite different. Generally speaking, the pollutants in industrial wastewater mainly include organic pollutants such as COD, BOD_5, ammonia nitrogen, cyanide, phenols and petroleum, heavy metals, solid suspended solids, and air pollutants. At present, the five pollutants such as COD, ammonia nitrogen, petroleum, cyanide, and volatile phenol can be directly calculated by statistical data.

The cost of pollutants treatment in industrial wastewater is as follows:

$$R_e = \sum_{e=1}^{5} r_e \times z_e \times k_e, \tag{12}$$

where r_e represents the emissions of heavy metals, cyanide, COD, petroleum, and ammonia nitrogen in industrial wastewater, z_e represents the treatment cost of five pollutants in industrial wastewater, and k_e represents the pollutant removal rate in industrial wastewater.

The calculation formula of urban domestic wastewater treatment cost is as follows:

$$Q_e = \sum_{e=1}^{2} A_e \times B_e \times C_e. \tag{13}$$

In the above formula, A_e represents the discharge amount of COD and ammonia nitrogen in urban domestic wastewater, B_e represents the treatment cost of COD and ammonia nitrogen in urban domestic wastewater, and C_e represents the removal rate of COD and ammonia nitrogen pollutants in urban domestic wastewater.

The calculation formula of treatment cost of livestock and poultry wastewater is as follows:

$$F_e = w_i \times \left(w_e - w_k\right) + h_i \times \left(h_e - h_k\right), \tag{14}$$

In the above formula, w_i represents the ideal removal amount of livestock and poultry breeding wastewater after dry process application, w_k represents the actual removal amount of livestock and poultry breeding wastewater after dry process application, w_e represents the cost of dry treatment of livestock and poultry breeding wastewater, h_i represents the ideal removal amount of livestock and poultry breeding wastewater after wet application, h_e represents the actual removal amount of livestock and poultry breeding wastewater after wet process application, and h_k represents the wet treatment cost of livestock and poultry breeding wastewater.

On this basis, the total physical quantity of environmental pollution is calculated, and the calculation formula is as follows:

$$C_W = \sum_{i=1}^{I} T_i \times C_A. \tag{15}$$

In the above formula, i is the amount of pollutants produced, I is the amount of pollutants removed, T_i is the amount of pollutants discharged, and C_A is the unit actual treatment cost of the fifth pollutant.

It is not difficult to see from the above cost accounting index system that the cost function is an important node to calculate the cost of pollutant treatment. Mathematical model is a new subject developed in recent years, which is a science combining mathematical theory with practical problems. It sums up the practical problems into corresponding mathematical problems and makes in-depth analysis and research on the basis of mathematical concepts, methods, and theories, so as to describe the actual problems from the qualitative or quantitative perspective and provide accurate numbers for solving practical problems according to reliable guidance. Discrete probability model is also a complex advanced multivariate statistical analysis technique for dealing with discrete, nonlinear qualitative data. In order to optimize the cost function, we need to use the discrete probability model to optimize two main statistical datasets: one is the total environmental loads (EL) data of the governance cycle, and the other is the average unit environmental cost (UEC) of the governance cycle. EL can be obtained from inventory analysis (IA) of UEC. The specific calculation formula of unit cost UEC_i of ecological environment load is as follows:

$$UEC_i = \frac{UEC_{\max} + 2UEC_a + 2UEC_m + UEC_{\min}}{2}. \tag{16}$$

In the above formula, $\mathrm{UEC}_{\max}$ is the maximum unit cost of ecological environment load, $\mathrm{UEC}_{\min}$ is the minimum unit cost of ecological environment load, UEC_a is the

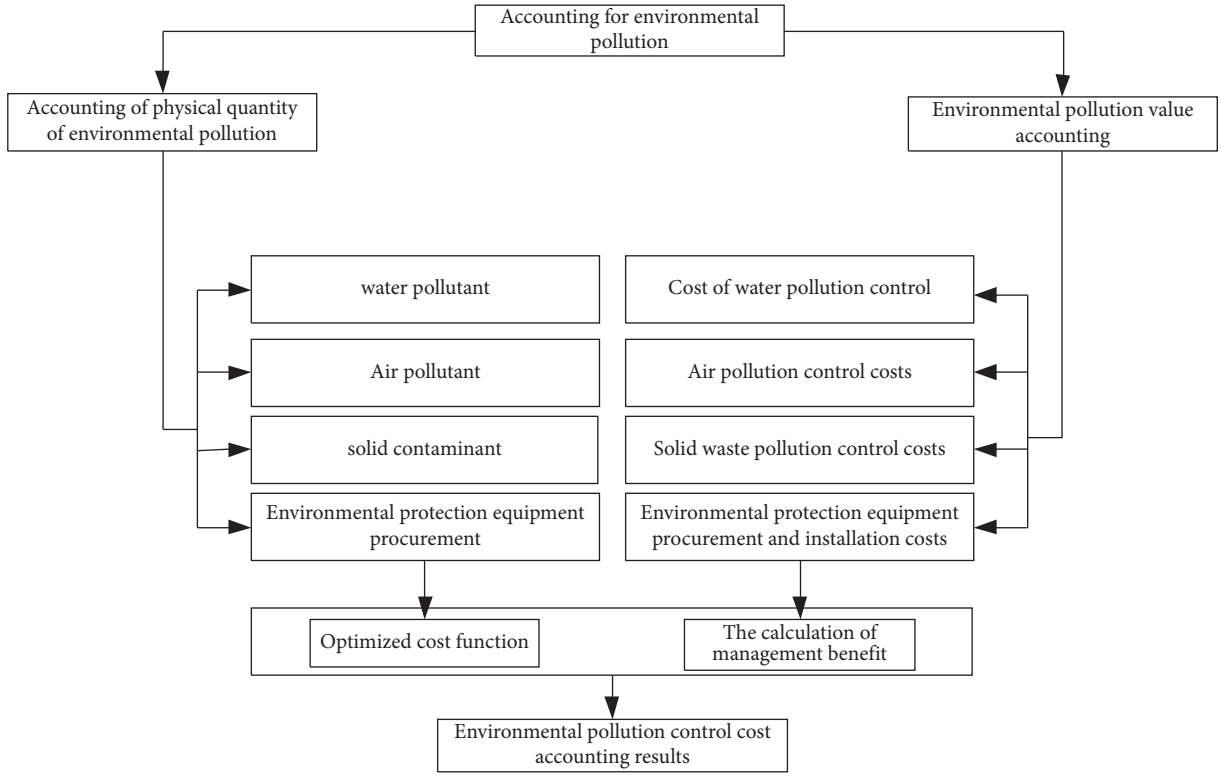

Figure 1: Cost accounting algorithm architecture of ecological environment pollution control.

average unit cost of ecological environment load, and UEC_m is the middle value of unit cost of ecological environment load.

The cost function $\cos t(a_1)$ optimized by discrete probability model can be expressed by the following formula:

$$\cos t(a_1) = K \times u\left(\sum_{i=1}^{n} E_{ij} \times UEC_i\right). \tag{17}$$

In the above formula, K is the cost value coefficient, u is the discrete probability, E_{ij} is the ecological environment load, and j are the various stages of inventory analysis. Using discrete probability model cost function for optimization can collect and compare the scattered ecological environment data information and improve the accuracy of ecological environmental pollution control cost accounting.

After optimizing the cost function, it is necessary to calculate the treatment benefit of a certain pollution control measure, which is expressed as follows:

$$\eta_i = \frac{T_i \times (I - T_i)}{S_i \times I}. \tag{18}$$

In the above formula, S_i is the maximum allowable emission concentration of the i-th pollutant, and the treatment cost coefficient of the pollutant is calculated:

$$\gamma_i = \frac{i \times \eta_i}{\sum_{i=1}^{n} \eta_i}. \tag{19}$$

In the above formula, γ_i is the treatment cost coefficient of the i-th pollutant, which is the proportion of the total actual treatment cost of waste gas or wastewater.

The treatment cost of a certain ecological environment pollution is as follows:

$$\overline{C} = \frac{C_i \times \gamma \times M_{jk}}{T_i}. \tag{20}$$

According to the above analysis, the cost accounting algorithm of ecological environmental pollution control is designed, and its architecture is shown in Figure 1.

The classification of environmental pollution costs is shown in Table 2.

3. Experiment Design and Result Analysis

In order to verify the practical application effect of the environmental pollution control cost accounting algorithm based on discrete probability, experimental test is needed. The experimental hardware device is a 64G solid-state hard disk, 16G cache, 8-core high-speed processor computer. SQL 2018 database and MATLAB 7.2 software are set inside the computer to improve the operation speed and ensure the scientific reliability of the experiment. This experiment sample data comes from the local ecological environment information platform, and all the data in the platform are taken as the experimental sample data. The cost accounting algorithm of environmental pollution control based on activity-based costing in [4], the cost accounting algorithm based on multiattribute analysis in [5], and the cost accounting algorithm for environmental pollution control

Table 2: Classification of environmental pollution costs.

Type	Specific project
The cost of disposing of pollutants	Recyclable pollutants Nonrecyclable pollutants
The cost of improving the environmental quality of enterprises	Road dust pollution prevention and control Rinsing and cleaning strength Putting an end to burn
The cost of emitting waste gas and water	Exhaust emission cost Wastewater discharge cost
The cost of developing environmentally friendly products	Prevention during production Using the process of processing
The cost of conducting environmental audits and monitoring	Cost of environmental audit Environmental monitoring cost

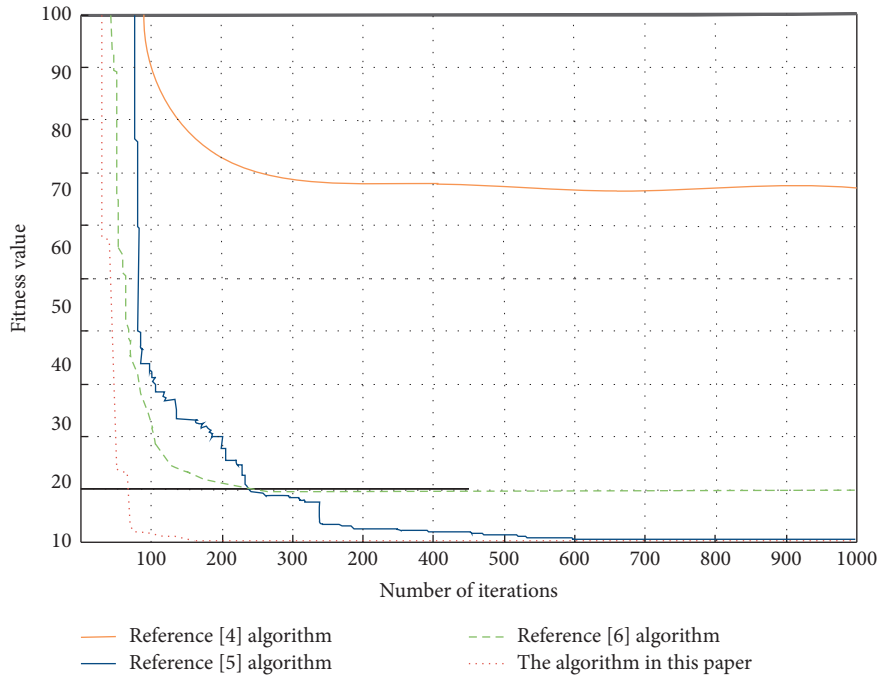

Figure 2: Comparison of convergence of algorithms.

based on BP neural network in [6] are selected as experimental comparative algorithms. The performance of the methods is tested by comparing the cost accounting indicators of different algorithms.

3.1. Comparison of Convergence of Algorithms. Firstly, the convergence of the four algorithms is compared, and the results are shown in Figure 2.

It can be seen from Figure 2 that the convergence of the algorithm in this paper is better than that of the comparison algorithm in the literature. The main reason is that the algorithm can quickly converge to the optimal within 70 iterations, and the shape of the convergence curve is close to the vertical downward, and there is almost no inflection point, so it has good convergence [43].

3.2. Accounting Error Rate. The algorithms in [4], [5], and [6] and the algorithm in this paper are used to carry out experiments, and the comparison results of the four algorithms are shown in Figure 3.

Analysis of Figure 3 shows that the accounting error rate of the algorithm in [4] is between -10.4% and 4.9%, that of the algorithm in [5] is between -10.3% and 5.2%, that of the algorithm in [6] is between -10.3% and 5.1%, and that of the algorithm in this paper is between -0.2% and 1.3%. Overall, the calculation error rate of this algorithm is the lowest, so the algorithm can accurately calculate the cost of ecological environmental pollution control.

3.3. Comparison of Accounting Time. Based on the above experiments, the calculation time of the four algorithms is further compared, and the results are shown in Figure 4.

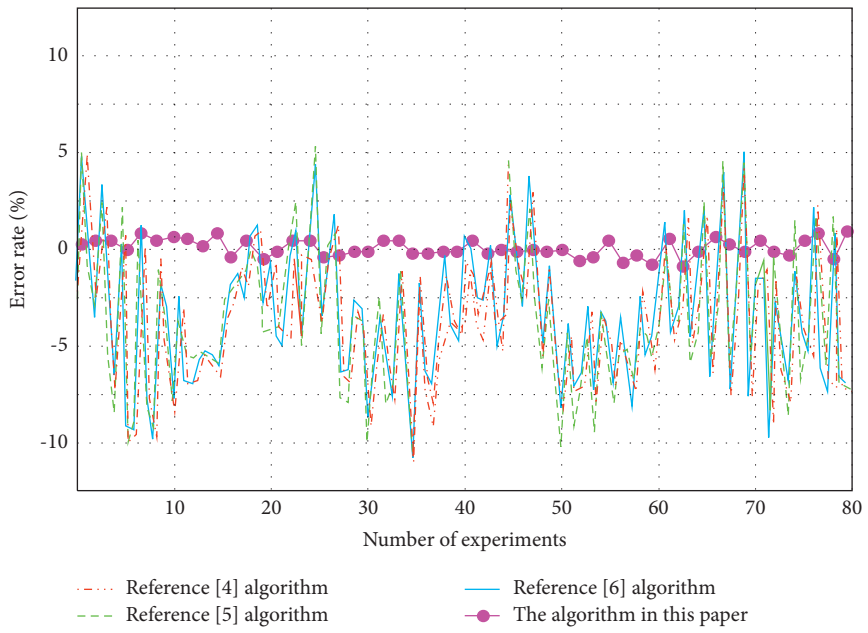

Figure 3: Calculation error rate.

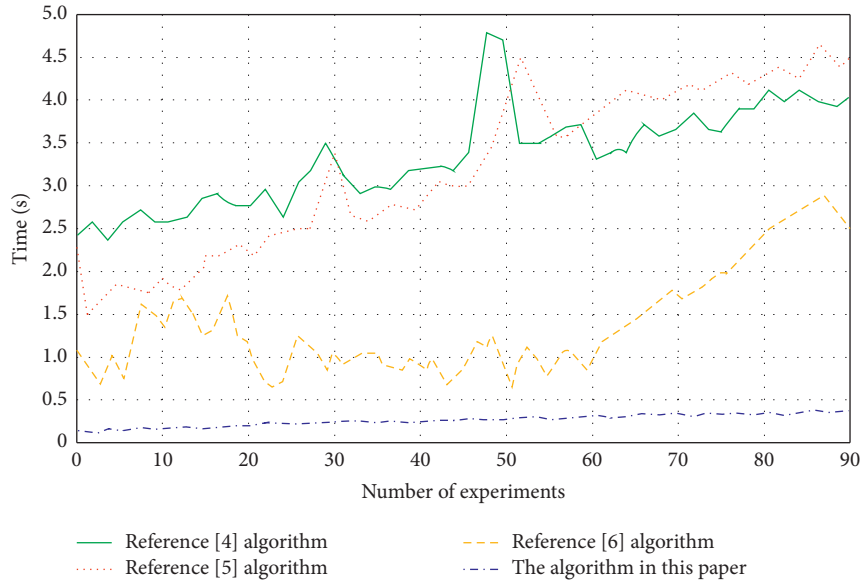

Figure 4: Accounting time.

It can be seen from Figure 4 that the accounting time range of the algorithm in [4] is 2.4 s–4.6 s, and the accounting time is the highest among the four algorithms. The calculation time range of [5] algorithm is 1.5 s–4.5 s, and the accounting time range of [6] algorithm is 1.3 s–3.7 s, while the accounting time of this algorithm is always less than 0.4 s, which is the lowest among the four algorithms, which shows that the algorithm can quickly calculate the ecological environmental pollution treatment cost [44].

4. Conclusion

Although the rapid development of industry has a certain role in promoting social economy, a series of ecological and environmental pollution problems have also followed, and the community began to pay more attention to environmental problems, so this paper proposes a discrete probability-based environmental pollution control cost calculation algorithm, and the effectiveness of the algorithm is verified by experiments. In the next step, the algorithm can be applied in practice to make a comprehensive and detailed cost accounting strategy for environmental pollution control, so as to provide technical basis for comprehensive decision-making of environmental pollution control.

As the current energy consumption structure is unreasonable, which poses a great threat to the environment, in the process of social and economic development in the future, attention should be paid to optimizing the energy

structure, reducing the proportion of high pollution energy consumption, and actively developing new energy technologies represented by nuclear energy, solar energy, wind energy, and biogas. We should strengthen the monitoring of key pollution industries and key pollution areas, increase pollution control efforts, strictly control the amount of pollutants discharged, and impose heavy taxes on enterprises that discharge pollutants beyond the standard. At the same time, we should pay attention to the development of circular economy and promote the recycling of waste resources, so as to reduce environmental pollution and realize the sustainable development of social economy.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

It is declared by the authors that there are no conflicts of interest regarding the publication of this article.

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Research Article

Quality Evaluation of Environmental Accounting Information Disclosure of Y Nonferrous Metal Company Based on AHP-FCE Model

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Environmental accounting information disclosure is an important way to achieve the goal of "carbon peak carbon neutrality", which plays a role in the link between economic development and environmental protection. Select Y Non-Ferrous Metal Company for case analysis, use the AHP-FCE model for comprehensive evaluation of environmental accounting information quality of the company, which use analytic hierarchy process to determine the evaluation factors and factors of weight value, and then use fuzzy synthesis method for multi-level fuzzy comprehensive evaluation. The results show that as a state-owned enterprise, the quality level of Y company's environmental accounting information disclosure is in the "general" level in the past 5 years, and the intensity of government environmental regulation will promote the quality of the company's environmental accounting information disclosure. Non-ferrous metal companies should enhance the concept of environmental protection, strengthen the awareness of environmental accounting information disclosure, promote technological innovation in energy conservation and emission reduction, and reduce carbon emission intensity. The government should also provide a favorable social environment and policy support for the non-ferrous metal industry to implement environmental accounting information disclosure, formulate relevant laws and regulations, and continuously strengthen supervision.

1. Introduction

At present, the global energy consumption structure is undergoing a third transformation. The main goal is to establish a low-carbon and sustainable energy supply and consumption system. Renewable energy has been extensively developed and utilized. Environmental accounting information disclosure refers to the disclosure of the company's management to the outside world in the form of an annual report, social responsibility report, and other ways to explain the company's environmental strategy in the process of production and operation and the implementation of environmental pollution discharge means and measures [1]. The disclosure of environmental accounting information is beneficial to standardize the environmental treatment of enterprises, optimize the low carbon economic structure, and guide and accelerate the transformation of the economic industrial structure.

The process of industrialization and urbanization in China has promoted the rapid development of the non-ferrous metal industry. The production process and characteristics of non-ferrous metals determine that the production of various metals is high energy consumption and high emissions. According to statistics from the China non-ferrous metals industry association, carbon emissions from the non-ferrous metals industry reached 660 million tons in 2020, accounting for about 4.7% of the country's total carbon emissions, making it one of the main sources of carbon emissions in China. China is actively promoting the goal of carbon peak carbon neutrality, and the non-ferrous metal industry, as an industry with high carbon emissions, is naturally the first to carry out reform and upgrading.

Y non-ferrous metal enterprise is the first domestic mining, electricity, and smelting triple production enterprise. Y Company's main business is lead, zinc, and other non-ferrous metals mining, zinc smelting, production and sales of extended products, and hydroelectric power generation. Y Non-Ferrous Metal Company is a state-owned holding company. The special status of state-owned enterprises enables Y Non-Ferrous Metal Company to obtain many preferential policies in its development.

As a listed company in the zinc and lead industry, Y company has serious heavy metal pollution, causing great damage to the local environment. In 2016, the central environmental protection inspection group and the local environmental protection Bureau pointed out that Y company did not treat 10 tons of solid waste according to the standard treatment, and Y company's subsidiary exceeded the emission of exhaust gas. It called for the complete elimination of potential environmental pollution by the end of 2018. In 2018, the central Environmental protection inspection team carried out an environmental inspection again and found that Y company did not solve the internal management chaos and prominent environmental safety problems, but the problem is further aggravated.

Under the background of carbon peak and carbon neutralization, the biggest challenge facing the non-ferrous metal industry is to reduce carbon emissions, increase carbon absorption, and show the effect of energy conservation and emission reduction on the industry enterprises. This requires enterprises to disclose environmental accounting information according to their own industrial characteristics, and to make carbon emissions, pollutant discharge, and related emission reduction scientific research and technology costs transparent. This study takes Y Non-ferrous Metal Company as a case study and selects the company's annual report, interim announcement, social responsibility report, and other data from 2017 to 2021. First, according to the requirements of accounting information quality, the AHP-FCE model is constructed from three aspects of relevance, reliability, and compliance. Then, the comprehensive score of Y company's environmental accounting information quality is decomposed and calculated to explore the problems existing in the disclosure of environmental accounting information in the non-ferrous metal industry and put forward suggestions for improvement.

2. Literature Review

2.1. The Influence of Government Regulation on Enterprise Environmental Accounting Information Disclosure. Government regulation mainly through promulgation and implementation of environmental protection-related laws and regulations to achieve rigid constraints on enterprises' environmental behavior. Hughes et al. [2] found that in order to cope with FASB and SEC's review, enterprises with poor environmental performance had to disclose their environmental information. Stefan Paul [3] believes that reducing environmental regulations does not necessarily bring better economic efficiency and financial benefits. Enterprises can partially or completely compensate for pollution control costs caused by environmental regulations from other aspects, and some enterprises can benefit from environmental regulations. Qian [4] found that the introduction of environmental information disclosure system brought enormous environmental pressure to enterprises and effectively improved the quality of corporate environmental information disclosure. The research of Chen and Qian [5] shows that the promulgation of the "new Environmental Protection Law" effectively improves the quality of enterprises' environmental information disclosure, which indicates that it is effective for the government to strengthen enterprises' environmental responsibility from the legislative level. Chai [6] concluded through empirical research that government supervision can increase the value of a company by improving its environmental information disclosure level. Qi et al. [7] found that government incentives have a great influence on guiding enterprises to disclose environmental accounting information.

2.2. The Influence of Enterprise Nature on Environmental Accounting Information Disclosure. There is a huge difference between China's political and economic environment and that of western countries. In western countries, the capital market is relatively complete and mainly private enterprises, while a large part of China's enterprises is controlled by the government. Many scholars have found that there is a very close relationship between the nature of enterprises and the quality of accounting information. Liu and Du [8] found that the probability of financial fraud was higher in state-controlled companies. Wang et al. [9] found in their study that no matter what the nature of enterprises, they would have a strong motivation to manipulate accounting information and earnings management. Chen [10] mainly studied the quality of accounting information of enterprises with different properties. Studies have found that when enterprises are state-owned, the quality of accounting information disclosure is high. Liu and Bai [11] found that the quality of monetary environment accounting information disclosure of state-owned enterprises was higher than that of non-state-owned enterprises, and there was a significant negative correlation between environmental supervision and the quality of monetary environment accounting information disclosure.

2.3. Selection of Environmental Information Disclosure Quality Evaluation Index Content. The construction of environmental information disclosure index system abroad is an evolving process. Clarkson et al. [12] divided the environmental information disclosure system into two types: hard and soft. Hard disclosure includes corporate governance structure, environmental performance indicators, and environment-related expenditures; Soft disclosure includes environment-related strategic statements, environmental status, and corporate environmental behavior. Beck et al. [13] believed that corporate environmental information disclosure behavior characteristics should be considered and added to the evaluation indicator system, such as environmental strategic arrangement, management system,

employee training programs, etc. Ren and Hong [14] constructed an enterprise environmental accounting information evaluation index system from soft disclosure and hard disclosure, assigned values and scored them, and then summarized the scores for comparative analysis. Li [15] proposed that government regulation, stakeholders, and enterprises' own factors should be fully considered in the construction of the index system.

2.4. The Scoring Standard of Environmental Information Disclosure Quality Evaluation Index. The core of the analytic hierarchy process is to establish the judgment matrix. First, the analytic hierarchy process model is established to refine the research questions, and then the importance of indicators is compared, and finally, the weight of each indicator in the model is obtained. Anirut et al. [16] improved the effectiveness of the analytic hierarchy process (AHP) in assessing environmental performance by integrating exploratory factor analysis and confirmatory analysis to validate appropriate criteria and sub-criteria. Research results show that quality policy, quality assurance, and quality control are the three most important factors in environmental performance measurement respectively, while organizational support in innovation is given the lowest priority. Wang and Han [17] used the AHP analysis method to evaluate the quality of environmental accounting information disclosure of listed companies. Yao [18] obtained the environmental performance evaluation results of various functional departments of the enterprise by AHP based on the performance management of the enterprise and analyzed the environmental performance differences of different departments of the enterprise.

The fuzzy comprehensive evaluation method is very effective when some indexes are difficult to be quantified in the evaluation. Based on the membership theory of mathematics, it changes qualitative indexes into quantitative indexes and reduces the influence of supervisor factors in evaluation. Chithambaranathan and other scholars [19] conducted a fuzzy comprehensive evaluation from the perspective of the value supply chain by integrating multiple influencing factors. Kumar et al. [20] used the fuzzy extension method to evaluate the environmental performance of suppliers to facilitate the selection of suppliers. Wang and other scholars [21] also chose this method when studying the environmental performance of the coal industry. Other scholars use the fuzzy comprehensive evaluation method to study the fulfillment of corporate social responsibility. For example, Junhua et al. [22] quantified qualitative indicators with a fuzzy comprehensive evaluation method when studying tanning companies.

3. Quality Analysis of Corporate Environmental Accounting Information Disclosure Based on the AHP-FCE Model

3.1. AHP-FCE Model. AHP-FCE model is an evaluation model based on Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE). Analytic hierarchy process (AHP) is a method proposed by Professor T. L. Saaty in the United States to make scheme decisions by using hierarchical weight. Its core is to split the factors related to decision into multiple levels, such as the target layer, criterion layer and scheme layer, and calculate the weight of each factor in turn to get the appropriate scheme. The fuzzy comprehensive evaluation method is proposed by American professor L.A. Zeh. Its core is to use the concept of the fuzzy set to carry out scientific quantitative analysis of many problems with unclear boundaries in reality, and it can well transform qualitative indicators into quantitative data evaluation methods. The main steps of the AHP-FCE model are as follows: first, a complete evaluation index system is established according to the target layer, criterion layer, and scheme layer; Second, from the evaluation index system, construct each judgment matrix and complete the consistency test. Then determine the fuzzy weight data, calculate the combined weight, and finally calculate the comprehensive score.

The quality of environmental accounting information disclosure is a comprehensive evaluation system. The quality of enterprise environmental accounting information disclosure can be reasonably evaluated only by selecting reasonable evaluation factors, establishing a hierarchical index system, and assigning an appropriate weight value to each evaluation factor. Environmental accounting information disclosure quality evaluation exists lots of fuzzy phenomena and concepts, and needs quantitative index and qualitative index to reflect the current state of the environment information, therefore, the study combined the two methods, using the analytic hierarchy process to determine index weight and the fuzzy synthesis evaluation of environment quality of accounting information, the two complement each other, improve the reliability of evaluation and effectiveness.

3.2. Establishment of Evaluation Index System. According to the AHP-FCE model, the AHP evaluation index system needs to be established first. According to between 2015 and 2022, the ecological environment of the People's Republic of China and the China Securities Regulatory Commission released the enterprise environment accounting information disclosure system files, and combining previous research results and the non-ferrous metal industry characteristics, this study builds A set of relevance, reliability, and compliance as the main indicators of the evaluation system, are shown in Table 1 below, from left to right in turn into A target layer, criterion layer B, Secondary criterion layer C and scheme *D*, form class time relationship. Correlation indicators refer to financial information and non-financial information such as rules and regulations, production and operation, development, and management related to enterprise environmental protection. The reliability index refers to the authentication of enterprise information disclosure, which can be internal authentication or third-party independent authentication. Compliance refers to whether the disclosure methods and contents of enterprises meet the requirements of laws and regulations.

Table 1: Environmental accounting information disclosure quality index evaluation system table.

Target layer	Criterion layer	Secondary criterion layer	Scheme layer
Quality of corporate environmental information disclosure A	Correlation B1	Environmental assets C1	Antifouling treatment facilities D1
			Environmental government subsidies, environmental governance awards, etc. D2
			Patented technology for environmental protection D3
		Environmental liabilities C2	Resource tax and environmental protection tax D4
			Environmental protection fees, pollution discharge fees, pollution liability insurance and other environmental protection expenses D5
			Environmental penalty expenditure D6
		Environmental attitude C3	Emergency plans related to the environment D7
			Environmental system certification and cleaner production D8
			Environmental protection education and training for staff D9
		Environmental performance C4	Carbon emission and pollutant emission D10
			Disposal of pollutants and wastes D11
			Comprehensive utilization rate of mineral resources and environmental rectification measures D12
	Reliability B2	Environmental information accuracy C5	Environmental credit evaluation D13
			Environment information internal control settings and operation D14
			Third-party environmental audit verification D15
			Instructions for ensuring the accuracy of environmental information D16
	Compliance B3	Environmental information compliance C6	Whether the form of disclosure complies with laws and regulations D17
			Whether the disclosure related to environmental information is timely D18
			Whether the disclosure time of major announcements is timely D19

3.3. Determination of Weight of Evaluation Index. Starting from the index system constructed in Table 1, using the nine-level scoring table in Table 2, experts compare and judge the importance of two elements at the same level, so as to construct a judgment matrix, and then use mathematical methods to calculate the weight of the judgment matrix.

$$\begin{bmatrix} 1 & 5 & 2 \\ \frac{1}{5} & 1 & \frac{1}{5} \\ \frac{1}{2} & 5 & 1 \end{bmatrix} * \begin{pmatrix} 0.5590 \\ 0.0887 \\ 0.3521 \end{pmatrix} = \begin{pmatrix} CW_1 \\ CW_2 \\ CW_3 \end{pmatrix}. \tag{1}$$

3.3.1. Weight of Environmental Liability Information

(1) Weight of Environmental Asset Information. The weight of each indicator is calculated according to the results of the judgment matrix. The weight calculation process is as follows:

First, multiply the elements of each row of judgment matrix C to obtain $\overline{ui}$, and calculate $\overline{u1} = 10$, $\overline{u2} = 0.04$, $\overline{u3} = 2.5$. Then multiply the product by the n power to obtain the vector ui, and calculate $u1 = 2.154$, $u2 = 0.342$, $u3 = 1.357$. Then divide each ui by the sum of all the root vector values, U to get $W1 = 0.5590$, $W2 = 0.0887$, $W3 = 0.3521$, Calculate the product of matrix C and feature vector CW to get the maximum eigenvalue $\mathrm{Max}(\lambda)$.

$$CW_1 = 1 * 0.5590 + 5 * 0.0887 + 2 * 0.3521 = 1.7071$$

By the same token, $CW_2 = 0.2709$, $CW_3 = 1.0754$.

$$\begin{aligned} \mathrm{Max}(\lambda) &= \frac{1}{n}\sum_{i=1}^{n}\frac{(CW)_i}{W_i} \\ &= \frac{1.7071/0.559 + 0.2709/0.0887 + 1.0754/0.3521}{3} \\ &= 3.0536. \end{aligned} \tag{2}$$

In order to judge whether the matrix has satisfactory consistency, a consistency index CR should be used to detect the consistency degree of the judgment matrix, and the

Table 2: Grade 9 grading table.

Factor A vs. factor B	Quantitative values
As important	1
A little important	3
More important	5
Highly important	7
Extremely important	9
The intermediate value of the quantized value	2, 4, 6, 8
Reverse comparison	Reciprocal of each of the above numbers

consistency degree should be modified by using the index of average random consistency RI. The fixed values of RI are shown in Table 3. When $CR = 0$, it indicates that the judgment matrix has a good consistency. When $CR < 0.1$, it indicates that the consistency is good; otherwise, it indicates that the consistency of the judgment matrix is not good. It is necessary to modify the values of the matrix until $CR < 0.1$.

$$CI = \frac{\max(\lambda) - n}{n-1} = \frac{3.0536 - 3}{2} = 0.0268, \quad (3)$$

$$CR = \frac{CI}{RI} = \frac{0.0268}{0.52} = 0.05155. \quad (4)$$

(2) Weight of Environmental Liability Information. According to the previous calculation ideas, the judgment matrix, weight allocation, and consistency test of environmental liability information are obtained, as shown in Table 4 below.

(3) Weight of Environmental Attitude Information. Similarly, the judgment matrix, weight distribution, and consistency test of environmental attitude information are obtained, as shown in Table 5 below.

(4) Weight of Environmental Performance Information. Similarly, the judgment matrix, weight distribution, and consistency test of environmental performance information are obtained, as shown in Table 6 below.

3.3.2. Determination of Weight of Environmental Reliability Index. Similarly, the judgment matrix, weight distribution, and consistency test of environmental information accuracy are obtained, as shown in Table 7 below.

3.3.3. Determination of Weight of Environmental Compliance Index. Similarly, the judgment matrix, weight distribution, and consistency test of environmental information compliance are obtained, as shown in Table 8 below.

3.3.4. Determination of Weights for Total Model Indicators

(1) Determination of the Weight of Information Index in the Sub-criterion Layer. Similarly, the judgment matrix, weight distribution, and consistency test of sub-criteria layer information are obtained, as shown in Table 9 below.

Table 3: RI values corresponding to the order.

Order	1	2	3	4	5	6	7	8	9
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46

Table 4: Judgment matrix, weight allocation, and consistency test of environmental liability information.

	D4	D5	D6	Weight	CI	CR
D4	1	1/5	1/4	0.0936		
D5	5	1	3	0.6267	0.4288	0.0825
D6	4	1/3	1	0.2797		

Table 5: Judgment matrix, weight allocation, and consistency test of environmental attitude information.

	D7	D8	D9	Weight	CI	CR
D7	1	2	1/2	0.3108		
D8	1/2	1	1/2	0.1958	0.0268	0.0516
D9	2	2	1	0.4933		

(2) Determination of Information Index Weight of Criterion Layer. Similarly, the judgment matrix, weight distribution, and consistency test of criterion layer information are obtained, as shown in Table 10 below.

The fuzzy weight and combined weight of indicators at each level are obtained by summary calculation, as shown in Table 11.

3.4. Comprehensive Results of Environmental Information Assessment. After determining the quality evaluation index system of environmental accounting information disclosure and the weight value of each index, the evaluation standard and grade evaluation of the index should be clarified. The evaluation index system includes a qualitative index and a quantitative index. This study mainly adopts the method of combining qualitative statements, monetary quantitative statements, and non-monetary quantitative statements to evaluate 19 environmental information disclosure indicators, with the highest score of 6 and the lowest score of 0. The specific scoring criteria are shown in Table 12.

Analyze the annual report, interim announcement, and social responsibility report of Y Non-ferrous Metal Company from 2017 to 2021. According to the evaluation score of each index and the combined weight, the comprehensive score of environmental accounting information quality of Y Company in recent 5 years is calculated, as shown in Table 13 below.

According to the score grade of comprehensive evaluation in Table 14, it can be seen from Figure 1 that the quality level of environmental information disclosure of Y Non-ferrous Metal Company is generally in the "general" level, and the evaluation level reached the "good" level in 2018. It indicates that there is a large room for improvement in the environmental accounting information disclosure of Y Company. According to the index disclosure score of each layer in Table 13, Y company has problems such as a

Table 6: Judgment matrix, weight allocation, and consistency test of environmental performance information.

	D10	D11	D12	D13	Weight	CI	CR
D10	1	3	1	1	0.2832	0.0201	0.0226
D11	1/2	1	1/2	1/2	0.1416		
D12	1	2	1	1/2	0.2382		
D13	1	2	2	1	0.3369		

Table 7: Judgment matrix, weight distribution, and consistency test of environmental information accuracy.

	D14	D15	D16	Weight	CI	CR
D14	1	1	2	0.3874	0.0091	0.0176
D15	1	1	3	0.4434		
D16	1/2	1/3	1	0.1692		

Table 8: Judgment matrix, weight distribution, and consistency test of environmental information compliance.

	D17	D18	D19	Weight	CI	CR
D17	1	1	1	0.3275	0.0268	0.0516
D18	1	1	1/2	0.2599		
D19	1	2	1	0.4126		

Table 9: Judgment matrix, weight distribution, and consistency test of environmental correlation information.

	C1	C2	C3	C4	Weight	CI	CR
C1	1	1	1/2	1/3	0.1411	0.0035	0.0039
C2	1	1	1/2	1/3	0.1411		
C3	2	2	1	1/2	0.2627		
C4	3	3	2	1	0.4550		

relatively single way of environmental accounting information disclosure, incomplete disclosure content, and nonstandard disclosure.

4. Cause Analysis of Y Company's Environmental Accounting Information Disclosure

4.1. The Intensity of Government Environmental Supervision Will Promote the Quality of Environmental Accounting Information Disclosure. According to the score of information quality level of Y Company, the quality of information disclosure is improved only when the government supervision is strengthened. Y company had serious environmental pollution problems in 2016 and 2017. The central environmental inspector clearly pointed out that the Y nonferrous metal company had serious potential environmental pollution problems, but did not punish it or demand rectification. The company did not disclose environmental information that year. Until 2018, the central environmental inspector carried out an environmental inspection again and criticized the environmental problems of Y company, so the company increased the disclosure of environmental information.

4.2. The Responsibility Consciousness of Enterprises to Implement Environmental Accounting Information Disclosure Needs to Be Improved. Kong and Tang [23] found that compared with non-state-owned enterprises, state-owned enterprises were sheltered by local governments, which interfered in their economic behavior and social responsibility fulfillment, thus covering up their inadequate performance of environmental responsibility and reducing the quality of environmental information disclosure. Y Nonferrous Metal Company is a listed company controlled by The State-owned Assets Supervision and Administration Commission (SASAC), making great contributions to the local economy. Central environmental inspectors have pointed out that one of the reasons for Y non-ferrous metal company's serious environmental pollution problems is the lax environmental supervision of the relevant local government departments.

Y enterprise as heavy pollution of nonferrous metals enterprise, daily production process of "three wastes" pollution to the ecological environment is larger, but Y enterprise in selecting environmental information disclosure forms still choose the lower cost of the annual report and disclosure of the interim report, has such problems as environmental information content is not complete, repetitive, or selective description, avoidance or not to disclose negative news. Although criticized by the regulatory authorities, Y company did not improve the form and content of environmental information disclosure, indicating its low awareness of environmental protection.

4.3. Lack of Professional Environmental Accounting Talents. Fang et al. [24] found that the industry work experience and knowledge update degree of financial directors had a significant positive effect on the quality of accounting information of companies. It can be seen from Table 13 that the company has not disclosed "environmental protection education and training for employees" in the past 5 years, which indicates that the management of the company has not paid enough attention to environmental protection and has not provided regular environmental protection training for employees. Xiong et al. [25] believed that the education level of the CFO would have a positive impact on the quality of accounting information. As shown in Table 15, in the past 5 years, the proportion of people with a bachelor's degree or above is on the rise, but the overall proportion is less than 20%, indicating that enterprise Y is short of comprehensive professionals in environmental accounting, and its environmental protection training for employees is seriously insufficient, resulting in a low level of environmental information disclosure.

4.4. Company Environmental Accounting Information Disclosure System Is Not Perfect. For the disclosure of enterprise environmental information, China's law currently provides

Table 10: Judgment matrix, weight distribution, and consistency test of the total model.

	B1	B2	B3	Weight	CI	CR
B1	1	1	1	0.3275		
B2	1	1	2	0.4126	0.0268	0.0516
B3	1	1/2	1	0.2599		

Table 11: Weight table of environmental accounting information disclosure quality index evaluation.

Target layer	Criterion layer	Secondary criterion layer	Scheme layer	Combination weight
Quality of corporate environmental information disclosure A	Correlation B1 (0.3275)	Environmental assets C1(0.1411)	Antifouling treatment facilities D1(0.5590)	0.0258
			Environmental government subsidies, environmental governance awards, etc. D2(0.0887)	0.0041
			Patented technology for environmental protection D3(0.3521)	0.0163
			Resource tax and environmental protection tax D4(0.0936)	0.0043
		Environmental liabilities C2 (0.1411)	Environmental protection fees, pollution discharge fees, pollution liability insurance, and other environmental protection expenses D5 (0.6267)	0.0290
			Environmental penalty expenditure D6(0.2797)	0.0129
			Emergency plans related to the environment D7(0.3108)	0.0267
		Environmental attitude C3 (0.2627)	Environmental system certification and cleaner production D8(0.1958)	0.0168
			Environmental protection education and training for staff D9(0.4933)	0.0424
			Carbon emission and pollutant emission D10(0.2832)	0.0422
		Environmental performance C4(0.4550)	Disposal of pollutants and wastes D11(0.1416)	0.0211
			Comprehensive utilization rate of mineral resources and environmental rectification measures D12(0.2382)	0.0355
			Environmental credit evaluation D13(0.3369)	0.0502
	Reliability B2 (0.4126)	Environmental information accuracy C5(1)	Environment information internal control settings and operation D14(0.3874)	0.1598
			Third-party environmental audit verification D15(0.4434)	0.1829
			Instructions for ensuring the accuracy of environmental information D16(0.1692)	0.0698
	Compliance B3 (0.2599)	Environmental information compliance C6(1)	Whether the form of disclosure complies with laws and regulations D17(0.3275)	0.0851
			Whether the disclosure related to environmental information is timely D18(0.2599)	0.0675
			Whether the disclosure time of major announcements is timely D19(0.4126)	0.1072

a combination of compulsory disclosure and voluntary disclosure. For example, the Standards for Disclosure format of Enterprise Environmental Information in accordance with the law standardize the disclosure format of enterprise environmental information but does not adopt mandatory requirements. The environmental information disclosure of Y company is more arbitrary and subjective, with a single form of disclosure and incomplete disclosure content.

5. Suggestions on Optimization of Environmental Accounting Information Disclosure in the Nonferrous Metal Industry

5.1. To Formulate Laws and Regulations, Continue to Intensify Supervision. Disclosure of environmental information in accordance with the law is an important enterprise environmental management system and the basic content of the

Table 12: Scoring criteria.

0	1 point	2 points	3 points	4 points	5 points	6 points
No description	Simple qualitative description (1–5 sentences)	Detailed qualitative description (more than 5 sentences)	Simple non-monetary quantitative description (1–5 sentences)	Detailed non-monetary quantitative statements (more than 5 sentences)	Simple monetary quantitative description (1–5 sentences)	Detailed monetization quantitative description (more than 5 sentences)

Table 13: Comprehensive score table of Y Company's environmental accounting information quality from 2017 to 2021.

Scheme layer	2017	2018	2019	2020	2021
Antifouling treatment facilities	0.1548	0.1548	0.1548	0.1548	0.1548
Environmental government subsidies, environmental governance awards, etc.	0.0246	0.0205	0.0328	0.0328	0.0328
Patented technology for environmental protection	0.0652	0.0652	0	0.0652	0.0652
Resource tax and environmental protection tax	0.0215	0.0215	0.0215	0.0215	0.0215
Environmental protection fees, pollution discharge fees, pollution liability insurance, and other environmental protection expenses	0.174	0.174	0.174	0.174	0.174
Environmental penalty expenditure	0	0.129	0	0	0.129
Emergency plans related to the environment	0.0267	0.0267	0.0267	0.0267	0.0267
Environmental system certification and cleaner production	0.0168	0.0168	0.0168	0.0168	0.0168
Environmental protection education and training for staff	0	0	0	0	0
Carbon emission and pollutant emission	0.2532	0.2532	0.2532	0.2532	0.2532
Disposal of pollutants and wastes	0.0844	0.1899	0.0844	0.0844	0.0844
Comprehensive utilization rate of mineral resources and environmental rectification measures	0.213	0.213	0.213	0.213	0.213
Environmental credit evaluation	0	0	0	0	0
Environment information internal control settings and operation	0	0.799	0	0	0
Third-party environmental audit verification	0	0	0	0	0
Instructions for ensuring the accuracy of environmental information	0.0698	0.0698	0.0698	0.0698	0.0698
Whether the form of disclosure complies with laws and regulations	0.0851	0.0851	0.0851	0.0851	0.0851
Whether the disclosure related to environmental information is timely	0.0676	0.0676	0.0676	0.0676	0.0676
Whether the disclosure time of major announcements is timely	0.1072	0.1072	0.1072	0.1072	0.1072
Total	1.3639	2.3933	1.3069	1.3721	1.5011

Data source: According to the 2017–2021 annual report, interim announcement, and social responsibility report of Y Nonferrous Metals Company.

Table 14: Grade table of comprehensive evaluation score.

Grade	Excellent	Good	General	Bad	Very bad
Composite scores	$2.5 \le X \le 3$	$2 \le X < 2.5$	$1.5 \le X < 2$	$0.5 \le X < 1.5$	$0 \le X < 0.5$

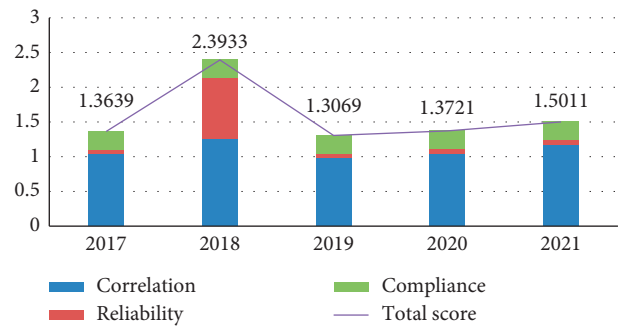

Figure 1: Comprehensive score of environmental accounting information quality. of Y Company from 2017 to 2021.

system of ecological civilization. Relevant departments in China should issue relevant laws and regulations, provide detailed implementation measures, and strengthen the compulsory disclosure of environmental accounting information in the non-ferrous metal industry. Environmental accounting standards for pollution control in the non-ferrous metal industry were issued, requiring industry enterprises to strengthen the clean management of production technology and encouraging enterprises to carry out technological reform and innovation in production. At the same time, guidelines on pollutants that can be discharged will be formulated to control the discharge of high-risk pollutants.

5.2. Enhance Environmental Awareness and Integrate Environmental Protection into Corporate Culture. Lin et al. [26] found that large companies and companies with strong profitability lack environmental protection awareness, and management generally ignores corporate environmental responsibilities when expanding the company scale and improving economic benefits. As can be seen from the annual report and interim report of Y Non-ferrous Metal Company, most of the company's disclosures are mandatory requirements of the government, while there is little disclosure of environmental information, even less negative environmental information disclosure. With the gradual

Table 15: Educational background of employees in Y enterprise.

	2017		2018		2019		2020		2021	
Education level	Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Graduate	6	0.37	6	0.37	5	0.30	5	0.29	6	0.33
Undergraduate	189	11.68	202	12.32	214	12.87	218	12.85	283	15.40
Junior college	453	28.00	453	27.64	459	27.60	453	26.71	602	32.75
High school and below	970	59.95	978	59.67	985	59.23	1020	60.15	947	51.52
Total	1618	100	1639	100	1663	100	1696	100	1838	100.00

establishment of a carbon emission trading market, nonferrous metal companies should link environmental protection and energy saving with corporate culture, actively promote environmental protection culture, strengthen environmental protection publicity and education and training, edify employees with corporate culture and practice environmental protection concepts. Through annual reports, social responsibility reports, and other forms, the company discloses environmental accounting information such as resource consumption, carbon emissions, pollutant production, and recycling utilization through multiple channels.

5.3. Promote Scientific and Technological Innovation, and Reduce the Carbon Intensity. Carbon peak carbon neutralization action brings new opportunities and challenges to the development of the non-ferrous metal industry. On the one hand, promote industrial enterprises to accelerate green transformation, strengthen technological innovation, actively promote and apply advanced energy-saving and low-carbon technologies, reduce indirect emissions in energy consumption, continuously optimize process control, reduce energy consumption and material consumption, and further reduce industrial carbon emission intensity. On the other hand, while promoting carbon peak, industrial enterprises will also rapidly reduce the carbon peak level, and make contributions to carbon peak and carbon neutrality.

5.4. Strengthen the Training of Environmental Accounting Personnel. Environmental accounting personnel is the discloser of environmental accounting information, which plays an important role in the process of environmental accounting information disclosure. The training expenditure of enterprise Y's environmental accounting personnel is zero, which leads to the accounting personnel's slackness on environmental accounting information and affects the disclosure of environmental accounting information. Environmental accounting includes accounting, economics, management, and other disciplines, which means that environmental accounting requires higher professional quality and higher comprehensive ability of accounting personnel. Enterprises need to strengthen the training of environmental accounting personnel and cultivate excellent environmental accounting personnel.

6. Conclusions

The construction of ecological civilization has been included in the overall layout of China's "five-in-one," and the proposal of "carbon peak and carbon neutrality" both emphasizes the change in the energy industry pattern. It is a prerequisite for environmental governance that the environmental information can be fully disclosed by high-polluting enterprises [11]. Environmental accounting information disclosure is an important way to achieve the goal of "carbon peak carbon neutrality."

This study takes Y non-ferrous metal company as a case study, introduces the AHP-FCE model to comprehensively evaluate the quality of environmental accounting information of Y Company, which uses an analytic hierarchy process to determine the evaluation factors and factors of weight value, and then use fuzzy synthesis method for multi-level fuzzy comprehensive evaluation. The results show that: as a state-owned enterprise, the quality level of Y Company's environmental accounting information disclosure is in the "general" level in the past 5 years, and the intensity of government environmental regulation will promote the quality of the company's environmental accounting information disclosure. Y Non-Ferrous Metal Company, as a state-owned listed company, should enhance the concept of environmental protection, strengthen the awareness of environmental accounting information disclosure, promote technological innovation of energy conservation and emission reduction, reduce carbon emission intensity, and strengthen the training of environmental accounting personnel. The government should also provide a favorable social environment and policy support for the non-ferrous metal industry to implement environmental information disclosure research, formulate relevant laws and regulations, and strengthen supervision.

Although a large number of domestic and foreign literature were used for reference to establish the quality evaluation index system of environmental accounting information disclosure of Y Non-ferrous metal Company, due to the particularity of Y non-ferrous metal Company's industry, the existing index may not fully cover the environmental accounting information of Y Company. In the future, it is necessary to continue to improve and optimize the indicators. The conclusion of this study hopes to provide new ideas for improving the information disclosure of environmental accounting in the non-ferrous metal industry through targeted case analysis.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Analysis of the Influencing Factors of Enterprise Environmental Ethics on Enterprise Economic Performance

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In the information age, people's awareness of living environmental protection has increased unprecedentedly, and the concept of green environmental protection in enterprise economic behavior has been paid more and more attention by the market and consumers. The integration of green ideas, the improvement of production technology, and the research and development of environmental protection products have become the development trend of enterprises, and environmental ethical responsibility has also become an inevitable problem for enterprises. This paper analyzes the impact of enterprises' conscious commitment to environmental ethics on their economic benefits, identifies the key influencing factors with the help of scientific statistical methods, analyzes the action mechanism of influencing factors in performance on the basis of the effect model and communication model, and analyzes the correlation between environmental ethics and economic benefits. The experimental results show that the long-term dissemination of innovation and reputation factors in environmental ethics is conducive to the dissemination of green innovative technologies and products, obtaining the attention and recognition of more enterprises and stakeholders, broadening the scope of cooperation and sales, and obtaining the support of German consumers. Environmental ethics has a short-term direct effect on performance. When the direct effect is reduced, the intermediary effect of innovation and reputation factors can achieve a positive effect on performance by transmitting benefits.

1. Introduction

The development of modern industry has brought great changes to the social economy and enriched human material life. But it also brings serious ecological damage and environmental pollution. Environmental problems have seriously affected people's quality of life by the aggravation of environmental problems. With the enhancement of people's awareness of environmental protection, environmental issues have gradually become a global hot topic. Although government agencies have formulated various environmental laws and regulations, various environmental pollution incidents have still occurred frequently in recent years. Enterprises are the main drivers of environmental problems, so solving environmental problems requires government regulation. It also requires enterprises to pay attention to environmental issues and consciously carry out environmental protection practices. An enterprise is a profit-making organization. The pursuit of profit is the driving force of enterprise development. Under the background of the era with sustainable development as the main melody, how to maintain a balance between environmental protection and economic performance has become a major problem faced by enterprise managers. Enterprise performance is not only an important issue concerned by enterprise managers but also a major direction concerned by academic researchers.

The change in material resources is relatively stable. Under the condition of limited quantity, the development of human society will inevitably change ecological resources. The process of pursuing economic improvement will have a negative impact on the balance of the natural environment and ecosystem, and even cause irreversible damage [1].

Similarly, the gradual deterioration of the natural environment and the gradual shortage of resources have an inhibitory effect on the development of human society, and the contradiction between the two is deepening. It is necessary for every country to take active and effective measures for ecological protection and sustainable development [2]. As an important part of the economic development, the economic activities that focus on ecological restoration cannot achieve the same negative impact on the initial scale of economic development, which cannot even double the time of economic development. People from all walks of life have gradually improved their awareness of ecological and environmental protection [3]. Relevant plans and reports advocate green production, green life, green technology, and green development, as well as reduce production and living energy consumption and pollution index, and jointly improve the quality of the natural environment [4]. Relevant experts and scholars stressed that eco-environmental protection is not achieved overnight, or can it be completed by a department or a system organization. It requires the participation of the whole society, improving relevant capital investment and protection and governance, building a scientific and perfect environmental supervision system, and optimizing environmental protection systems and processes.

Relevant laws have clear provisions on the standards to be met by enterprises' economic activities. This standard is the minimum standard that enterprises need to meet and bear the minimum responsibility, but it is not enough for enterprises to only meet the specified standards [5]. Whether considering the long-term development plan of the enterprise itself or for social development and human living space, the enterprise must face the choice of whether to actively undertake environmental ethical responsibility, which is its inevitable development trend [6]. Therefore, some enterprises choose to take the initiative to undertake the corresponding environmental ethical responsibility from the perspective of long-term development. Some enterprises linger between obtaining benefits in the short term and undertaking environmental protection responsibility. The main reason is that they have a different understanding of the relationship between enterprise development and economic benefits. Studying and understanding the impact effect and path of environmental ethical responsibility on enterprise performance can provide a decision-making basis for enterprise planning and management.

The innovation contribution of this paper is to test the relationship and interaction between environmental ethical commitment behavior and economic benefits through empirical analysis. It improves the cognitive depth of enterprises on green environmental protection and enriches the cognitive level and content of enterprise system management. We will identify the key factors that affect performance, establish dynamic panel model, intermediary effect model, and other analysis factors, and analyze the paths and principles that affect economic benefits. Some components of the internal innovation environment are closely related to performance and have a significant promoting effect on the latter. It is very necessary and important to improve enterprise performance by building an internal innovation environment. Through correlation regression analysis, it is concluded that enterprises' conscious assumption of environmental ethical responsibility has a lagging positive impact on performance, that is, from the perspective of long-term development, undertaking environmental ethical responsibility has a significant role in promoting performance improvement.

2. Research Development and Current Situation of Enterprise Environmental Ethics

As the most direct factor affecting enterprise innovation, the internal innovation environment of enterprises is gradually attracting the attention of management theorists and business circles. Many related studies show that some components of the internal innovation environment are closely related to performance, and have a significant promoting effect on the latter. Therefore, it is necessary to analyze the constituent factors of the internal innovation environment and study the relationship between the internal innovation environment and performance. It is very important to improve enterprise performance by building an internal innovation environment. The first five internal factors that promote enterprise innovation are as follows: the support of senior leaders, the cooperation of functional departments, technical leaders, high-level talents, and a reasonable system. The top five obstacles are as follows: lack of funds, lack of talents, lack of information, high innovation risks, and inadequate incentives. It can be seen that most of these factors are related to management support, rewards, or incentives, organizational structure, and resource availability. The concept of enterprise environmental ethics integrates the concept of ecological and environmental protection on the basis of enterprise ethics. It is not only an affirmation of the dominant position of enterprises in society but also an expression of the dual attention of enterprises to economic performance and environmental performance [7]. Some scholars pointed out that environmental ethics is not an additional behavioral responsibility beyond the economic activities of enterprises. From the perspective of long-term development, it is an indispensable and unavoidable part of the strategic planning of enterprise development. It is both a challenge and an opportunity [8]. Other scholars believe that in the process of actively undertaking environmental ethical responsibility, enterprises will form difficult to replicate competitive advantages and immeasurable intangible assets, which are of strategic significance [9]. In addition, some scholars analyzed from the perspective of human coexistence that the importance of enterprises to the construction of environmental ethics is related to the strength, sequence, and results of environmental pollution protection and governance [10]. If enterprises take their own interests first and still choose the development mode of pollution before treatment, it is easy to produce the tragedy of ethical commons in the allocation of environmental resources, which is a major hidden danger for the development of society and enterprises [11].

Relevant research results show that the restriction of environmental ethics will promote the use of materials in production and business activities. Waste disposal from production to sales will consciously follow the principle of reducing resource waste and environmental pollution, increase the innovation investment of green technology and green products, virtually form a competitive barrier, and improve the core competitiveness [12, 13]. Some scholars take the interaction between environmental ethics and green technology innovation as the starting point. Through empirical analysis, the results show that the green intellectual capital of enterprises will be positively affected by environmental ethics and promote the economic benefits of green innovation [14]. Other scholars pointed out that the enhancement of enterprises' awareness of green environmental management has a certain impact on their economic benefits and market competition, but many studies pay too much attention to the research on the change in green management cost, ignore the role relationship of other influencing factors, and the research results are inconsistent [15]. In terms of the impact of environmental ethics on enterprises, some scholars believe that environmental ethics is one of the specific manifestations of the corporate culture. It has an innovative influence on the technological innovation, management strategy, and operation concept of enterprises, directly or indirectly promotes the decision-making direction of the management for the development of enterprises, and high awareness of environmental ethics will also increase the initiative of enterprises to undertake environmental management responsibilities [16].

The development of the information age comprehensively and systematically shows the destruction of the natural ecological environment. More people are aware of the importance of environmental protection and green development. Relevant systems and regulations are constantly revised and improved to form a binding force on the economic behavior of enterprises [17]. Relevant research shows that the operation and production activities of enterprises are easily constrained by legitimate pressure from the outside. If enterprises want to achieve the profit goal, they need to invest in green technology and green products, realize green innovation, and obtain the recognition of the external environment and organization [18]. Therefore, some scholars pointed out that the environmental ethics responsibility to be undertaken by enterprises is a long-term responsibility integrated into various daily activities of enterprises, reflecting the consideration of ecological, social, and economic benefits [19]. Some scholars further pointed out that the reasons for the initiative of enterprises to undertake environmental ethical responsibility can be divided into internal driving forces and external driving forces. Among the external driving forces, the national legal system has important constraints on the norms of enterprise behavior; the cultural environment has a far-reaching impact on corporate culture and management concepts; the important node of the formation of ethics is the environment; and the feelings of stakeholders on corporate environmental ethical responsibility are related to the sustainable development ability of enterprises. Among the internal driving forces, corporate culture is the criterion reflecting the awareness and behavior of managers. Green environmental protection culture can promote enterprises to bear environmental responsibility and is one of the indirect indicators for enterprises to seek cooperation; the spirit displayed by the enterprise leadership is the core spirit of the enterprise behavior. The moral belief of the leadership largely determines the enterprise's ethical behavior [20]. In the Internet era, the status and role of enterprises in social development are more prominent. The greater the ability, the greater the responsibility. At present, the research results on the impact of enterprises' conscious environmental ethical responsibility on their performance are not accumulated, and further diversified, multifactor and multidirectional analysis and research are needed.

3. Factor Identification and Model Construction of Enterprise Environmental Ethics Affecting Enterprise Economic Benefits

When enterprises begin to change their ideas and take the initiative to undertake environmental ethical responsibility, their original business model will be affected, and the economic benefits will also change under the joint action of various influencing factors. Any change is multifaceted, and promoting the sustainable development of enterprises needs more positive influence and impetus. Therefore, identifying the influencing factors of economic benefits, understanding the action mechanism of influencing factors, and establishing relevant analysis theoretical models will be the content of this section [21].

3.1. Factors and Ways of Enterprise Environmental Ethics Affecting Enterprise Economic Benefits. According to the research data and literature related to enterprise environmental ethics and economic benefits, the research keywords are counted and analyzed with the help of appropriate and scientific measurement methods. The results show that the research focus of environmental ethics has been changing with the development of the global economy, science and technology, and society. In the literature published in the past 35 years, the research focuses most on the social responsibility of enterprises in environmental ethics, followed by the research on the sustainable development of enterprises and the environment. On this basis, it extends the changes and benefits of enterprises in environmental ethics. Among many keywords, the more they appear, the greater the basic function they play in relevant research, which is the basic driving force for the development of environmental ethics. During this period, there were two important changes in the keywords of environmental ethics research. Since 2010, keywords such as management strategic layout, innovation, and green environment have emerged, that is, in the initial stage of research, more research factors have been introduced with the changes in the external environment, which has enriched the research content and laid a foundation. Since 2015, under the influence of the Internet

economy, words about enterprise supply chains have entered the research field in an explosive way, and words related to environmental management and enterprise trust have begun to appear frequently, which has become an important goal of research on enterprise environmental ethics.

Enterprise ecological ethics is moral research on the relationship between enterprise and ecology, which expands enterprise ethics from enterprise social ethics to enterprise natural ethics. This is first the expansion of enterprise ethical values, and then the expansion of enterprise ethical objects and scope. It requires the formulation and implementation of new moral principles, moral norms, and moral practices of enterprise ecological ethics, which is a new field of enterprise ethics. Putting forward the problem of enterprise ecological ethics, it is rooted in the change in the relationship between enterprise activities and ecology. In the ethics system of enterprises, people generally only pay attention to dealing with the relationship between enterprises and the state, society, the public, and internal interpersonal relationships, that is, enterprise ethics mainly focuses on dealing with the relationship between people, pays attention to the social morality and interpersonal morality of enterprises, and pays little attention to the relationship between enterprises and the natural environment [22].

In the research in this field, when the number of studies on the factors affecting the economic benefits of enterprises by their environmental ethics is insufficient, the results are shown in Figure 1. Combined with the empirical analysis of the corresponding literature, the direct impact of social responsibility factors on the economic performance of enterprises is small in the actual environment. The environmental ethics consciousness generated by it can enhance the corporate culture and drive the innovation consciousness and ability of enterprises in green environmental protection. These scarce and irreplaceable resources obtained are innovation ability, reputation, and green technology. On the contrary, human resources and other factors have a sustained indirect effect on economic benefits. Therefore, in environmental ethics, the economic benefits of enterprises are most affected by enterprise innovation and reputation factors [23].

The influence of key factors is not only produced in a direct way but also has an indirect influence on each other. The direct impact has two sides, not only showing enthusiasm but also the fundamental purpose of enterprise operation is to obtain profits. It actively undertakes social responsibility, reduces the pressure on the government, is conducive to obtaining policy support, effectively forms strategic relations with stakeholders, and obtains additional economic value. A positive public image reduces the risk level of capital evaluation, improves the freedom of business activities, increases brand recognition, widens the market, and drives economic benefits. However, if the economic benefits obtained by the enterprise are far lower than the capital cost invested, the economic loss will reduce the amount of funds. Under the condition of limited capital resources, the enterprise will face the pressure of operation pressure and increased

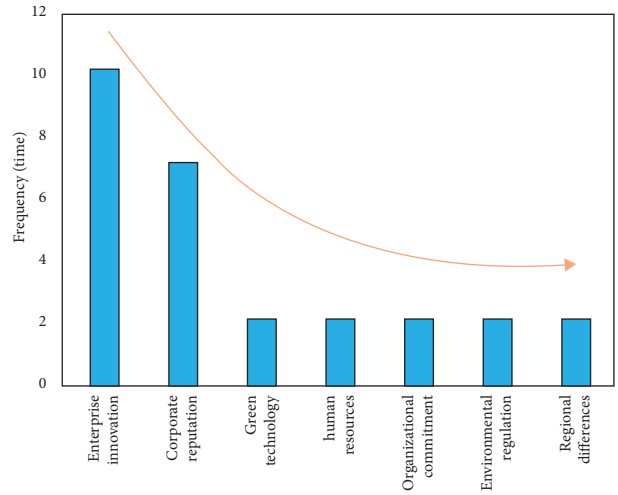

Figure 1: Identification results of key factors in environmental ethics research in the cited literature.

opportunity cost. As shown in Figure 2, it is the way in which enterprise environmental ethics factors affect economic benefits.

Compared with the direct impact, the indirect impact has more sustainability and importance in terms of enterprise benefits. If enterprises voluntarily meet higher green environmental protection standards, they must improve and innovate the existing systems, management methods, and technologies, promote the research and development of new products, and improve the innovation ability of enterprises. In the information age, the level of independent innovation capability reflects the productivity level and development potential of an enterprise. Therefore, the development process of innovation effect is also a process for enterprises to expand the scope of cooperation and improve economic benefits. At the same time, the responsible behavior of the enterprise can obtain a good reputation, strengthen the identity of the interest community and partners inside and outside the enterprise, improve the understanding of the industry and other industries in a short time, and provide positive and effective help for the production and development of the enterprise. In addition, the high-quality corporate image can attract more high-quality employees, cooperation, and consumers, create a relatively stable and good living environment for enterprises, and promote the expansion of market share.

3.2. Theoretical Model and Intermediary Mechanism of Enterprise Environmental Ethics. According to the mediating effect and path theory, the mediating effect of the key factors of enterprise environmental ethics can be divided into three parts. The first part mainly shows the effect of enterprises actively undertaking environmental protection responsibility on their performance. This part will be combined with the habitual characteristics of performance economic indicators. The basic dynamic panel model takes Y_{mt-1} as the independent variable, and $t-1$ represents the delayed period, as shown in formula (1):

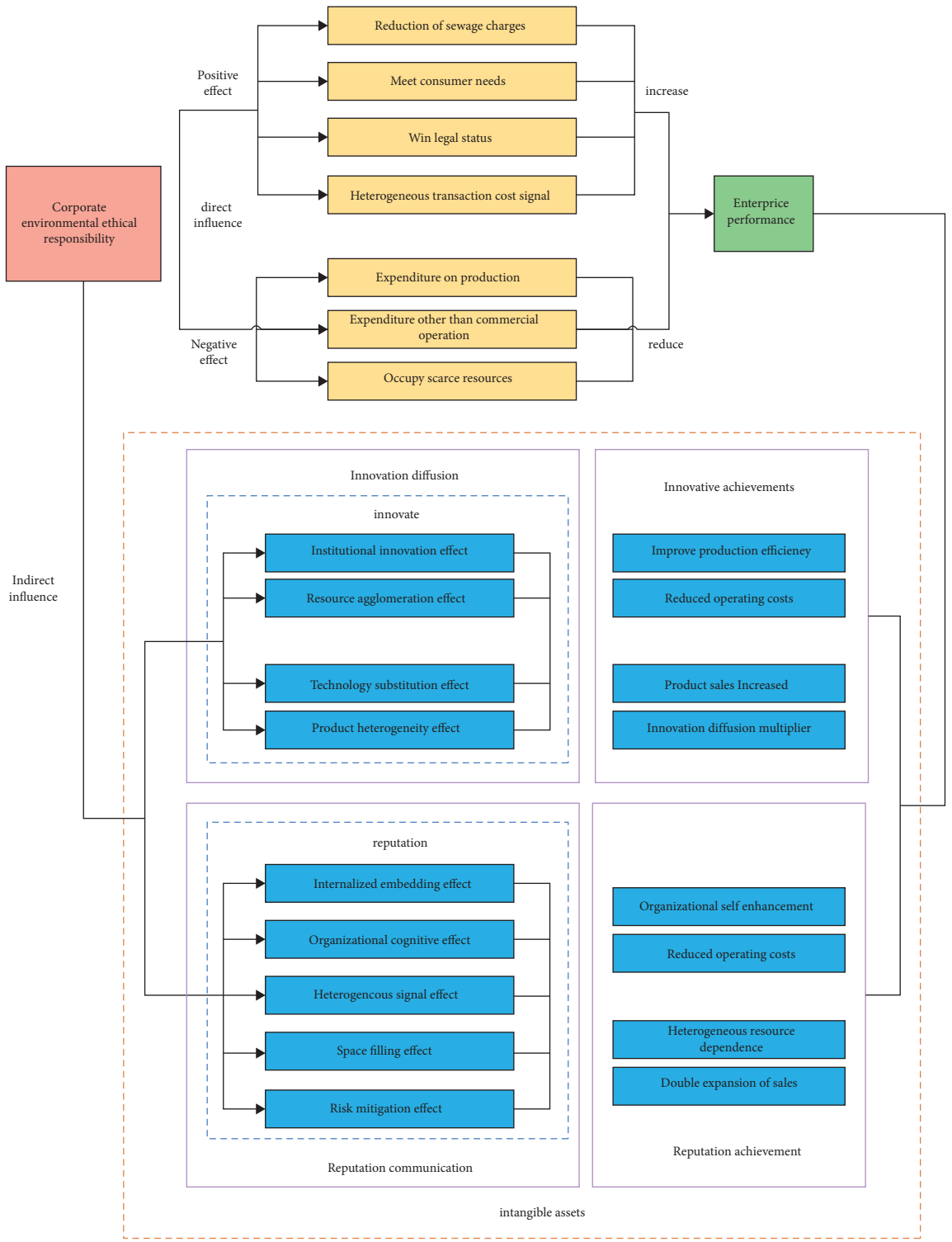

Figure 2: The way of the influence of enterprise environmental ethics factors on economic benefits.

$$Y_{mt} = \lambda_{10} + \varphi_{11} \cdot Y_{mt-1} + \varphi_{12} \cdot \text{Ceer}_{mt-1} + \sum_{n=3}^{k} \varphi_{1n} C_{mnt} + \alpha_{1mt}, \quad (1)$$

where Ceer_{mt-1} stands for the delayed corporate environmental ethics responsibility, C_{mnt} is the control variable, and φ stands for the impact.

The second part shows the effect of innovation and reputation as intermediary variables, as shown in formula (2):

$$Me_{mt} = \lambda_{20} + \varphi_{21} \cdot Me_{mt-1} + \varphi_{22} \cdot \text{Ceer}_{mt-1} + \sum_{n=4}^{k} \varphi_{2n} C_{mnt} + \alpha_{2mt}. \quad (2)$$

It shows the effectiveness of the intermediary function of the intermediary variable, as shown in formula (3):

$$\begin{aligned} Y_{mt} &= \lambda_{30} + \varphi_{31} \cdot Y_{mt-1} + \varphi_{32} \cdot \mathrm{Ceer}_{mt-1} \\ &\quad + \varphi_{33} \cdot \mathrm{Me}_{mt} + \varphi_{34} \cdot \mathrm{Me}_{mt} \cdot \mathrm{Ceer}_{mt-1} \\ &\quad + \sum_{n=5}^{k} \varphi_{3n} C_{mnt} + \alpha_{3mt}. \end{aligned} \tag{3}$$

According to the regulation effect, (4) and (5):

$$\begin{aligned} Y_{mt} &= \lambda_{40} + \varphi_{41} \cdot Y_{mt-1} + \varphi_{42} \cdot \mathrm{Ceer}_{mt-1} \\ &\quad + \varphi_{43} \cdot Mo_{mt} \cdot \mathrm{Ceer}_{mt-1} \\ &\quad + \varphi_{44} \cdot Mo_{mt} + \sum_{n=5}^{k} \varphi_{45} C_{mnt} + \alpha_{4mt}, \end{aligned} \tag{4}$$

$$\begin{aligned} Y_{mt} &= \lambda_{50} + \varphi_{51} \cdot Y_{mt-1} + \varphi_{52} \cdot \mathrm{Ceer}_{mt-1} \\ &\quad + \varphi_{53} \cdot \mathrm{Me}_{mt} + \varphi_{54} \cdot Mo_{mt} + \varphi_{55} \cdot Mo_{mt} \cdot \mathrm{Me}_{mt} \\ &\quad + \sum_{n=6}^{k} \varphi_{5n} C_{mnt} + \alpha_{5mt}. \end{aligned} \tag{5}$$

Among them, if φ_{43} shows obvious statistical significance, it plays an obvious regulatory effect in the direct impact of environmental ethical responsibility on performance; and if φ_{55} shows obvious statistical significance, it will play an obvious regulatory effect in the indirect impact of environmental ethical responsibility on performance, as shown in Figure 3.

The above formula is solved by the system generalized moment estimation method. According to the relevant acquisition principles, the overall moment conditions are expressed in (6):

$$E\left(Z_m'\left(\Delta y_m - \lambda \Delta y_{m,-1} - \Delta X_m \varphi\right)\right) = 0. \tag{6}$$

The corresponding sample moment conditions are expressed in (7):

$$g_j = \frac{1}{N} \sum_{m=1}^{N} Z_m'\left(\Delta y_m - \lambda \Delta y_{m,-1} - \Delta X_m \varphi\right) = 0. \tag{7}$$

The minimization objective function is shown in (8):

$$\begin{aligned} &\min_{\lambda,\varphi} \left[\frac{1}{N} \sum_{m=1}^{N} Z_m'\left(\Delta y_m - \lambda \Delta y_{m,-1} - \Delta X_m \varphi\right)\right]' W_N \left[\frac{1}{N} \sum_{m=1}^{N} Z_m'\left(\Delta y_m - \lambda \Delta y_{m,-1} - \Delta X_m \varphi\right)\right], \\ &W_N = \left(\frac{1}{N} \sum_{m=1}^{N} Z_m' Z_m\right)^{-1}. \end{aligned} \tag{8}$$

After solving, the parameter estimation solution can be obtained as expressed in (9):

$$\begin{pmatrix} \widehat{\lambda} \\ \widehat{\varphi} \end{pmatrix} = \left(\left(\sum_{m=1}^{N} \begin{pmatrix} \Delta y_{m,-1}' \\ \Delta X_m' \end{pmatrix} Z_m\right) W_N \left(\sum_{m=1}^{N} Z_m \left(\Delta y_{m,-1} \;\; \Delta X_m\right)\right)\right)^{-1} \left(\left(\sum_{m=1}^{N} \begin{pmatrix} \Delta y_{m,-1}' \\ \Delta X_m' \end{pmatrix} Z_m\right) W_N \left(\sum_{m=1}^{N} Z_m' \Delta y_m\right)\right). \tag{9}$$

The innovation and reputation of enterprises play a driving force in economic performance. In addition to meeting internal needs, they should also continue to spread, realize innovative applications in a wider range, and obtain reputation recognition in a wider field. Enterprises acquire relevant knowledge through knowledge transfer in cooperation, which can increase their understanding of the feasibility of knowledge innovation, so as to improve the willingness of enterprises to cooperate and innovate and promote the improvement of innovation income. Knowledge flows among enterprises through transfer, and the diversification and differentiation of knowledge make cooperative enterprises expand the breadth and depth of shared knowledge, and improve the speed of enterprise learning, which is conducive to the formation of cooperative innovation ability. Further, promote value creation and improve innovation performance. Therefore, the way and breadth of factor communication will bring changes to the benefits of enterprises to a certain extent. The communication of innovation and reputation has a latent period, that is, the accumulation of enterprises in two aspects. Once the two meet the communication conditions, they will continue to spread to the supply chain and the market, and have a corresponding impact.There are M enterprises in the communication network, and they meet the conditions

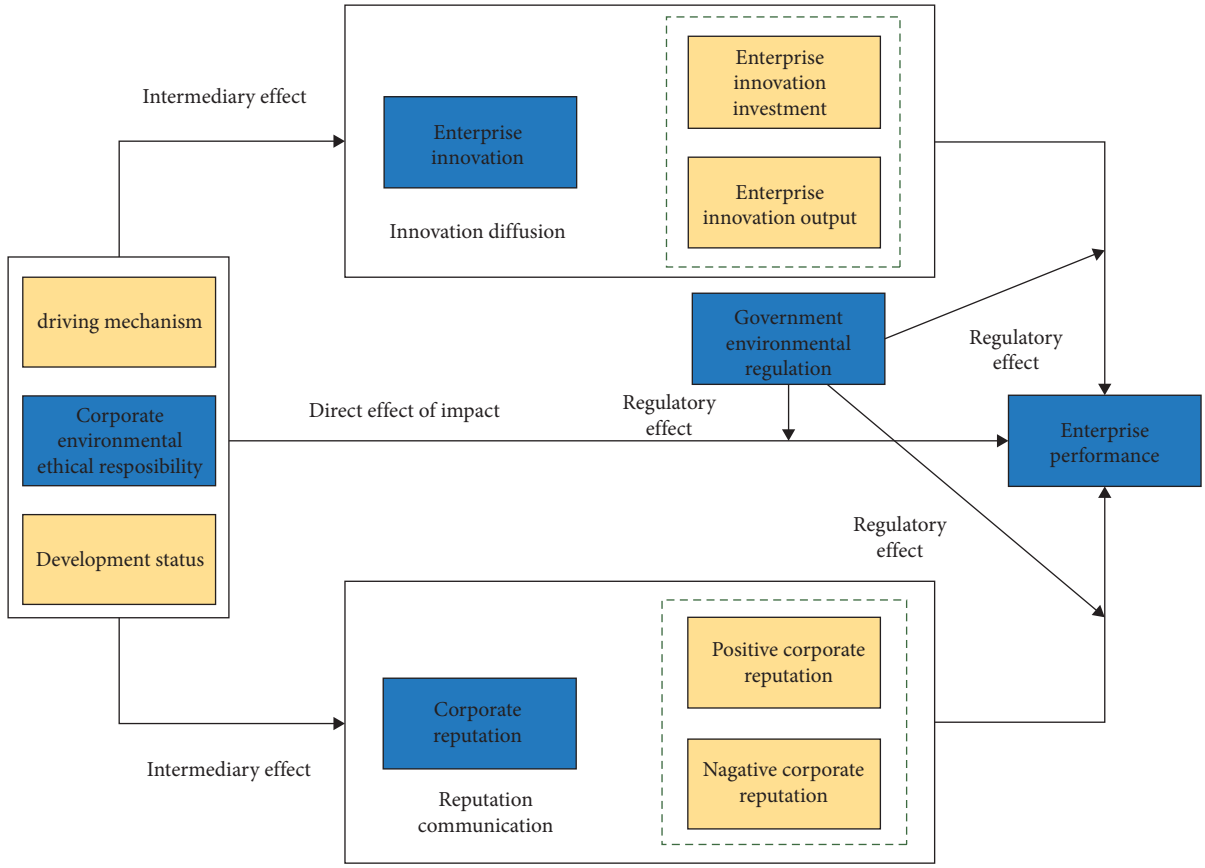

Figure 3: Schematic diagram of the mechanism of corporate environmental ethical responsibility affecting corporate performance.

stated in (10):

$$\begin{cases} s(t) = \dfrac{S(t)}{M}, \\ e(t) = \dfrac{E(t)}{M}, \\ i(t) = \dfrac{I(t)}{M}, \\ r(t) = \dfrac{R(t)}{M}. \end{cases} \tag{10}$$

The factor propagation equations are shown in (11):

$$\begin{cases} \dfrac{\mathrm{d}s(t)}{\mathrm{d}t} = \varepsilon r(t) - \alpha s(t) - bs(t), \\ \dfrac{\mathrm{d}e(t)}{\mathrm{d}t} = \alpha s(t) - \beta e(t) - ve(t), \\ \dfrac{\mathrm{d}i(t)}{\mathrm{d}t} = \beta e(t) - \sigma i(t), \\ \dfrac{\mathrm{d}r(t)}{\mathrm{d}t} = bs(t) + \sigma i(t) + ve(t) - \varepsilon r(t), \end{cases} \tag{11}$$

α represents the acceptance probability of the factor, β represents the propagation conversion rate of the factor, v represents the failure probability of the transformation of potential propagation targets, σ represents the success probability of the transformation of propagation targets, ε represents the probability of repropagation conversion of the transformation failed targets, and b represents the rate of rejection of propagation.

Formula (12) represents the propagation equation of the innovation factors transformed by the above formula in the complex network:

$$\begin{cases} \dfrac{\mathrm{d}s(t)}{\mathrm{d}t} = \varepsilon r(t) - \langle k \rangle (\alpha_1 e(t) + \alpha_2 i(t)) s(t) - bs(t), \\ \dfrac{\mathrm{d}e(t)}{\mathrm{d}t} = \langle k \rangle (\alpha_1 e(t) + \alpha_2 i(t)) s(t) - \beta e(t) - ve(t), \\ \dfrac{\mathrm{d}i(t)}{\mathrm{d}t} = \beta e(t) - \sigma i(t), \\ \dfrac{\mathrm{d}r(t)}{\mathrm{d}t} = bd(t) + \sigma i(t) + ve(t) - \varepsilon r(t), \end{cases} \tag{12}$$

where α_1 represents the coefficient of easily accepted communication target transformed from accepted communication target to accepted communication target, α_2

represents the coefficient of easily accepted communication target transformed from transmitted target to accepted communication target, and $\langle k \rangle$ is the average value of the number of connections between all enterprises in the network and other enterprises.

The propagation system is a boundary region, i.e., $D\{(e,i,r)|e,i,r \geq 0 \text{and} e+i+e \leq 1\}$. Combined with the normalization condition $s(t)+i(t)+e(t)+r(t)=1$, the propagation threshold is obtained through the equilibrium relationship, as shown in formula (13):

$$\hbar = \frac{\varepsilon\langle k \rangle (\alpha_1 \sigma + \alpha_2 \beta)}{\sigma(\beta+\nu)(b+\varepsilon)}. \tag{13}$$

When the threshold is greater than 1, innovation continues to spread, otherwise, it stops gradually.

The scale-free propagation model of the reputation factor is shown in (14):

$$\begin{cases} \dfrac{\mathrm{d}s(t)}{\mathrm{d}t} = -k(\alpha_1\Theta_1 + \alpha_2\Theta_2)s_k(t) - bs_k(t) + \varepsilon r_k(t), \\ \dfrac{\mathrm{d}e_k(t)}{\mathrm{d}t} = k(\alpha_1\Theta_1 + \alpha_2\Theta_2)s_k(t) - \beta e_k(t) - \nu e_k(t), \\ \dfrac{\mathrm{d}i_k(t)}{\mathrm{d}t_k(t)} = \beta e_k(t) - \sigma i_k(t), \\ \dfrac{\mathrm{d}r_k(t)}{\mathrm{d}t_k(t)} = bs_k(t) + \sigma i_k(t) + \nu e_k(t) - \varepsilon r_k(t), \end{cases} \tag{14}$$

where $\Theta_1 = \sum kp(k)E_k(t)/\langle k \rangle$ represents the communication probability between the reputation recognition target and any user at this time, and $\Theta_2 = \sum kp(k)I_k(t)/\langle k \rangle$ represents the communication probability between the reputation communication target and any user at this time. The threshold is expressed as formula (15):

$$h = \frac{\langle k^2 \rangle}{\langle k \rangle}\left(\alpha_1 \frac{\sigma}{\beta} + \alpha_2\right)\frac{\varepsilon\beta}{b\nu\sigma + b\beta\sigma + \nu\sigma\varepsilon + \sigma\varepsilon\beta}. \tag{15}$$

4. Simulation Experiment Results

4.1. Analysis of the Influence Factors of Enterprise Environmental Ethics on Economic Benefits. Suppose there are 400 enterprises in the network, and the communication model parameter is $\alpha = 0.5, \beta = 0.2, b = 0.04, \nu = 0.1, \varepsilon = 0.07$, and $t = 0.01$. The influence of factors is analyzed in the time dimension. The time of the communication process starts from 0 to 30, as shown in Figure 4. The results show that in the whole communication process, the communication speed of innovation factors is gradually decreasing, and the proportion of enterprises that accept innovation communication and turn into communicators has been increasing. The number of enterprises that are easy to accept communication, potential to accept communication, and refuse to participate in communication shows different downward trends, that is, a certain number of enterprises turn into

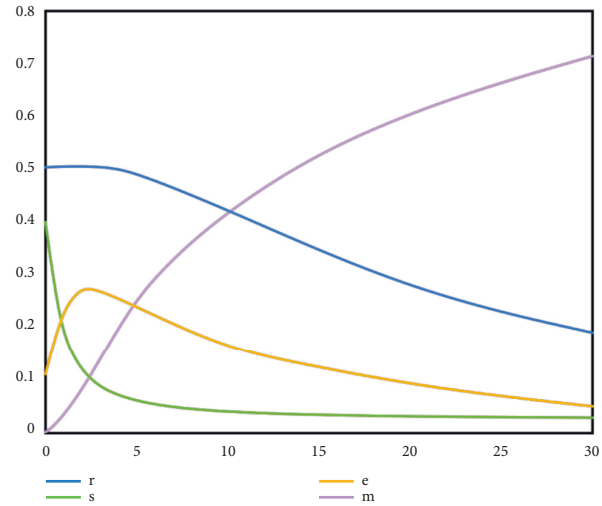

Figure 4: Innovation factors affect the change results in time dimension.

communicators with different acceptance targets, The higher the conversion rate, the wider the propagation speed and range. In addition, the increase in exchanges between different enterprises will promote the dissemination of innovation factors and attract more attention from enterprises. The larger the scale of dissemination, the more it can promote the dissemination of innovative technologies and products and obtain more economic benefits. Compared with traditional technologies and products, green technologies and products can improve the production capacity of enterprises, optimize processes, and reduce costs, which is more in line with the needs of society for environmental protection, improve market competitive advantage, and achieve higher performance. Improving the green ability of enterprises will help enterprises better solve environmental problems, help enterprises win green benefits, occupy a strong position in the competition, and finally, help enterprises achieve green development.

In the reputation factor propagation model, the number of users is 25000, the parameter values are $\alpha = 0.8, \beta = 0.3$, $b = 0.04$, and $\nu = 0.1, \sigma = 0.01, \varepsilon = 0.07$, and the propagation time is 20. Figure 5 shows the change results of reputation factors in the time dimension. The proportion of communicators keeps increasing in the overall communication process of reputation factors, and the proportion of easily accepted communication targets has maintained a downward trend and the decline rate is gradually decreasing. The rate of its transformation into communication will largely affect the communication speed and scale of reputation factors, and there is a certain positive correlation between them; the proportion of targets who agree with reputation but do not spread first maintains the upward trend of decreasing rate, and then changes to the downward trend until it is relatively stable; and the target proportion refusing to accept the communication has been declining at a stable rate, which can reflect the negative public opinion of the enterprise, but the reputation of the enterprise cannot be completely erased by a certain amount of negative

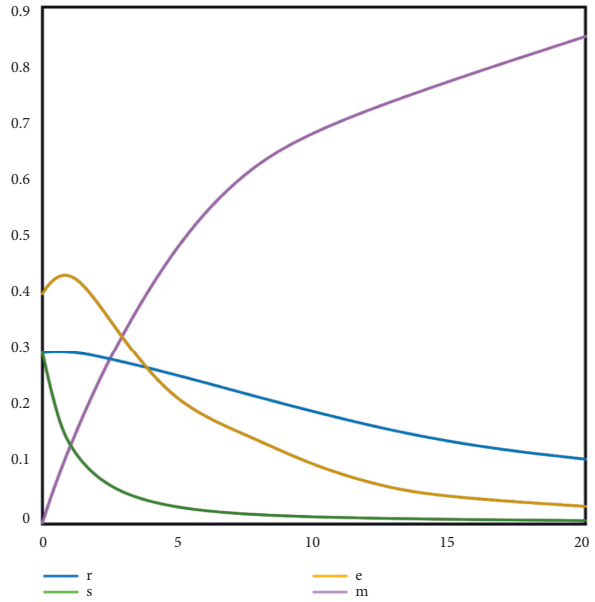

Figure 5: Reputation factors affect the change results in the time dimension.

information, and the nonprincipled and essential negative information will not completely cut off the communication channel of the enterprise reputation. This shows that the longer the reputation factor spreads, the more attention, familiarity, and recognition it will receive, improve brand awareness, promote enterprises to cooperate with more enterprises, obtain more production factors, reduce enterprise costs, increase consumers' purchase possibility, and increase enterprise economic benefits. In addition, a good reputation creates a better environment and market for the development of the enterprise to a great extent. In the face of sudden negative public opinion, it can obtain processing time and maintain the operation of the enterprise.

4.2. Empirical Results on the Factors of Enterprise Environmental Ethics Affecting Enterprise Economic Benefits. According to the relevant social responsibility reports, this paper selects 460 listed enterprises in recent 10 years as the research sample, selects 16 variables such as score, performance, return on assets, scale, debt ratio, and innovation obtained by enterprises taking the environmental ethics responsibility actively, and carries out the corresponding sample regression analysis through the statistical method. In big data analysis, regression analysis is a predictive modeling technology, which studies the relationship between dependent variables (targets) and independent variables (predictors). This technique is usually used for predictive analysis, time-series models, and the discovery of causal relationships between variables. Figures 6 and 7 show the test results and relevant variable coefficients of the direct impact of corporate environmental ethics on performance. It can be seen from the results that there is an obvious correlation between the scores obtained by enterprises taking the initiative to bear environmental responsibility and their performance, scale, and debt ratio. The first two are positive correlations

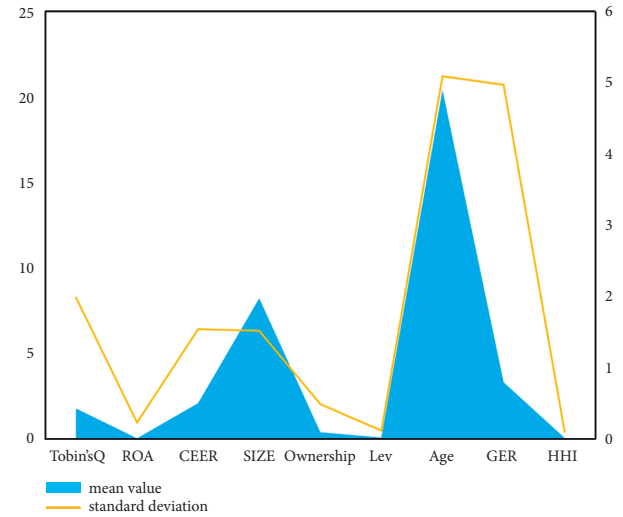

Figure 6: Test results of the direct impact of corporate environmental ethics on performance.

	one	two	three	four	five	six	seven	eight
Tobin'sQ	1.00							
ROA	0.151***	1.00						
CEER	0.053***	0.01	1.00					
SIZE	-0.288***	0.041**	0.009***	1.00				
Ownership	0.182***	-0.014	-0.07	-0.238***	1.00			
Lev	-0.277***	-0.027	-0.069***	0.082***	-0.187***	1.00		
Age	-0.107***	-0.029**	0.034**	-0.079**	-0.108***	0.122***	1.00	
GER	0.032***	-0.024	0.005	-0.008	-0.078***	0.092***	0.02	1.00
HHI	0.061***	-0.002	0.036	0.092***	-0.059***	0.05***	-0.049***	0.048***

***(p<1%); **(p<5%); *(p<10%)

Figure 7: Enterprise environmental ethics has a direct impact on performance.

and the last one is a negative correlation. There is no obvious correlation between it and the overall return on assets of the enterprise. The corresponding regression analysis shows that the short-term return on assets will be positively affected by environmental ethical responsibility factors, but it is not obvious. The positive corresponding effect will be prominent after the extension of time. At this time, it is the long-term return on assets index. In terms of direct impact effect, enterprises' active undertaking of environmental ethics responsibility will have a delayed positive impact on economic benefits, and the effect is not obvious in the initial stage, but obvious in the long term.

As shown in Figure 8, the results of the mean and standard deviation of the variables related to innovation factors and reputation factors are shown in Figure 9 and Figure 10. From the results, there is a certain difference in the correlation between the environmental responsibility score and innovation factor variables, that is, it shows an obvious correlation between the cost generated by innovation and the innovative output breaking through the tradition. When the innovative output still maintains the traditional performance, the correlation is not obvious. Regression analysis shows that enterprises' voluntary improvement of environmental ethics standards has a positive

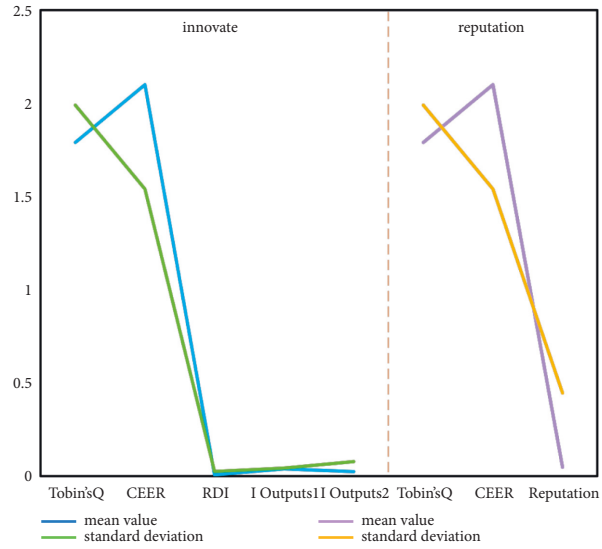

Figure 8: The mean and standard deviation results of variables related to innovation factors and reputation factors.

	one	two	three	four
Tobin'sQ	1			
CEER	0.0522***	1		
RDI	0.3429***	0.0207*	1	
Innovation	0.1468***	0.0306	0.1884***	1
Innovation	0.1345***	0.0608**	0.0163	0.303***

***(p<1%); **(p<5%); *(p<10%)

Figure 9: Innovation factor variable correlation coefficient results.

	one	two	three
Tobin'sQ	1		
CEER	0.0519***	1	
Reputation	0.0502***	0.0444***	1

***(p<1%); **(p<5%); *(p<10%)

Figure 10: Reputation factor variable correlation coefficient results.

effect on the cost input increased by innovation, but it has different effects on different types of innovation output, that is, it has no obvious effect on breakthrough output, while nonbreakthrough output has an obvious positive effect. Therefore, when the direct effect of enterprises undertaking the role of environmental ethical responsibility on their own performance is weak, nonbreakthrough innovation factors will affect part of the effect on performance in the communication process, resulting in a conductive effect.

Compared with innovation factors, there are few variables related to corporate reputation factors, and the values of sample corporate reputation indicators are not high, which indirectly reflects that it is difficult for enterprises to maintain a good reputation. In addition, the reputation of the sample enterprises is uneven, and the difference is obvious. The reputation is obviously positively affected by the enterprise's initiative to bear environmental responsibility. In its regression performance, it also has a conductive effect on performance, that is, in the process of the gradual weakening of the direct effect, it will partially affect the transmission and play a role in performance.

To sum up, the longer the reputation and innovation factors exist, the more they will attract the attention of the enterprise; and the longer the acceptance time of the enterprise's reputation and innovation, the more they will play a role in promoting the economic growth of the enterprise. In addition, the direct effect of environmental ethical responsibility on performance is delayed, and the effect is more obvious in the long run. When the direct effect is weakened, the intermediary effect of innovation and reputation factors will transmit part of the influence to economic benefits and play a role. There is a positive correlation between the performance of corporate environmental responsibility and corporate value. Enterprises' performance of environmental responsibility will improve their social reputation, thereby increasing enterprise value. When there is a negative correlation, it means that undertaking environmental responsibility will increase costs and reduce short-term profits. This leads to the disadvantages and lack of competitiveness of enterprises in the same category. Irrelevant means that enterprises will increase production costs by assuming social responsibility, but it will also bring benefits. For example, it improves the utilization rate of resources and so on.

5. Conclusion

The ecological environment is the basic space for human survival and social development. The deterioration of natural environmental conditions and the shortage and scarcity of resources are mostly caused by the excessive pursuit of economic interests and human survival interests. Facing the problems and negative effects brought by the change in the ecological environment, all sectors of society should take the initiative to bear the corresponding ethical responsibility. Taking effective environmental protection measures, improving environmental protection technology, and developing green products are the trend for enterprises to achieve sustainable development. However, due to the differences in the cognition of different enterprises on environmental ethical responsibility and environmental awareness, it is difficult to make reasonable and effective decisions. Based on the relevant literature, this paper analyzes the factors that enterprises actively undertake environmental ethical responsibility and the key factors that affect performance. And through the effect model and communication, the mechanism of influencing factors in performance is analyzed. The experimental results show that the longer the transmission

time of innovation and reputation factors, the more enterprises accepted and recognized, and the more likely the enterprises that initially did not accept to become communicators so as to increase the scope and attention of enterprise resources, improve market competitiveness, and promote the improvement of economic benefits. At the same time, a good reputation helps enterprises develop a good living environment, obtain the support of more stakeholders and the recognition of consumers, and increase the probability of cooperation and consumption. In addition, through correlation regression analysis, it is concluded that enterprises' conscious undertaking of environmental ethical responsibility has a lagging positive impact on performance, that is, from the perspective of long-term development, undertaking environmental ethical responsibility plays an obvious role in promoting performance improvement. In the empirical analysis, this study gives all dimensions of the internal innovation environment and all indicators of enterprise performance completely equal weight. This may be different from the real situation. Therefore, future research needs to consider more practical factors and improve the internal innovation environment of enterprises to form an important factor system. There is no dynamic analysis of the samples, so the respondents can be tracked in the future in order to get a more detailed and specific analysis.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Real Estate Tax, Housing Price, and Housing Wealth Effect: An Empirical Research on China Housing Market

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Housing market occupies a large part of the wealth of the whole society in most countries, and real estate tax plays an important role for the government to maintain sustainable development for the economy. As consumption being a major issue nowadays, in this paper, we want to find out (1) whether real estate taxes affect the house price in China and whether the affects vary among different tax types? (2) whether there exists wealth effect in China housing market? That is, whether the change in house wealth (price) affects the consumption? (3) whether and how do real estate taxes affect wealth effect? We set up the empirical model by using the GMM method on panel data from 2002 to 2016 to explore the relations among real estate tax, housing price, and wealth effect. We considered the influence of four different types of real estate tax on the housing price and found the results are mixed. Besides, there is a significantly negative wealth effect on China housing market. Finally, house price plays a mediator role in the effect of the real estate tax on the consumption.

1. Introduction

China housing market has shown rapid growth along with the glorious economic development since 2000—the wealth of housing market occupied 6.8% of the GDP in China in 2018, and the expenditure of house account for nearly 80% of the family assets. In this case, the healthy development of China real estate industry plays an essential role in household wealth and consumption, as well as the social stability. As real estate tax is the vital fiscal policy, the implementation of real estate tax policies would have a crucial impact on both housing market price and household wealth [1, 2]. Therefore, it is meaningful for the policymakers to find out how to develop an appropriate real estate tax system to manipulate the market, and accordingly, the consumption.

Real estate tax has its own unique characteristics in China. Different from other developed countries, instead of a single real estate tax, there are two subjects should pay for the taxes in China: the real estate developer and the house buyer, and they should pay for the taxes when the transaction happens, including farmland occupation tax, urban land utilization tax, value-added tax, deed tax, and so on. Even though China government has already developed a number of tax policies in housing markets, for instance, piloting the house property tax in Chongqing and Shanghai in 2011, making the legislative plan of house property tax law in 2015, and putting the housing property tax in the fiscal and taxation reform in 2016, the major tax policies are still maintained for most of the province [3, 4]. More recently, the China government reviled that the new real estate tax policies, specific policy details are still not determined, would be applied in more cities and extend from business real estate to living real estate, which would maintain 5 years since 2022. According to these situations, in this paper, we will still consider how the multiple real estate taxes impact the housing market.

Fundamentally, as the real estate taxes overlap to some extent, and the government does not have consistent or clear principles in making a real estate tax system, we want to

explore whether and how do real estate taxes types affect the housing price. And then, as consumption being a major issue nowadays in China, with a low consumption rate, we want to explore the wealth effect in the housing market, that is, to find out whether the change in real estate value would affect the consumption. Besides, we would also test whether the real estate taxes will influence the wealth effect and what is the mechanism. It is important to administrations and governments to understand how real estate taxes impact housing market wealth, so as to inform the appropriate designs and implementations of real estate taxes.

The present literature found inconsistent results in the above questions. First, the wealth effect in the housing market is mixed. While some of the research studies argued that the change of housing prices would increase the consumption in multiple countries [5–7], however, the others found insignificant results [8, 9]. The studies referred to real estate tax mostly test the relation between tax and price, while few considered the impact of tax on consumption, and even the results of tax and housing price were inconsistent [10–12]. Leaving aside the debates in the present studies, the majority of research studies are concerned the mature markets and advanced economies, while the characteristics of the housing markets have not been yet systematically researched for China and other emerging market economies. Therefore, this paper focuses on China housing market, considers the wealth effect in China housing market, and explores how different types of real estate taxes, affect the house price and consumption. The paper contributes to the extant literature by considering the housing market characteristics in China and analyzing the wealth effect from the tax aspect. Besides, it is also meaningful for the policymakers to make an appropriate real estate tax system to develop a sustainable housing market and a macroeconomy.

2. Literature Review

2.1. Real Estate Tax and House Price. The real estate tax is the vital means and tool for government to make macroeconomic adjustments and its functions can be summarized into three aspects: increasing the local government revenue, stabilizing housing market price, and reallocating the income [13–15]. The second function, which related to the housing price, is the vital means to adjust housing market price and has attracted much attentions in the previous literature [16].

Theoretically, the impact of real estate tax is not so straightforward. First, the literatures focus on the taxation shifting perspective. Similar with other kinds of taxation, the real estate tax will also turnover, shifting between buyers and sellers of properties. As such, imposing tax would cause the fluctuation in the housing market. The housing market elasticity determines the relation between real estate tax and price [17, 18]. Second, from the capital pricing perspective, researchers argue that tax tends to restrict the growth of house. In short-term, imposing property tax will reduce the supply, which then lead to low efficiency. In long-term, imposing property tax will lead to price decrease. In this sense, imposing the property tax shall be an effective means contributing to restrict speculative demand in housing market [19, 20].

Accordingly, plenty of prior empirical studies have tested the influence of real estate tax on housing market prices, yet research outcomes are not consistent [12, 21–28]. Some researchers argue the negative role of the tax to housing price. Slemrod et al. [21] tested the influence of estate tax on national wealth using the dataset from US estate return data and found that national wealth is negatively associated with the level of estate taxation. Similarly, Van den Noord [22] analyzed the relationship between tax and price euro nations and revealed the negative role of tax to housing price, saying the larger tax incentives trigger larger house price volatility. Also, the research of Cebula [12] explored property tax in Georgia using the dataset of single-family houses and found that the property tax level is negative to price of a household. Best and Kleven [23] analyzed the influence of UK transaction taxes on housing market, pointed out that transaction taxes significantly distort the price. Other researches show the opposite results, claiming the positive effect of the tax on housing prices. Rosen and Fullerton [24] found that the tax would transfer into public service and at least 75% of them would shift to the housing price. Cheung et al. [25] claimed tax is a regulatory component of price. Still, the rest studies argue that real estate tax does not have a significant impact on housing price. Kuang [26] has argued that property tax does not show a big effect on housing price. Rather, it is the price elasticity that plays a dominant role to impact housing price. Duca et al. [27] revealed that real estate taxes may lead to diversity in the international and regional house prices which would affect consumer's behavior in multiple dimensions. Agarwal et al. [28] found that Capital gains tax increase in the housing market leads to higher tax evasion and the house price shows the different impact on cash buyers verse financial buyers.

Specifically, in China, the studies about real estate are also mixed and vary among provinces. In the work of Wang et al. [29], they critically evaluated how China property tax policy impacts the local housing market and found consumers' demand elasticity will change due to the property tax, so as to trigger the change of housing price. Wu [30] found that the real estate tax has been completely shifted to buyers in China housing market, which further pushes the higher housing price. Bai et al. [31] examine the influence of policy experiment of property taxation in 2011 on price in China. The empirical results revealed that the property tax experiment has a negative influence on Shanghai. However, in Chongqing, the property tax experiment plays a positive role. Du and Zhang [32] empirically assessed how trial property taxes in selected control cities in China. They reveal trial property tax reduces the price growth in Chongqing, while it does not have significant influence in Shanghai. Liu [33] pointed out that a majority of urban households have purchased housing properties in the absence of a property tax which may lead to a less sensitive reaction to the new real estate tax policies. Wang et al. [34] found that with the development of digital technologies, the online listing information of house price index construction would contribute to clarify the house price structure.

As we can conclude from the above literature, the relation between real estate tax and house price has attracted plenty of attentions, however, there are still no consistent conclusions on it, especially in China housing market, which the real estate tax system is still immature. Apart from that, the literature focused on different types of real estate is even rare, which bring us an opportunity to explore it in emerging markets.

2.2. Wealth Effect in Housing Market. In housing market, the wealth effect refers that the real estate wealth will directly change along with the change of housing price, and consequently, the increased or decreased real estate wealth will impact the consumption expenditure of people [35].

There are mass of research studies focusing on housing price and consumption, while results are still inconsistent. First, based on the assumption of the permanent income hypothesis [36] and life-cycle hypothesis [37], the increase of house price would lead to a high consumption level. Carroll et al. [38] tested the data in the USA and found that higher house prices indicate the higher household consumption on an aggregate level. Similarly, Poterba [39] found that even though the house owners did not sell the house, the increasing house price would still make them fell wealthier and spend more. Campbell and Coco [6] claimed the real estate could substitute for saving, and he used the survey data from British and found if the house price increased 1%, the consumption would increase 1.7% accordingly. Second, however, some researchers argued the negative effect of house price on consumption, result from the high expenditure on purchasing a house or paying back the house loan [8, 36]. Phang [8] used the data from Singapore to figure out that higher house price leads to a lower total consumption, which results in the spillover effect. Burrows [40] found that no matter how the house price changed, people always maintain a low consumption level. Apart from these two opposite findings, some literature claim the insignificant relation between them [41, 42]. For example, Buiter [41] said that the wealth effect in the housing market is not significant and it only works for the people who have multiple houses. Browning et al. [42] tested housing wealth and consumption in Danish and their statistical results indicate that housing price has little influence on resident consumption. De Roiste et al. [43] investigate the housing wealth on consumption by using synthetic panel series of household survey data and found that the house wealth shows a curve shape and an asymmetric effect. Suari-Andreu [44] estimates housing wealth by Dutch panel data and measures the house price shocks by self-reported house price expectations, which lead to the results that the correlation between house prices and consumption is ascribed to common causality. Christelis et al. [45] explored the heterogeneous wealth effects in real estate industry and found that the average house wealth effect is between 2 and 5% and the consumption response to positive wealth shocks is greater than the response to negative shocks.

In Chinese market, previous studies also still have debates about whether the wealth effect of real estate is positive or negative though most studies have revealed that there is wealth effect in housing market [46–52]. Dong et al. [46] the wealth effect occurs when price-to-income ratio is low by using the data from 35 major Chinese cities. Chen et al. [47] used permanent–transitory variance decomposition analysis to indicate that short-term consumption is permanent, and the long-term consumption will change along with the house price. Koivu [48] used the structural vector autoregression method and found that the wealth effect is weakly positive but significant in China. Contrary to the former findings, Ye et al. [49] unveiled the negative effect and claimed that it is the major effect in most cities in China. Still, the mechanism is still ambiguous. Chen et al. [50] used a countrywide survey data to examine the house wealth effect and found that compared with developed economies, China has a much larger housing wealth effect and a household's consumption varies across housing tenure. Li et al. [51] considered the discontinuity in house size to identify the house wealth effect and found that the young generation with high repayment capacity is more responsive to gains in housing wealth. Wu and Bian [52] explored the house wealth effect in three different tier cities in China and the results showed that raising interest rates has a stronger negative effect on house prices in developed cites.

Even though many prior studies have explored multiple aspects of wealth effect in the housing market, there are still few of them directly tested the influence of real estate tax on wealth effect or consumption. As an important tool for the policymakers, whether and how real estate tax affects consumption is a big issue nowadays, especially in the Chinese market, where the policy system is still not mature in housing market. Some studies found that general taxes, income taxes, and sales taxes have an influence on consumption [1, 29, 30]. Thus we want to find out whether real estate also works and what the implied mechanism is.

3. Data and Model Specification

3.1. Data and Variables. We intended to explore real estate taxes, housing price and wealth effect in China, hoping to provide useful results and recommendations to the policymakers in China and other emerging markets. Therefore, we collected the data related to these above issues. In this study, specifically, all the data are collected from *The National Bureau of Statistics of the People's Republic of China* [53]. The panel data covers the period from 2002 to 2016 and contains 30 major provinces in China, including 450 observations for each variable.

To examine the above research questions in our paper, we defined the following variables from our data set. Table 1 shows all the variables and their code and definitions we would use in the following empirical analysis (see Table 1).

Here, *house price (HP)* is the average price of commercial houses per square meter. *Household consumption expenditure (HCE)* is the per capita consumption expenditure of urban residents.

Apart from these two major variables, due to the complicated real estate tax system in China, we would test the function of different types of real estate taxes.

Table 1: Variable explanation.

Variables		Code	Definitions
	Household consumption expenditure	HCE	Per capita consumption expenditure of urban residents
	Housing price	HP	Average price of commercial houses
	Urban land utilization tax	ULU	Average urban land utilization tax in each province
	Farmland occupation tax	FOT	Average farmland occupation tax in each province
	Land value-added tax	LVT	Average land value-added tax in each province
	Deed tax	DET	Average deed tax in each province
Controlling variables	Income of urban residents	IUR	Per capita disposable income of urban residents
	Savings deposit of households	SDU	Savings deposit balance of urban and rural households at year-end
	Urbanization rate	URB	Urban population/total population
	Provincial GDP	GDP	Provincial GDP per capita

Accordingly, we chose four major types of property taxes in China, referring to *Urban land utilization tax (ULU), Farmland occupation tax (FOT), Land value-added tax (LVT)* and *Deed tax (DET)*. These are four traditional taxes related to real estate in the country and account for most of the part of property tax. Here, it should be highlighted that these four kinds of taxes could be divided into two types according to the subject: ULU, FOT, and LVT should be paid by the real estate developers, while the DET should be paid by the house buyers. We also want to highlight that the amount of FOT for each square meter is fixed in a province, but the specific amount varies among provinces; ULU is calculated based on the land area; LVT is associated with the value-added amount of the land, which basically according to the sales income; DET is related to the value of the house and paid by the buyer. In the following analysis, we will test the influence of these kinds of taxed respectfully, to find out whether they have different impacts to the house market.

Besides, some important control variables are also considered in this paper. First, we collected *Income of urban residents (IUR)* and *Saving deposit of urban and rural households (SDU)*, which represent the financial wealth and highly connected with the consumption [29]. Meanwhile, *urbanization rate (URB)*, which is the ratio of urban population divided by the total population in each province, representing the social-economic development level in a province in China, is a variable that could measure the overall consumption and income level and implies the characteristics in Chinese real estate market during the urbanization process [30]. What's more, due to the unbalanced development between regions, we also considered the *Provincial GDP (GDP)* as well [29].

To tease out multicollinearity problem, we tested the correlation matrix and Table 2 displays the correlations between the variables. First, we could see from the table that the variables show significant correlations (see Table 2). Second, the correlation coefficients show that there are no multicollinearity effects in our data according to the test standards [32]. Moreover, we also calculated the VIFs value among the variables and the maximum VIF is less than 10, which also exclude the influence of multicollinearity.

3.2. Model Specification. In this paper, we need to answer three major questions. First, we want to find out whether the taxes have impacts on the house price? And then, we also want to explore the influence of housing price on consumption, or the wealth effect in the housing market. Finally, we tested whether the real estate taxes affect the wealth effect? And, whether the effects vary among different taxes?

Accordingly, we will apply three empirical models to the above panel data of multiple provinces in China (2002 to 2016) to make the following analyses:

First, to test how real estate taxes affect price, we construct a fixed impact model. The specific model is as follows:

$$\begin{aligned}\ln HP_{\mathrm{it}} = {} & \alpha + \beta_1 \mathrm{FOT}_{\mathrm{it}} + \beta_2 \mathrm{ULU}_{\mathrm{it}} + \beta_3 \mathrm{LVT}_{\mathrm{it}} + \beta_4 \mathrm{DET}_{\mathrm{it}} \\ & + \beta_5 \ln HP_{\mathrm{it-1}} + \beta_6 \ln \mathrm{IUR}_{\mathrm{it}} + \beta_7 \ln \mathrm{SDU}_{\mathrm{it}} \\ & + \beta_8 \mathrm{URB}_{it} + \beta_9 \ln \mathrm{GDP}_{\mathrm{it}} + \varphi_{\mathrm{it}} + \varepsilon_{\mathrm{it}},\end{aligned} \tag{1}$$

where we measure all the variables by the natural logarithm referred to Basten et al. [2]. Here, $\beta_1, \beta_2, \beta_3$, and β_4 present the impact of FOT, ULU, LVY, and DET on house price, respectively, and i presents the province i and t presents the year t. Here, we also added the HP_{t-1} as one of the dependent variables to measure the consumption level of the last period of a household, as well as the lagging of consumption. φ_{it} is a fixed impact vector, and $\varepsilon_{\mathrm{it}}$ is a random error vector. We consider the fixed impact model rather than a random impact model because we can undoubtedly presume that there are natural differences among provinces and cities due to economic and tax policies, while the differences in time-series data are not large enough. Meanwhile, the Hausman test also supports the fixed-effect model ($F = 50.071$, $p < 0.001$).

Second, regarding to the wealth effect in housing market, we establish

$$\begin{aligned}\ln \mathrm{HCE}_{\mathrm{it}} = {} & \alpha + \beta_1 \ln HP_{\mathrm{it}} + \beta_2 \ln \mathrm{HCE}_{\mathrm{it-1}} + \beta_3 \ln \mathrm{IUR}_{\mathrm{it}} \\ & + \beta_4 \ln \mathrm{SDU}_{\mathrm{it}} + \beta_5 \mathrm{URB}_{\mathrm{it}} + \beta_6 \ln \mathrm{GDP}_{\mathrm{it}} \\ & + \varphi_{\mathrm{it}} + \varepsilon_{\mathrm{it}}.\end{aligned} \tag{2}$$

Here, consistently, we also measure all the variables by the natural logarithm. And, the Hausman test ($F = 43.201$, $p < 0.001$) supports this fixed-effect model as well.

Table 2: Correlation analysis of the variables.

	HCE	HP	ULU	FOT	LVT	DET	IUR	SDU	URB	GDP
HCE	1.000									
HP	0.925*	1.000								
ULU	0.426*	0.243*	1.000							
FOT	0.298*	0.131*	0.798*	1.000						
LVT	0.739*	0.634*	0.699*	0.507*	1.000					
DET	0.748*	0.645*	0.763*	0.558*	0.914*	1.000				
IUR	0.958*	0.896*	0.492*	0.412*	0.764*	0.774*	1.000			
SDU	0.652*	0.565*	0.737*	0.541*	0.869*	0.912*	0.697*	1.000		
URB	−0.103	0.156*	0.396*	0.331*	0.264*	0.364*	−0.039	0.529*	1.000	
GDP	0.562*	0.428*	0.818*	0.623*	0.845*	0.907*	0.624*	0.952*	0.599*	1.000

Note: *represents $p < 0.05$; **represents $p < 0.01$; ***represents $p < 0.001$.

Finally, we want to explore the relation between real estate taxes and wealth effect. Therefore, we test how the real estate taxes impact the consumption? Whether the impact works through the house price? Accordingly, we set up the model as follows:

$$\begin{aligned} \ln \mathrm{HCE}_{it} = {} & \alpha + \beta_1 \mathrm{FOT}_{it} + \beta_2 \mathrm{ULU}_{it} + \beta_3 \mathrm{LVT}_{it} \\ & + \beta_4 \mathrm{DET}_{it} + \beta_5 \ln HP_{it} \\ & + \beta_6 \ln \mathrm{HCE}_{it-1} + \beta_7 \ln \mathrm{IUR}_{it} \\ & + \beta_8 \ln \mathrm{SDU}_{it} + \beta_9 \mathrm{URB}_{it} \\ & + \beta_{10} \ln \mathrm{GDP}_{it} + \varphi_{it} + \varepsilon_{it}. \end{aligned} \tag{3}$$

The fixed-effect assumption for the third model (equation (3)) is supported by the Hausman test as well ($F = 60.4521$, $p < 0.001$).

4. Empirical Results

4.1. Real Estate Tax and House Price. In the empirical estimate section, we use the dynamic GMM method to examine the data and the model. We choose the GMM method according to the following reasons: (1) compared with other data, the consumption data are more inertia, which can be captured by the dynamic GMM method. (2) It is likely that the consumption and some explanatory variables are determined simultaneously, which leads to endogeneity of the explanatory variables. GMM method can solve this endogeneity to some extent. (3) GMM estimation uses transformed data can overcome the problem of unobservable variables being correlated with explanatory variables, or omitted variables.

We analyze equation (1) using to explore the first-order question to the policymakers. The results are shown in Table 3.

In Table 3, we can see from the full model (model 5) that all the four kinds of real estate taxes have a significantly positive effect on the house price: the farmland occupied tax shows a positive impact on house price ($\beta_1 = 0.013$, $p < 0.001$), so as the urban land utilization tax ($\beta_2 = -0.478$, $p < 0.001$). Furthermore, the land value-added tax shows a much greater positive impact on the price ($\beta_3 = 3.066$, $p < 0.001$), and the deed tax also has a large influence ($\beta_4 = 5.161$, $p < 0.001$).

Table 3: The impact of real estate tax on house price.

	Independent variable: HP				
	Model 1	Model 2	Model 3	Model 4	Model 5
FOT	0.018*** (0.001)				0.013*** (0.001)
ULU		0.926*** (0.001)			0.478*** (0.001)
LVT			5.928*** (0.001)		3.066*** (0.001)
DET				9.055*** (0.001)	5.161*** (0.001)
HP($t-1$)	−0.024 (0.219)	−0.053 (0.230)	−0.021 (0.353)	−0.024 (0.250)	−0.021 (0.261)
IUR	1.110*** (0.001)	1.170*** (0.001)	0.910*** (0.001)	0.891*** (0.001)	1.008*** (0.001)
SDU	0.234*** (0.001)	0.326*** (0.001)	0.261*** (0.001)	0.218*** (0.001)	0.210*** (0.001)
URB	1.289*** (0.001)	3.177** (0.002)	2.850** (0.003)	1.894** (0.003)	1.593*** (0.001)
GDP	0.298*** (0.001)	0.281*** (0.001)	0.220*** (0.001)	0.276*** (0.001)	0.248*** (0.001)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	450	450	450	450	450
AR(1)	0.008	0.006	0.006	0.007	0.006
AR(2)	0.380	0.401	0.397	0.361	0.717
Sargan test	0.837	0.815	0.823	0.811	0.900

Note: *represents $p < 0.05$; **represents $p < 0.01$; ***represents $p < 0.001$.

According to the results, we can see that different kinds of taxes in the housing market play unequal importance to the house price.

First, the farmland occupied tax is fixed per square in each province, and the tax ranged from 30 to 40 RMB according to the specific province [43]. This means, if the real estate developer wants to use the land, he must pay this tax according to the total land area. Since the tax is fixed and the tax is much lower than the house price, which could be as high as 10 thousand RMB [43] on average, this tax, therefore, shows a small influence on the house price.

Second, the urban land utilization tax, which is associated with the land area that occupied to build the houses, is ranged from 0.6RMB to 40RMB per square

[43]. More specifically, if the land is located on the center of the first-tier city or big city such as Shanghai, then the land utilization tax coud be as high as 40RMB, while if it is located in the small cities or towns, the tax would be much lower. Thus, the urban land utilization tax also positively affects house price. However, the tax fee is still a very small percentage to the total sales income thus the impact is lower compared with the deed tax and the land value-added tax.

The value-added tax and the deed tax related to the house sales price, total price times a specific tax rate, instead of the land area. Thus, if the government increases these two taxes, the real estate developer would increase the sale price by making up the fee they should pay, however, the increase part would transfer to the consumers, and which would push the consumers to have to buy the house in a higher price. That is also why the impact taken by the deed tax is larger than the land value-added tax since the consumer in China house market is seller's market and the increased tax would finally transfer to the consumers from the house developers.

The results also show housing price of the last period is insignificant to the next period house price, which means the house price in China house market cannot be affected by the previous price, but is more affected by other factors.

4.2. Wealth Effect in Housing Market. Here, we apply equation (2) and want to explore whether, in China house market, the house price has an impact on the consumption, which is called the wealth effect in the house market (see Table 4).

Table 4 (model (2)) shows that there is a positive wealth effect in China house market, which mean when the house price increases, the consumption also increases accordingly ($\beta_1 = 0.344$, $p < 0.001$). That is to say, in China, resident consumption is largely impacted by the wealth effect in the housing market. In this sense, the wealth effect caused by housing price change has triggered changes in consumption levels and overall economic development in China. The phenomena can be explained as when the house price increased, residents would feel that the wealth they have is significantly increased, so that they would feel more likely to spend instead of saving. Furthermore, we can also see from the results that the income still plays an important role in consumption ($\beta_3 = 0.645$, $p < 0.001$). What's more, the consumption of the last period shows a negative impact on next-period consumption, which figure out that the consumption still keeps a balance between income and spending for a resident, and he would not continually increase the expenditure even though the house wealth has already increased.

4.3. The Mediate Role of House Price. In this part, we want to find out the relation between real estate taxes and wealth effect. Therefore, we test how the real estate taxes impact the consumption. Whether the impact works through the house price, or whether the house price plays as a mediator in the effect?

Table 4: The impact of housing price on consumption (wealth effect).

Independent variable: HCE		
	Model 1	Model 2
HP	0.933***	0.344***
	(0.001)	(0.001)
HCE($t-1$)		−0.542***
		(0.001)
IUR		0.645***
		(0.001)
SDU		−0.072
		(0.580)
URB		6.966***
		(0.001)
GDP		0.269***
		(0.001)
Control variables	No	Yes
Observations	450	450
AR(1)	0.009	0.006
AR(2)	0.610	0.803
Sargan test	0.806	0.911

Note: *represents $p < 0.05$; **represents $p < 0.01$; ***represents $p < 0.001$.

Table 5: House price, tax, and consumption.

Independent variable:	HCE Model 1	HP Model 2	HCE Model 3
FOT	0.065***	0.013***	0.091
	(0.001)	(0.001)	(0.001)
ULU	1.616***	0.478***	0.455
	(0.001)	(0.001)	(0.001)
LVT	3.748	3.066***	−1.656
	(0.101)	(0.001)	(0.124)
DET	0.656	5.161***	0.391
	(0.605)	(0.001)	(0.660)
HP			0.196***
			(0.001)
HCE($t-1$)	−0.027*	−0.021	−0.041**
	(0.261)	(0.261)	(0.009)
IUR	1.002***	1.008***	0.792***
	(0.001)	(0.001)	(0.001)
SDU	0.103***	0.210***	−0.700*
	(0.001)	(0.001)	(0.047)
URB	1.092***	1.593***	6.181***
	(0.001)	(0.001)	(0.001)
GDP	0.205***	0.248***	0.206***
	(0.001)	(0.001)	(0.001)
Control variables	Yes	Yes	Yes
Observations	450	450	450
AR(1)	0.007	0.006	0.005
AR(2)	0.432	0.717	0.891
Sargan test	0.817	0.900	0.903

Note: *represents $p < 0.05$; **represents $p < 0.01$; ***represents $p < 0.001$.

According to equation (3), we apply the GMM on the equation and can get the following results as shown in Table 5. In order to clarify the mediating effect, we refer to the method of Baron and Kenny [54].

Table 5 shows that the house price plays as a mediator in the effect of real estate tax on consumption. According to Baron and Kenny [54], we should test the three-step models. First, model (1) shows the main effect, which indicates that real estate taxes have a positive effect on housing wealth effect; second, model (2) shows that real estate tax positively affects the housing price; finally, when we put real estate tax and housing price together in the model (3), the results show that real estate taxes are insignificant on housing wealth effect while housing price plays a significant positive role. According to the above three-step model test, we can conclude that housing price plays as a mediator.

Meanwhile, the farmland occupied tax and the urban land utilization tax are also significantly positive, meaning that the increased consumption lead by these two kinds of taxes are totally shows the effect on house price. However, we can see that the land value-added tax and the deed tax, which are related to the total sale price, are not significant in the model, which claims that these two kinds of taxes do not lead to the increasing consumption all by house price, but also by themselves. The results figure out that the different kinds of taxes have different mechanisms about the effect of the real estate tax on consumption, and we can also say that they improve the consumption or the wealth effect by different ways according to their attributions of whether related to the land area or to the house sales value.

5. Conclusions and Discussion

This paper focuses on the China house market and wants to explore the relations among real estate tax, housing price, and the wealth effect in the house market. Based on the above empirical analysis, we have come to the following conclusions:

(1) Overall, the real estate taxes are positively affecting the housing price, which means, the house price would be improved if unveil higher real estate tax policies. More specifically, taxes that calculated by the land area (farmland occupied tax and the urban land utilization tax) have a smaller influence on the house price compared with the taxes that calculated by the house wealth (land value-added tax and deed tax). And we can also find that the deed tax, which pay by the consumer, shows the largest influence on the house price.

(2) For the wealth effect in house market, whether the change of housing price would affect the consumption, we find the significant positive wealth in China house market. It means that the increase in house price makes the consumer feel wealthier and leads to a higher willingness to spend more.

(3) The results also show the mediated role of house price on the housing price on consumption. Results show that when taking into account of the relation of real estate price and wealth effect, the house price plays as a mediator. To be more specific, the farmland occupied tax and the urban land utilization tax, which are related to the land area, affect the consumption all through house price, while land value-added tax and deed tax, related to house wealth, affect consumption through both house price and the taxes.

Based on research conclusions, this paper makes some policy recommendations to China housing market.

In the current housing market in China, the government has made policies and implementations to control housing price to stimulate the consumption. However, the administrative implementations and interventions seem to be less likely contributing to cool down the housing price, neither to improve the consumption. In this sense, China government might consider reducing the administrative interventions but promote the marketization of the housing market to reduce the costs in transactions. What's more, since for most Chinese households, a house is a rigid demand for them and accounts for a huge part of the entire family income, the influence of real estate tax might show a different role compared with forging countries as a market regulation tool. The real estate tax is viewed as a vital means of impacting housing market. Therefore, making the appropriate tax policy becomes a big issue.

The empirical results also show us that the different kinds of real estate taxes have different impacts. At the current moment, the real estate tax system has multiple types of taxes in China housing market, which would bring a large tax burden press. In this case, the government might consider reducing the repeated sections of tax and simplifying the process of taxation and reducing costs, to push the healthy development in China housing market. Also, China has not issued the real estate tax law yet, indicating the housing market might be still lack of system protection and support, so it is urgent to legalize and normalize the objects and transaction sections in the housing market in the low level. Moreover, the specific real estate policies should be made more diversified and covered multiple dimensions after referring to the mature forging housing tax systems while combining China traditional consumption culture and investment contexts.

Finally, the implementation of a differentiated real estate tax system and tax preference policy could be beneficial to enhance the social equality and guarantee the stable real estate market. While large unbalance in economic development among east, middle, and west region in China, Therefore, the government could apply the differential real estate taxes targeting at regions with different economic development and land usage to make the resource allocations in different regions more reasonable. Also, the government could consider making differentiated real estate tax systems to residents with different income levels.

From a theoretical perspective, this paper contributes to the existing literature by extending the discussion on multitax types of the real estate tax and exploring the differences influence of them. Meanwhile, the research also tests the mechanism of housing price as a mediator to the impact of the real estate tax on the housing wealth effect, which clarifies the cause-influence to some extent.

The study still has some limitations that can be improved in future research studies. First, even though we have considered some control variables in our empirical model,

there are still some confounding and endogeneity problems. Second, other meaningful variables that might affect the house wealth effect, such as social security insurance, are not concluded in our studies, which can be discussed afterward. Third, due to the data limitation, we only use the urbanization rate to measure the differences among rural and urban areas. If possible, the future studies should capture more specific characteristics from individual-level data.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Collaborative Innovation Mechanism of Water Pollution Control Industry Chain Based on Complex Scientific Management

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In the process of collaborative innovation of water pollution control industry chain, there are some problems, such as chain break and lack of chain, which lead to poor effect of water pollution collaborative governance and low economic benefits. Therefore, this paper proposes a research method of collaborative innovation mechanism of water pollution treatment industry chain based on complex scientific management. In view of the problems existing in the current industrial chain of water pollution control, the collaborative economic model and matter-element extension model of the industrial chain of water pollution treatment are constructed to improve the synergy effect of each link in the industrial chain and solve the contradictions of each link in the coordination process, so as to provide guarantee for the collaborative innovation of the industrial chain of water pollution control. The experimental results show that the proposed method can bring high economic benefits in the stage of source emission reduction, process interruption, and end treatment, and the water pollution treatment effect is good, which fully verifies the practical application effect of the method. After using the design method to purify, the maximum purification rate reaches more than 80%, and the purification effect reaches class *v*. The effect is remarkable, which has practical application value.

1. Introduction

At present, the development of water pollution control industry chain is not stable, problems such as chain break and lack of chain, make the development of water pollution treatment industry unbalanced. When the relevant enterprises in the upstream of the industrial chain lack investment in technology research and development, it directly leads to the problems of low added value of relevant equipment, backward governance technology, and low governance efficiency. In addition, the infrastructure of water pollution treatment enterprises needs to be improved, the service level of franchised enterprises is low, and a perfect and standardized public service platform for water pollution treatment industry has not been built, resulting in the relatively backward development of service industry, and the whole industrial chain shows a weak pattern at both ends and strong in the middle [1, 2]. In addition, based on the analysis of the overall industrial chain structure, the water pollution control industry chain is seriously broken and the chain becomes short. At present, there is still a lack of fixed source, mobile source treatment, pollutant detection technology research, and development and related equipment manufacturing enterprises, which make the whole industry chain broken [3, 4].

At present, a large number of scholars have studied the industrial chain of water environment treatment. The organization for economic cooperation and development (OECD) defines the industrial chain of water pollution as "terminal control and end treatment," which refers to the industry that provides services, information technology, and high-tech equipment for environmental protection such as environmental treatment, water pollution control, energy conservation and emission reduction, and wastewater treatment. The industrial structure of water pollution control had been specifically analyzed, including: water

pollution environmental protection treatment equipment production industry (such as water environmental protection pharmaceutical manufacturing industry, water environmental pollution treatment equipment and environmental monitoring, and analysis instrument industry), water environmental protection service-oriented industry (such as water pollution engineering design and construction unit, water pollution consulting service industry, and water pollution treatment facilities operation service industry), and waste water pollution control equipment production industry water comprehensive utilization industry. When defining the concept of water pollution control industry chain, one must clearly understand the characteristics of industrial chain [5, 6]. Relevant domestic scholars have not formed a unified understanding of the definition of the industrial chain. There is a broad intermediate zone between hierarchical enterprise organizations and perfectly competitive market organizations, and economic organizations in this zone are called intermediate organizations. Different periods and different scholars gave different definitions of the industrial chain from different perspectives, which fully reflected people's awareness of the industrial chain at that time, and also truly reflected the level of industrial chain theoretical research [7–10]. The emergy analysis method of ecological economics is introduced into the quantitative study of water pollution ecological compensation standard, which overcomes the shortcomings of traditional methods, and the ecological economic value of pollutant dilution water is determined as the ecological compensation standard of water pollution. In this process, the key pollutants in the river are determined through water quality evaluation, and then the water dilution model is established according to the purification of key pollutants. To determine the diluted water volume when the pollutant concentration reaches the water quality section standard [11, 12], this paper aims to overcome the defects of the traditional seabed optical sensor network water pollution monitoring method. Based on secondary clustering, a new monitoring method is proposed. Firstly, based on the relative entropy, the dimension of network data is obtained, and the time window entropy corresponding to the dimension of network data source IP address is given. Then, the hierarchical structure of network data is obtained, and the data is clustered using effective index criteria. The fuzzy membership degree is used to determine the category of each sample, and the clustering center of each group of data is calculated to obtain the best threshold of fuzzy classification of the data set, so as to complete the monitoring [13, 14]. Although the above methods have high monitoring accuracy, it lays a foundation for improving the quality of environmental monitoring, but the above methods do not have high economic benefits in the stages of source emission reduction, process interruption, and end treatment, and the effect of water pollution control is poor.

Compared with the definition put forward by domestic scholars, this paper defines the scientific definition of industrial chain as: enterprises in the same or different industries take products as the object, input generation as the link, value-added as the orientation, aiming to meet the needs of users, and form a dynamic chain industrial organization according to the specific spatial and temporal layout and logical relationship. Complex scientific management is based on the assumption that an organization is a brain that can think systematically. That is to say, the organization has an intelligent structure, which includes three levels: knowledge structure—the organization has basic knowledge; ability structure—the organization can apply knowledge to solve problems; intelligent structure—organizations can apply systematic thinking mode to integrate internal and external functions of the organization to solve problems. It has both theoretical and practical significance to apply complex scientific management ideas and methods to the research of collaborative innovation of water pollution control industry chain. The effective integration of complex scientific management theory and water pollution control industry chain is an important breakthrough. It is not only the expansion of CSM theory itself, but also provides new ideas and methods for the innovation research of water pollution control industry chain, which has theoretical and practical significance.

2. Problems Existing in the Industrial Chain of Water Pollution Control

2.1. Slow Development of Upstream Industry Chain Enterprises. The upstream of water pollution control industry chain is the continuous extension of supplier enterprises according to the development of water pollution treatment industry. The production technology of the water pollution treatment industry is obtained by the suppliers, but they do not have the R&D ability, lack of scientific and innovative technology, and it is difficult to jointly research and develop with the water pollution treatment industry [15–17]. In order to ensure the sustainable development of its own interests, the water pollution treatment industry usually suppresses the suppliers, which leads to the suppliers having to reduce the price and profits, thus unable to guarantee the R&D funds.

2.2. The Production Enterprises in the Middle Reaches of the Industrial Chain Are Lack of Core Technology. At present, there are some problems in the water pollution treatment industry, such as weak support capacity and low technical level. Although the water pollution control technology has been improved, it is still in a passive development situation, which only meets the local or national emission control requirements, but it is difficult to effectively support the future higher water environment indicators, and the technical strength is insufficient. Due to the lack of relevant technology and talents in the water pollution treatment industry chain, and the narrow scope of information exchange and cooperation, the development of related industries is slow, and the operation efficiency of water pollution treatment industry is low due to various factors.

2.3. The Internationalization Characteristics of Industrial Chain Construction Are Not Clear. At present, with the rapid development of world economy, especially in India, the rapid development of water pollution treatment technology and equipment also presents diversified development needs. Water pollution treatment enterprises must seize the opportunity to further expand their own business and market. However, the current technological development of water pollution treatment industry can only passively meet local emission requirements, but cannot face the water environmental protection requirements of the international market, especially the strict emission standards, and cannot support environmental protection goals, and the technical strength is relatively weak [18, 19].

3. Collaborative Innovation Mechanism of Water Pollution Control Industry Chain Based on Complex Scientific Management

According to the existing problems in the current water pollution control industry chain, it is necessary to use scientific means to improve it. Therefore, a complex scientific management innovation theory is proposed. Based on the innovation theory of complex scientific management (CSM) and the logic of organizational evolution, a collaborative economic model of water pollution control industrial chain is constructed. Based on the market-oriented vertical cooperation behavior of water pollution control industry chain, an extension model of matter-element is established.

3.1. Complex Scientific Management (CSM) Innovation Theory. The theoretical basis of complex scientific management (CSM) innovation mainly includes four aspects: CSM theory, strategic management theory, system science theory, and industrial economics theory [20, 21]. CSM theory is the most important pillar theory in this paper, which provides a unique research perspective, a complete theoretical system, and a series of practical theoretical tools for this study [22, 23].

Integrity is an important concept in complex scientific management. Integrity is one of the essential attributes of the system. In the research of system science, it has become the most important part of system science. Holistic thinking is the core content of systematic thinking, which determines the contents and principles of systematic thinking.It is impossible to reveal the true nature of things without grasping the development laws of things from a holistic perspective. The holistic view of CSM is the basic perspective of the CSM research system. The holistic view first considers the most important and core features of the system as a whole when guiding and thinking about problems. Applying this theory to the collaborative innovation of the water pollution treatment industry chain, the water pollution treatment industry chain can be identified as the coordination between enterprises, markets, and intermediate organizations. Among them, the enterprise is equivalent to the water environment management enterprise, the market is equivalent to the wastewater recycling link, and intermediate organizations are equivalent to industries that provide services for water pollution and environmental protection [12, 23]. It is generally believed that the social economy has two basic economic organizations: enterprise and market. In fact, many researchers in the theoretical and business circles believe that there is an intermediate organization between the enterprise and the market, such as multinational companies, virtual organizations, and network organizations. The evolution logic of the three kinds of organizations in the water pollution control industry chain is: after the market organization is produced, the intermediate organization is produced, and then the enterprise organization is produced, or the opposite evolution logic. However, in the evolutionary history of organizations, intermediate organizations are the last to emerge. Therefore, this intermediate organization should be the third type of organization. Network organization is not an intermediate organization but a third type of organization [24–27]. The growth of corporate network organizations is an important growth method for companies in the complex global business environment. The network organization absorbs the advantages of the market and the enterprise, and is an organization that sublates the two. The resulting logic is shown in Figure 1.

3.2. Establishment of a Collaborative Economic Model for the Water Pollution Control Industry Chain. Based on the complex scientific management (CSM) innovation theory and organizational evolution logic, the collaborative economic model of water pollution treatment industry chain is constructed. The basic premise of establishing the collaborative economic model of water pollution treatment industry chain is to determine the environmental quality change of water pollution treatment industry [28, 29]. Based on the utility equation of water pollution treatment enterprises, the following formulas are constructed:

$$A_i(t) = \frac{P_i(t) - Q_i(t)}{M_i(t)},$$

$$D_j(t) = \frac{\left|I_j(t) - \Delta H_j(t)\right|}{N_j(t)}, \tag{1}$$

$$F_{i,j}(t) = \exp\left[l\left[A_i(t) - D_j(t)\right]^2\right],$$

where $A_i(t)$ is the utility function of the water pollution treatment enterprise, i represents the commodity vector set consumed by the water pollution treatment enterprise in the treatment process, t represents the water pollution degree; $D_j(t)$ is determined by the quality of pollutants discharged when the water pollution treatment industry produces goods, $D_j(t) > 0$; I represents the industrial production function of the water pollution control industry; H represents the input of production factors of the water pollution control enterprise, that is, labor input and capital input; F represents the degree of environmental pollution caused by the production of water pollution control enterprises; l represents the amount of environmental pollutants discharged when the water pollution control industry produces

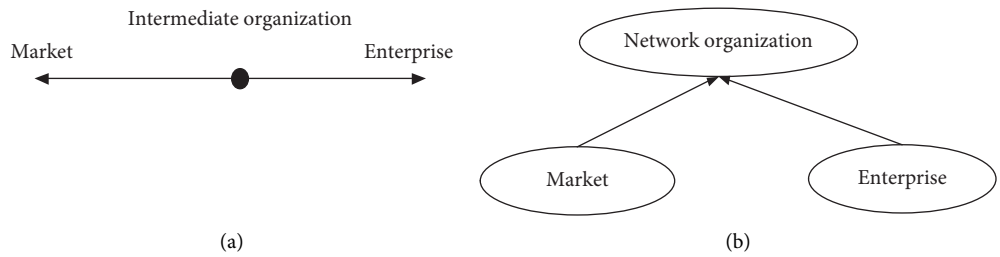

Figure 1: Three types of organizational evolution. (a) Linear evolution of three kinds of organizations. (b) Nonlinear evolution of three kinds of organizations.

goods; and M represents the pollution damage function of the water pollution treatment industry. The direct function of this parameter is to transform the environmental pollution problem that the water pollution treatment company cannot control into the environmental damage problem in real life, so as to facilitate data collection and analysis.

It can be seen from equations that when the degree of water pollution changes, the profit of the water pollution control company is directly affected. In this case, it is obvious that the cost the water pollution treatment enterprises are willing to pay in order to improve the water environment quality is equal to the compensation cost when other factors damage the water environment quality of the mining area. For consumers of water pollution control, the situation is slightly complicated. If consumers of water pollution control commodities have to pay for water pollution environmental quality control fees, the cost of related commodities consumed by the water environment treatment industry will be reduced [30, 31]. Suppose V_1 and V_2 represent the degree of water pollution before and after water pollution treatment, respectively; u represents the overall cost; and Z represents the product price consumed by the water pollution treatment industry in the water pollution treatment process. If consumers of products related to the water environment treatment industry are willing to pay compensation fees for water pollution treatment, c_1 is used to represent the effectiveness of higher water pollution treatment quality. On the contrary, if consumers of products related to the water environment treatment industry are unwilling to pay compensation fees for water pollution treatment, c_2 is used to represent the effectiveness of lower water pollution control quality, so we can get

$$W_1 = F_{i,j}(t)\left[u\left(P, Z\left(V_1\right), c_1\right) - u\left(P, Z\left(V_2\right), c_1\right)\right], \quad (2)$$

$$W_2 = F_{i,j}(t)\left[u\left(P, Z\left(V_1\right), c_2\right) - u\left(P, Z\left(V_2\right), c_2\right)\right], \quad (3)$$

where W_1 represents the cost of related products consumed by the water environment treatment industry; W_2 represents the water pollution environment quality treatment cost indirectly paid by consumers of water pollution treatment products.

Under normal circumstances, in the above consumption process, the value of W_1 is greater than the value of W_2. It can also be seen from the above equations (2) and (3) that not all the environmental pollution control benefits of the water pollution control industry are determined. Since the relationship between W_1 and W_2 is uncertain in real life, the function W_1 has two possible values, which are represented by W_i and W_j, respectively; E represents the income level of water pollution control companies; and R represents the water pollution control companies. The other expected utility of the available values of W_i and W_j are

$$W_i = E\left(W_1 - W_2\right) + R\left(W_1 + W_2\right),$$
$$W_j = \frac{E\left(W_1 - W_2\right)}{R\left(W_1 + W_2\right)}. \quad (4)$$

Reorganizing the above formula shows that when there are small changes in W_1 and W_2, the water pollution control income W_i of the water pollution control industry (that is, the ratio of the utility difference between the two states and the expected marginal utility of water pollution control in the water pollution control industry) will have corresponding changes [32]. The amount of environmental quality change in the water pollution treatment industry is determined, and a pollution treatment economic model for the water pollution treatment industry is established. The specific calculation formula is as follows:

$$G = \frac{\left[u\left(E, W_1\right) - u\left(E, W_2\right)\right]}{R\left(W_i - W_j\right)} \times A_i(t). \quad (5)$$

The above model only shows the decision-making behavior of water pollution control companies from the theoretical model, but in reality, the decision-making behavior of water pollution control companies is subject to more constraints. Consumers who participate in the governance behavior of water pollution control companies respond quickly to the market and can respond more efficiently. Therefore, it is necessary to analyze the vertical cooperation behavior of the water pollution control industry chain based on market orientation.

3.3. Vertical Cooperation Behavior Based on Market-Oriented Water Pollution Control Industry Chain. From the perspective of transaction cost economics, there are also a large number of transaction costs in the main transaction process of each link in the water pollution control industry chain. Therefore, the transaction cost issue is also seen as affecting the choice of vertical cooperation mode in the water pollution control industry chain. In the selection process of the specific vertical cooperation mode, the transaction characteristics, market environment, water pollution control

product characteristics, and business operation characteristics faced by both parties to the transaction are different, leading to multiple forms of cooperation modes. Also, among the above factors, transaction characteristics are considered to be the most important factors [14]. Under normal circumstances, transaction characteristics include bounded rationality, opportunism, asset specificity, uncertainty, and transaction frequency. Among them, asset specificity, transaction uncertainty, and transaction frequency are considered to a greater extent in the analysis process. Under different asset specificity, transaction uncertainty, and transaction frequency, the vertical organization mode of the agricultural industry chain is also different. From the perspective of transaction costs, the vertical cooperation mode of the water pollution control industry chain is shown in Figure 2.

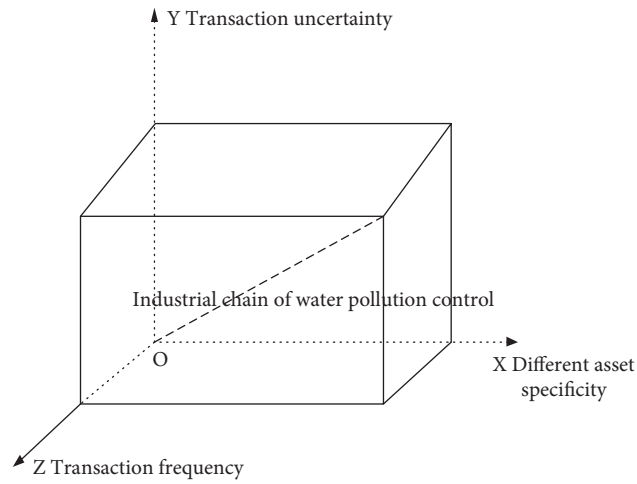

Figure 2: The vertical cooperation model of the water pollution control industry chain from the perspective of transaction costs.

3.4. Constructing an Extension Model of Matter Element. From the perspective of transaction cost, the vertical cooperation mode of water pollution treatment industry chain shows that all links of water pollution treatment industry chain are interrelated. Therefore, in the process of water pollution control industry chain coordination, some contradictions will inevitably occur between each link, which will affect the effect of water pollution treatment. In order to solve this problem, the matter-element extension model is constructed. the matter-element extension model is constructed based on the comparison and optimization of a variety of known general decision-making. According to the needs of incompatible contradictory problems generated at various levels and stages, this model breaks through the conventional and expansionary way but adopt creative decision-making skills, grasp key strategies, maximize the main system, incompatible contradictions into compatible relations, so as to achieve the global optimal decision policy objectives [33].

The indicator layer in water pollution control is set as b, and the characteristic value is L. The two together constitute the evaluation matter-element T structure level [34], and the classic domain matrix of the classification standard is

$$O = \begin{bmatrix} N & b & L_1 & L_2 & L_3 & L_4 & L_5 \\ b_1 & (0-20) & (20-40) & (40-60) & (60-80) & (80-100) & \\ b_2 & (0-20) & (20-40) & (40-60) & (60-80) & (80-100) & \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \\ b_3 & (0-15) & (15-30) & (30-45) & (45-60) & (60-75) & \end{bmatrix}. \quad (6)$$

The node area matrix O' can be determined according to the value range of the grading standard [35]:

$$O' = \begin{bmatrix} N & b_1 & L_1 & 15 \\ b_2 & L_2 & 30 & \\ \vdots & \vdots & \vdots & \\ b_3 & L_5 & 75 & \end{bmatrix}. \quad (7)$$

The element matrix is determined to be evaluated:

$$O_r = \begin{bmatrix} N_r & b_1 & L_1 & 15 \\ b_2 & L_2 & 30 & \\ \vdots & \vdots & \vdots & \\ b_3 & L_5 & 75 & \end{bmatrix}. \quad (8)$$

After normalization, a new element matrix to be evaluated is obtained:

$$O_r' = \begin{bmatrix} N_r & b_1 & L_1 & 0.15 \\ b_2 & L_2 & 0.30 & \\ \vdots & \vdots & \vdots & \\ b_3 & L_5 & 0.75 & \end{bmatrix}. \quad (9)$$

According to the matter-element extension model, the contradiction of each link in the coordination process of water pollution treatment industry chain can be effectively solved [36], and the collaborative innovation mechanism of water pollution treatment industry chain based on complex scientific management has been completed.

4. Experimental Analysis

In order to verify whether the designed collaborative innovation mechanism of the water pollution control industry chain based on complex scientific management can realize the effective deployment of the water pollution control industry chain, and whether the application of this mechanism can give full play to the economic utility of each link in the industrial chain, experiments are conducted on the study.

4.1. Introduction to Experimental Subjects. The experimental area contains a water pollution control project, which is mainly aimed at the main flood control and drainage channel in the experimental area. The river has not been cleaned in the past 5 years, the flow rate is slow, the discharge capacity is limited, and the long-term sedimentation has

reduced the river bed section. The original flood control and drainage capacity of the river are reduced, and the flood disaster is serious. To ensure water safety in the area, the water system is dredged and the urban natural ecological water system is restored. Through the upgrading and transformation of sewage treatment plants, an efficient automatic monitoring system and corresponding supporting facilities are established. The water ecosystem is protected and restored, the healthy life of the river is maintained, and a coordinated, green, and livable environment is created. Figure 3 shows the overall overview of water pollution in the experimental area.

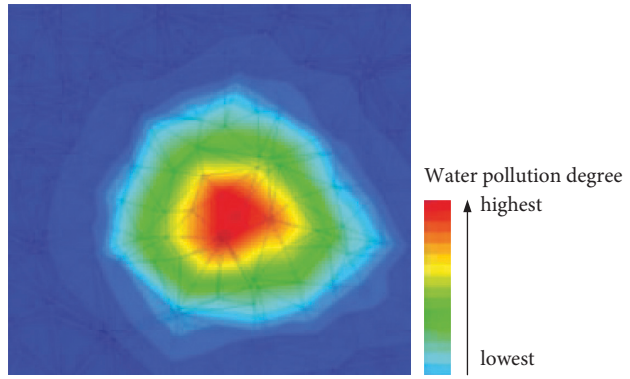

Figure 3: Overall overview of water pollution in the experimental area.

4.2. Data Collection. Relevant data and environmental data on the production activities of the plot to be investigated are collected such as production technology, raw and auxiliary materials, products, production facilities and auxiliary facilities layout, production equipment level, accident records, mark the location and purpose of nearby groundwater wells, the relationship between groundwater and surface waters, the distribution of residents, and other sensitive targets.

4.3. Monitoring Points. The layout of water pollution monitoring wells is determined based on the original production and auxiliary equipment layout of the plot to be investigated and the surrounding environment, and the locations are located in areas where environmental impacts may occur. Generally, there are 10 sites, 3 around the production area, 3 auxiliary facilities for raw and auxiliary material storage, sewage and solid waste treatment, and 4 plant boundaries. According to the groundwater flow direction of the site, at least 3 of the holes shall be installed as groundwater monitoring wells, and the depth of the groundwater monitoring well shall be 2 m below the static water level.

4.4. Construction of the Evaluation Index System of the Water Pollution Control Industry Chain

4.4.1. Definition and Selection Method of Indicators. The evaluation index standard mainly refers to the "National River Health Evaluation Index, Standard and Method" and "National Lake and Reservoir Health Evaluation Index, Standard and Method"; Combined with relevant domestic and foreign research experience on river pollution control, it is divided into 5 levels. Ineffective is grade I, invalid is grade II, generally grade III, more effective grade IV, very effective grade V. Table 1 shows the specific classification levels of water quality indicators, and Table 2 shows the specific classification levels of flow rate indicators.

4.4.2. Selection of Evaluation Indicators. According to the index selection description and the research results of urban river pollution control, combined with cases, source emission reduction, process interruption, and end treatment (end river water quality control, end river habitat restoration, and end river bank restoration) were selected as evaluation indicators.

4.5. Result Analysis

4.5.1. Source Reduction. The water pollution control industry chain collaborative innovation method based on complex scientific management was used to treat the water pollution in the experimental area, and the effect of reducing water pollution at the source of the area before and after treatment in 2019 was compared. The results are shown in Figure 4.

Analyzing Figure 4, it is can be seen that in the source emission reduction link, before applying the collaborative innovation method of the water pollution control industry chain based on complex scientific management, the purification rate of ammonia nitrogen content in water pollution is significantly lower than the purification rate after system treatment. The designed method is used. After purification, the maximum purification rate had reached over 80%, and the purification effect had reached Grade V, which is very effective. Before using the designed method, the maximum purification rate was only 30%, and the purification effect was Grade IV. It shows that through the coordination and treatment of the water pollution control industry chain, the quality of the water environment can be effectively improved, and the effect of water pollution control can be improved. It further shows that the designed method has reliable theoretical basis, strong adaptability, and remarkable engineering experiment results. It is an environmentally friendly and reductive water control system, which is particularly suitable for the treatment of different polluted water bodies, and has achieved the expected goals and effects.

4.5.2. Process Blocking. In addition to emission reduction at the source, there is also a link in the water pollution control industry chain that is responsible for process interruption. In order to verify the effect of the designed method in the process of water pollution interruption, the treatment cost of the water pollution treatment company in the process of interruption is used as an indicator. Comparing the cost of

Table 1: Water quality index classification standard.

Grade	Total phosphorus purification rate (%)	Purification rate of ammonia nitrogen content (%)
I	0–5	0–10
II	6–15	11–25
III	16–20	26–35
IV	21–40	36–45
V	41–100	46–100

Table 2: Classification standard of flow rate index.

Grade	Specific description
I	Basically no water
II	No change in velocity of each section
III	There is no obvious change in the flow velocity of each section
IV	The flow velocity of each section is not obvious
V	More sections have different speeds

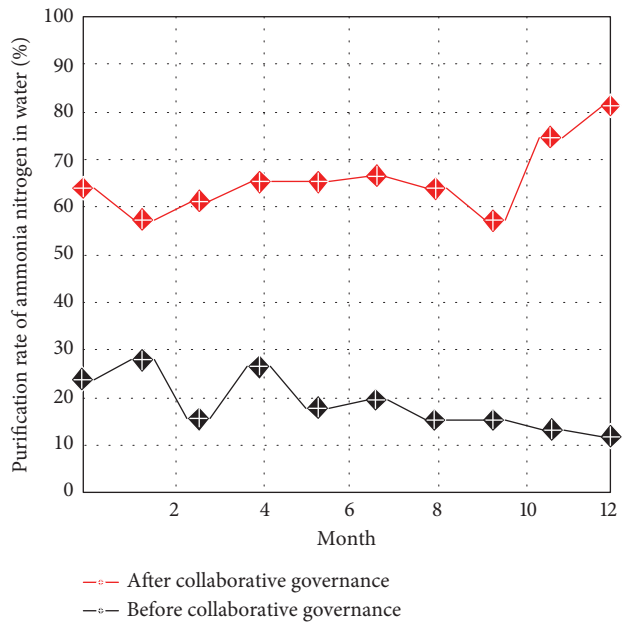

Figure 4: Comparison results of ammonia nitrogen purification rate in water pollution before and after coprocessing.

water pollution treatment before and after the design method was adopted in the region in 2019, the result is shown in Figure 5.

Analyzing Figure 5, it can be seen that before adopting the designed method for water pollution treatment, the overall cost is higher, and after using the designed method, the cost of water pollution treatment has been significantly reduced. This is because the design method is based on complex scientific management theory to regulate and control each link in the industrial chain of water pollution control, so that the cost of water pollution treatment in each link is reduced, thus reducing the overall treatment cost. It shows that the design method has obvious economic benefits and is worthy of application in the collaborative management of water pollution treatment industry chain.

4.5.3. Terminal Treatment. The industrial structure of water pollution control includes water pollution environmental protection equipment production industry (such as water environmental protection pharmaceutical manufacturing industry, water environmental pollution control equipment, and environmental monitoring and analysis instrument industry), water environmental protection service industry (such as water pollution engineering design and construction units), water pollution consulting service industry, water pollution treatment facility operation service industry, and wastewater comprehensive utilization industry. Among them, the comprehensive wastewater utilization industry belongs to the end treatment link. This link uses the wastewater that has undergone source emission reduction and process blocking treatment for secondary use. For this purpose, the wastewater utilization rate is used as an indicator to compare the effects before and after using the designed method, as shown in Figure 6.

Analyzing Figure 6 shows that in the end treatment link, before the designed method is used to coordinate the optimization of the water pollution industry chain, the waste water utilization rate is low, and the highest value still does not exceed 20%, indicating that all links in the industry chain are not paid attention to. The utilization of wastewater only takes wastewater treatment as a goal, and lacks attention to wastewater utilization. After the collaborative control of water pollution industry chain, the utilization rate of wastewater has been significantly improved, which shows that the method attaches importance to all aspects of the industrial chain of water pollution, and does not ignore the problem of wastewater utilization. Therefore, it improves the utilization of wastewater in water pollution treatment, and fully verifies the effectiveness and economic value of this method in water pollution control. This is because this method is based on the complex scientific management (CSM) innovation theory and organizational evolution logic to build a collaborative economic model of water pollution control industrial chain.

5. Discussion

The most basic characteristic of an enterprise is the pursuit of profit maximization. Whether the enterprises can form an economic chain or not depends on whether they can realize their own interests, which is the key to the construction of industrial chain. The companies in the circular economy industry chain are also same as the above. They all consider their own interests before deciding whether to cooperate with other companies. An enterprise in a high-quality circular economy industry chain should have the following two

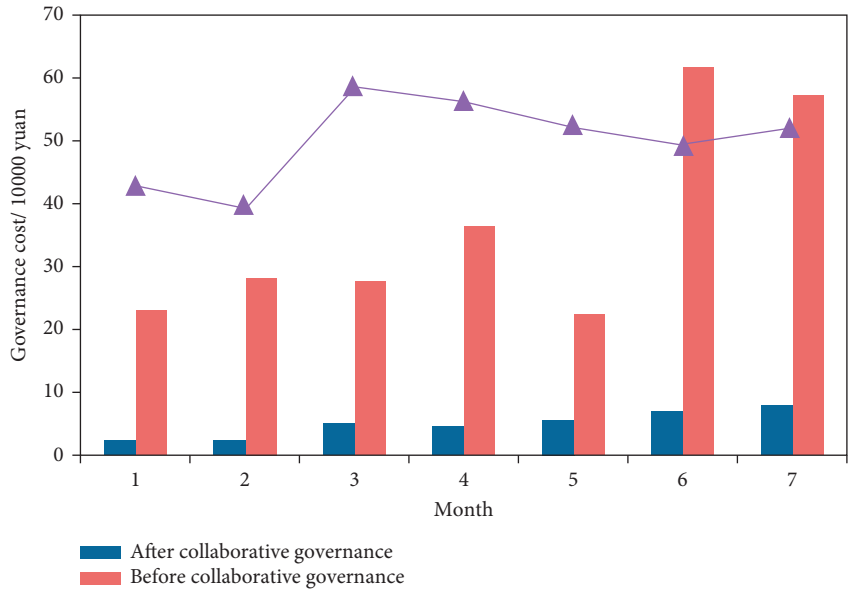

Figure 5: Comparison of water pollution control costs before and after adopting the designed method.

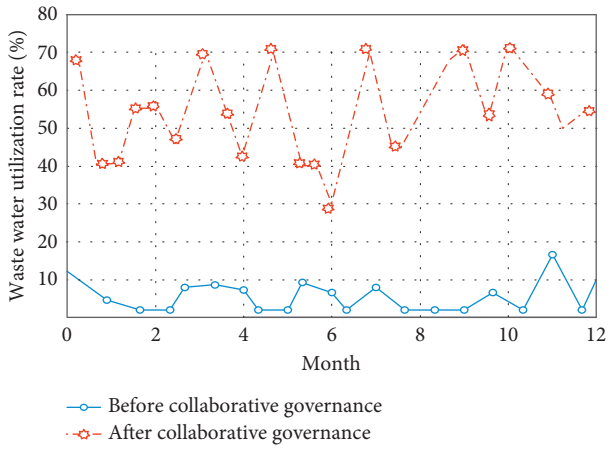

Figure 6: Comparison of wastewater utilization before and after adopting the designed method.

characteristics: one is that its own interests can be satisfied and its own value can be reflected; the other is that the enterprise can create value for other enterprises and make other enterprises' value also be reflected. In the process of operation, enterprises in circular economy industry may need to pay the economic price. However, in the absence of external factors such as the government, they need to withdraw; under the constraints of external conditions, enterprises will still follow the "instinct" of maximizing their own interests. The most basic characteristics of enterprises can maximize their own interests. Therefore, to ensure that enterprises are profitable is the most basic condition for constructing circular economy industrial chain.

Under the condition of fully considering the above factors, this paper puts forward the collaborative innovation mechanism of water pollution treatment industry chain based on complex scientific management. The theory of CSM contains unique views and views on innovation, especially the research from the perspective of time and space has important practical significance. From the perspective of time and space, CSM innovation theory can guide people to rethink the creation of innovation value in the process of practical innovation, and open up a better innovation environment. It can be said that CSM innovation theory is one of the most important theories that CSM theory plays a role in practice, and has obvious practical significance. Relying on the complex scientific management theory, the water pollution control effect has been significantly improved by coordinating all links in the industrial chain of water pollution control.

6. Conclusions

In order to solve the problem of chain break and lack of chain in the current water pollution control industry chain, the research method of collaborative innovation mechanism of water pollution treatment industry chain based on complex scientific management was proposed. Based on the analysis of the problems existing in the current industrial chain of water pollution control, the collaborative economic model of the industrial chain of water pollution treatment is established, and the vertical cooperation behavior of the industrial chain of water pollution treatment is analyzed based on the market orientation. According to the analysis results, the matter-element extension model is established to effectively solve the contradictions in each link of the water pollution control industry chain coordination process. The experimental results show that the design method can effectively restrict the industrial chain of water pollution control, the water treatment effect has been significantly improved, and the economic benefits have been improved, which show that the method can be applied in practice and has practical application value. In the future development, the introduction of more advanced science and technology

and information technology has more effectively solved the contradictions in various links in the coordination process of the industrial chain of water pollution control.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Dynamic Evaluation of Carbon Emission Performance of New Energy Enterprises based on Orthogonal Projection Method

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The rapid development of economic society causes people to increase the energy demand, produce more and more carbon dioxide, environmental pollution is becoming more and more serious, to solve the problem of carbon peak is imminent. Under the same and complete evaluation system, the carbon emission performance varies slightly according to different R&D directions of new energy enterprises. Therefore, it is particularly important to select evaluation indicators. In fact, each enterprise has different efforts to control carbon emissions. While studying the performance of carbon emissions, the direct and indirect impacts of carbon dioxide produced by each enterprise in the process of production on the ecological environment should be considered. In order to guarantee systematic and scientific outcomes, carbon emissions performance evaluation indicator system for new energy enterprises is constructed. With new energy enterprises as examples, based on the construction of carbon emissions performance evaluation indicator system of new energy enterprises, orthogonal projection method is used to carry out an empirical analysis of the dynamic evaluation of carbon emissions performance of thirty new energy enterprises. Through the questionnaire survey of thirty new energy enterprises, the indicator weight of carbon emission performance evaluation of new energy enterprises was determined, and the carbon emission performance of new energy enterprises was analyzed. The results will reflect the actual situation of China's new energy enterprises, and provide the data support and references for future research on carbon emission control by the country and enterprises.

1. Introduction

In order to reach the consensus on global sustainable development, "low-carbon Economy" has virtually become a principle, with less emissions, less pollution, and lower energy consumption gradually becoming the goal pursued by major enterprises. Renewable and clean energy, such as biomass, solar, wind and water, has long been studied to replace non-renewable fossil energy, in order to minimize the direct and indirect environmental impact of the large number of greenhouse gases emitted by enterprises in the production process. The so-called new energy refers to energy like solar energy, ocean energy, geothermal energy, nuclear fusion energy, wind energy, and so on, which have just begun to be researched and utilized or are actively researched and developed and needs to be promoted urgently. The enterprises that mainly focus on the development and utilization of new energy are called new energy enterprises, and the new energy industry refers to a series of procedures engaged in the activities of institutions or units engaged in the development of new energy. Sustainable development, huge storage, and environmental protection as the biggest characteristics of new energy are widely known and attracted much attention. A large amount of energy consumption aggravates carbon emissions, leading to the deterioration of the ecological environment, global climate warming, and the exhaustion of non-renewable resources. Countries all over the world take new energy as the breakthrough point to vigorously develop new energy enterprises to combat the carbon emissions caused by

traditional energy and further promote economic development to a certain extent. Irrational use of energies and extravagances have certain impacts on China's national economy. Many scholars and experts no longer blindly pursue rapid economic growth but began to tilt toward economic growth in quality. In order to practice the concept of sustainable development, energy conservation, and emission reduction, the state gives strong support to the development of new energy enterprises. A new energy has become an important measure to cope with environmental change. Therefore, a batch of new energy enterprises began to develop. In the Decision of The State Council on Accelerating the Cultivation and Development of Strategic Emerging Industries issued by the government, new energy enterprises are regarded as an important enterprise of the country's seven strategic emerging industries in the future, and will soon become the country's leading and pillar industry. In response to the national call, most enterprises begin to stride forward in the field of new energy and begin to research and develop new energy systems with clean, environmental protection, safe and sustainable development, so as to achieve the purpose of reducing carbon emissions. Since then, new energy enterprises continue to expand. Although the development of new energy can significantly reduce carbon emissions, it is very difficult to implement. As the government's policy on new energy is variable, and new energy enterprises have high operational capital and operational risks, as well as huge investments, which leads to the interests of many groups, investors in all fields of society are very concerned about the actual situation of their carbon emission performance. Therefore, to satisfy all stakeholders, the reasonable construction of the carbon emission performance evaluation system for new energy enterprises is also a problem that cannot be ignored. Low-carbon economy is playing an increasingly important role in China's economy. In terms of solving environmental problems, controlling carbon emission performance within enterprises has become the focus of the government's inspection of carbon emissions. In view of this problem, the emergence of new energy can effectively alleviate it. Fossil energy, as non-renewable energy, is not only rare but also produces far more carbon than the clean energy of new energy. Replacing non-renewable energy with new energy can greatly reduce carbon emissions. At this time, new energy enterprises become the main force to reduce energy consumption. For a long time, the emission of carbon dioxide and other greenhouse gases has seriously polluted the atmospheric environment and thus has an irreversible impact on the healthy and harmonious development of human society. It is urgent to solve the problem of carbon emission. Without energy, human beings cannot carry out normal production activities. With the rapid development of China's economy in recent years, in order to cope with the constantly developing and changing economic situation at home and abroad, China's energy consumption keeps rising. China's total energy consumption is one-fifth of the world's total energy consumption. The main reason for the high energy consumption is the large population base and population density, but the per capita energy consumption is relatively low, one-third of Japan's and one-sixth of the United States. On the whole, such a result will undoubtedly have a serious impact on China's environment. Although the overall trend of new energy enterprises still has some shortcomings, but after this period of development, China's wind power equipment and photovoltaic cells occupy a place in the international market, the development speed of new energy enterprises gradually climbed to the forefront of the world. In the new era of increasingly important new energy, the efficiency of the impact of resources on the environment can reflect the quality of economic growth to a certain extent. Scholars put emphasis on the importance of carbon emission performance of new energy enterprises, the relevant research results of carbon emission performance evaluation indicator system and evaluation model of new energy enterprises are relatively few, the relevant research results of the dynamic evaluation of carbon emission performance of new energy enterprises based on orthogonal projection method are also relatively few. As the most basic elements of nature, carbon emission performance is of great theoretical and practical significance to new energy enterprises. The theoretical and empirical analysis results will reflect the actual situation of China's new energy enterprises, and provide the data support and references for future research on carbon emission control by the country and enterprises.

2. Literature Review

In recent years, in order to accelerate the completion of the national strategic transformation goals, government departments and the CPC Central Committee have always been very concerned about carbon emission reduction, and attach great importance to the introduction and implementation of relevant policies. Many experts home and abroad regarding the carbon emission performance of new energy enterprises as a hot research issue. The key to studying this problem is to construct a scientific and reasonable carbon emission performance evaluation indicator system and select appropriate and effective evaluation methods. Compared with developing countries, developed countries carry out research on energy performance evaluation earlier. Up to now, widely used evaluation systems in the world mainly include the EU energy efficiency indicator system, UK energy industry indicator system, IAEA sustainable development energy indicator system, and WEC energy efficiency indicator system. In our country, the construction of a carbon emission performance evaluation indicator system is based on the above international common evaluation system. Research method and indicator system are equally important.

As for the research methods, Li et al. [1] used "Vertical distance" instead of "Euclidean distance" to calculate the closeness of the scheme, and then constructed a dynamic evaluation model considering the time factor to calculate the comprehensive evaluation value of the object to be evaluated under the condition of the different degree and increase the degree of the indicator value. Finally, the evaluation value of each time period is comprehensively calculated by the quadratic weighting method, and the comprehensive

evaluation result of the program to be evaluated is obtained. Li et al. [2] studied the projection decision method for hesitating fuzzy information. The vector expression of the scheme and positive and negative ideal points is defined under hesitating fuzzy information, and the vector projection measure method for hesitating fuzzy information is constructed. The calculating formula of closeness degree based on positive and negative ideal points is proposed. An attribute weight determination model based on Jaynes maximum entropy principle and scheme fair competition is constructed. Huang et al. [3] proposed an improved TOPSIS multi-attribute decision-making method VSPA-TOPSIS based on the vertical surface distance of the relation vector under the condition of unknown attribute weight. This method will set positive ideal point and negative ideal point as a contradictory and uncertain system, fully considers the measure target plan, positive ideal point, negative ideal point of connection degree, the existence of collection of opposites, introduces the connection vector of vertical surface with the help of distance concept, calculates relative closeness to some certain extent, and overcomes the deficiency of the SPA-TOPSIS method of inverse order. Chen et al. [4] introduced vertical distance into intuitionistic fuzzy decision theory, and proposed an intuitionistic fuzzy multi-attribute decision rule based on vertical distance by replacing vertical distance with Euclidean distance. Based on the IFE minimum principle and vertical distance minimum idea, an attribute weight determination model combining subjective and objective information preferences was constructed. In [5], hesitation intuitionistic fuzzy sets and language function are defined on the basis of the average-standard deviation preference Hamming distance and put forward based on intuitionistic fuzzy language hesitation sets from the multiple attribute decision-making method of TOPSIS and TODIM, further use of the two methods of the bidding scheme, for instance, problem builders. The sensitivity analysis of preference parameters to ranking results is also discussed. Research on the problem of indicator system, domestic experts, and scholars have also made favorable findings after many studies. Guo [6] pointed out that in the era of global low carbon, with the end of the Copenhagen Climate Conference, countries all over the world began to play a secret game in low-carbon development, and new energy enterprises should take measures to actively respond. In order to take advantage of the changing energy market, enterprises should increase the research and development of low-carbon technologies and products, and enhance their own low-carbon core competitiveness. Zhuang [7] believed that with the gradual development of urbanization in China, it was necessary to speed up the finding of the sustainable development path to reduce greenhouse gas emissions. The development of a low-carbon economy was essential to improve the efficiency of energy use. Continuous institutional and technological innovation was needed to find out a feasible way to reduce carbon emissions, and then accelerate the achievement of the ambitious goal of sustainable development. Li et al. [8] argued that the low carbon mode of development should carry out the low carbon product production by taking into consideration of each process, which mainly included four links, respectively, low carbon production, circulation, distribution, and consumption, the enterprise fused into the development of clean energy, energy conservation and emissions reduction, low carbon technology, continuously saved energy and renewable energy technologies in order to achieve the low-carbon process of production, circulation, distribution and consumption, and to promote the rapid development of the low-carbon economy. Zhu et al. [9] believed that the development concept and development mode of low-carbon economy was a comprehensive issue, which was determined by many different factors interwoven together, and these factors also affected and constrained the development of low-carbon economy. Therefore, all factors should be taken into consideration when developing the country's low-carbon economy. Sun et al. [10] indicated that carbon emission management was an important guarantee for the development of the national low-carbon economy. Performance management of carbon emissions was a very important aspect of national competitiveness. In order to improve carbon management, European countries constantly introduce carbon emission policy standards, and the level of carbon emissions has become an important aspect to reflect the level of carbon management of an enterprise. Its position in the international economy depends on the development of a low-carbon economy to some extent. Improving carbon management can not only deal with climate negotiations and improve the national carbon competitiveness but also reduce the cost of energy conservation and emission reduction and improve the competitiveness of enterprises, which affects the long-term development of enterprises and is of great significance. Shi et al. [11] analyzed the connotation and characteristics of corporate carbon emissions through internal requirements and external measures of energy conservation and emission reduction measures of various enterprises, and put forward systems and policies to implement energy conservation and emission reduction and reduce carbon emissions from the perspectives of society, enterprises, and the government. Wang [12] pointed out that the indicator system of carbon emission could be elaborated from six aspects, namely, the key areas of energy consumption, energy efficiency and structure, industrial and agricultural water consumption and water saving, pollutant discharge, pollutant treatment and utilization, and environmental quality. Wang and Shi [13] studied the electric power and chemical industry and combined process and result indicators to list in detail how to calculate each indicator, so as to construct a relatively complete carbon emission indicator system for major projects with high energy consumption and great potential for energy conservation and emission reduction. Liu and Zhang [14] constructed a carbon emission indicator system mainly for the carbon emission of the construction industry. They pointed out that enterprises could not ignore the existing problems while developing. Sun and Shi [15] followed the principle of sustainable development, combined with relevant data, referred to relevant literature home and abroad, and used the evaluation method of sustainable energy development level to conduct an empirical analysis on low-

carbon development of energy conservation and emission reduction in China. Yang and Jiang [16] proposed a dynamic evaluation method based on the orthogonal projection method to construct evaluation indicators and systems from the dimensions of resource consumption, harmless, pollutant discharge, comprehensive utilization, and supporting capacity. The method can scientifically and systematically evaluate the overall development level of different research objects at different times.

To sum up, from the micro point of view, the carbon emission research of new energy enterprises has just started. By comparing the above literature, the conclusion can be drawn: compared with the study of carbon emissions from the macro and medium perspectives, there are few studies from the micro perspective, especially the specific enterprise as the research object. The research of relevant experts and scholars only stays on the connotation and concept of new energy enterprises, especially the carbon emission performance evaluation system is not detailed and comprehensive. The existing literature shows that the current evaluation indicator system cannot be well connected with reality, and further research is needed to investigate the operability of the study. Therefore, this study further studies the carbon emission performance evaluation of new energy enterprises.

3. Carbon Emission Performance Evaluation Indicator System Construction

3.1. Principles of Evaluation Indicator Selection. The principle for new energy enterprises to construct carbon emission evaluation indicator system is to select appropriate indicators reasonably and scientifically, and these indicators can comprehensively and objectively reflect the development status, trend and potential of carbon emission performance. In the systematic screening of evaluation indicators, the principles of comprehensiveness, representativeness, pertinence, independence, comparability, combination of quantitative and qualitative indicators, and data availability are mainly followed. Due to the short development time of new energy enterprises, it is difficult to obtain data in various aspects, which makes it difficult to control the selection of indicators in the evaluation system and the scope of application of indicators. In order to determine the effectiveness of the purpose of this study, the equilibrium data and indicator of the comprehensive precision, after careful research and design of the carbon emission performance evaluation indicator system of new energy enterprises, the external research investigators cannot direct contact to the enterprise internal data, the indicator system not only can carry on the comprehensive evaluation of carbon emissions performance, data can also be easily manipulated and measured [17–24].

3.2. Evaluation Indicator System Construction. According to a series of studies of the carbon emission performance evaluation, the analysis of the actual development situation of China's new energy enterprises, the different division of labor workers of new energy enterprises, based on the previous scholars, experts, combined with the theory of stakeholders and the principle of indicator selection, the evaluation indicator system of carbon emission performance of new energy enterprises is determined [25–32]. The measurement instruments are developed and adapted by previous research results and achievements [25–32], finally, five indicators of enterprise self-awareness (environmental protection), enterprise emission reduction awareness, low-carbon technology R&D investment, environmental protection investment increase rate, enterprise system management and environmental protection investment effect are selected as the evaluation indicators in the overall evaluation indicator system of this study. The final carbon emission performance evaluation indicator system can be seen in Table 1.

4. Evaluation Model Construction

4.1. Key Points and Principle Analysis. The orthogonal projection method improves the defects of the traditional ideal solution, that is, the closer the Euclidean distance between the ideal solution and each evaluation scheme, the closer the Euclidean distance between the negative ideal solution and each evaluation scheme is. Therefore, it is not accurate to evaluate each scheme by arranging the Euclidean distance of each scheme with the traditional ideal method [33–35]. The orthogonal projection method uses Vertical distance instead of Euclidean distance to judge the degree of closeness of each scheme. Vertical distance refers to the distance between two planes, which is calculated by connecting the two target points that perpendicular to the ideal solution and the negative ideal solution, respectively. The two planes take the connecting line as normal vectors [1–5].

Suppose that points A and B are positive and negative ideal solution points respectively, and the corresponding vectors are A and B respectively. Suppose the points where AB intersects the two planes with AB as normal vectors are M and N, and the points X and Y are arbitrary points on the two planes, and the corresponding vectors are X and Y, respectively. According to the above-known points, the distance between points X and Y can be calculated as follows [36–41]:

$$\frac{|(a-b)\cdot(x-y)|}{\|a-b\|}. \tag{1}$$

Among them: stands for the absolute value, stands for the norm, and stands for the dot product.

4.2. Problem Description. Assume that there are m evaluation schemes, evaluation indicator number is n, m corresponds to evaluation scheme "$A_1, A_2, \ldots, A_m$," evaluation indicator corresponds to "$C_1, \ldots, C_n$." The original data are $x_{ij}(t_k)(i = 1, 2, \ldots, m; j = 1, 2, \ldots, n; k = 1, 2, \ldots, N)$. Weights of indicators "C_j" are "w_j," and $\sum_{j=1}^{n} w_j = 1\,(i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)$. Time is right to reuse "W_k," $W_k = (k/\sum_{k=1}^{N} k)\,(k = 1, 2, \ldots, N)$.

4.3. Calculation Steps. Let $x_{ij}\,(i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)$ be the original data values. The calculation steps of the orthogonal projection method can be divided into five steps:

Table 1: Carbon emission performance evaluation indicator system.

Indicators	Number	Code
Enterprise self-awareness (environmental protection)	1, 2, 3	X1
Enterprise emission reduction awareness	4, 5, 6	X2
Low carbon technology R&D investment	7, 8	X3
Increase rate of environmental protection investment	9, 10	X4
Enterprise system management	11, 12, 13	X5
Environmental protection investment effect	14, 15, 16	X6

constructing normalized matrix, calculating weighted matrix, simplifying the calculation process and finding out positive ideal solution, determining negative ideal solution, and calculating the "vertical surface" distance between ideal solution and each scheme. The specific calculation methods are as follows [1–5]:

Step 1: Construct normalization matrix $Z = (z_{ij})_{m\times n}$.

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} (i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n). \quad (2)$$

Step 2: Calculate the weighted matrix $R = (r_{ij})_{m\times n}$.

$$r_{ij} = w_j z_{ij} (i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n). \quad (3)$$

Step 3: Simplify the calculation process by taking the ideal solution point as the origin of coordinates.

Ideal solution can be obtained at $S^+ = \{S_j^+ | j = 1, 2, \ldots, n\}$ and change after the origin of coordinates matrix $Q = (q_{ij})_{m\times n}$, namely:

$$S_j^+ = \begin{cases} \max\limits_{1\le i\le m}\{r_{ij}\} C_j \text{ for efficiency criterion, namely positive indicator,} \\ \min\limits_{1\le i\le m}\{r_{ij}\} C_j \text{ for cost criterion, namely reverse indicator,} \end{cases}$$
$$q_{ij} = r_{ij} - S_j^+ (i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n). \quad (4)$$

Step 4: Determine the negative ideal solution H_j^-. In this case, the ideal solution is $\{0, 0, \ldots, 0\}$.

$$H^- = \{H_j^- | j = 1, 2, \ldots, n\},$$
$$H^- = q_{lj} q_{lj} \text{ meet } |q_{lj}| \ge |q_{ij}| (1 \le l \le m, i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n). \quad (5)$$

Step 5: Calculate the vertical distance P_i, Compute $|(a-b)\cdot(x-y)|$, namely:

$$P_i = |H^- \cdot Q_i| = \sum_{j=1}^{n} H_j^- q_{ij}. \quad (6)$$

The final scheme is inversely proportional to the value of P_i.

4.4. Evaluation Steps. The evaluation is divided into two cases. The first case is without considering the increasing degree of the indicator value, and the steps are as follows:

Step 1: The standardized method is adopted to process the indicator value of the original data, and the standardized matrix $Z = (z_{ij})$ is obtained. The larger the standardized indicator value is, the better the data is.

Step 2: Determining the weight through the entropy method, and then calculating the weighted standardized matrix.

$$Y = (y_{ij}) = (w_j z_{ij}) (i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n). \quad (7)$$

Step 3: Finding positive and negative ideal solutions.

The maximum value after the normalization of the matrix, namely the most satisfactory value, is the positive ideal solution of all schemes on the indicator. The positive ideal solution point can be taken as the origin of coordinates, and the positive ideal solution Y^+, the matrix $V = v_{ij}$ after changing the origin of coordinates can be obtained.

$$Y^+ = \left(\max_{1\le i\le m}\max_{1\le k\le N} y_{ij}(t_k)\right) = (y_1^+, y_2^+, \ldots, y_n^+),$$
$$v_{ij}(t_k) = y_{ij}(t_k) - y_j^+. \quad (8)$$

After changing the origin of coordinates, the ideal solution becomes $\{0, 0, \ldots, 0\}$. The negative ideal solution can be obtained:

$$|y_j^-| \ge |v_{ij}(t_k)| (i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n;\ k = 1, 2, \ldots, N),$$
$$Y^- = (y_1^-, y_2^-, \ldots, y_n^-). \quad (9)$$

Step 4: Find the distance between each solution and the ideal solution P_i: the distance between positive and negative ideal solutions and each solution is constant, so it can be obtained by V_i (the "i" row vector of the matrix "V").

$$P_i(t_k) = |Y^- \times V_i(t_k)| = \sum_{j=1}^{n} y_j^- v_{ij}(t_k). \quad (10)$$

In order to get a better solution, P_i will be smaller.

Step 5: Find out the normalized matrix P_i^*, contrary to the previous, the larger the value, the more reasonable the scheme.

In the second case, the increase degree of the indicator value is considered, and the calculation steps are as follows:

Step 1: Find out the growth matrix.

Standardizing the matrix $Z = (z_{ij}(t_k))$, the calculated growth matrix $d_{ij}(t_k)$ is as follows:

$$d_{ij}(t_k) = z_{ij}(t_k) - z_{ij}(t_{k-1}) (i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n;\ k = 1, 2, \ldots, N). \quad (11)$$

Step 2: Weight out the matrix.

$$\Delta Y = (\Delta y_{ij}) = (w_j d_{ij}). \quad (12)$$

Step 3: Find out positive and negative ideal solutions.

The positive ideal solution ΔY^+, the matrix $\Delta V = \Delta v_{ij}$ after changing the origin of coordinates.

$$\Delta Y^+ = \left(\max_{1\le i\le m} \max_{1\le k\le N} \Delta y_{ij}(t_k) \right) = (\Delta y_1^+, \Delta y_2^+, \ldots, \Delta y_n^+),$$
$$\Delta v_{ij}(t_k) = \Delta y_{ij}(t_k) - y_j^+. \tag{13}$$

Negative ideal solution:

$$\left|\Delta y_j^-\right| \ge \left|\Delta v_{ij}(t_k)\right| (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n; k = 1, 2, \ldots, N),$$
$$\Delta Y^- = (\Delta y_1^-, \Delta y_2^-, \ldots, \Delta y_n^-). \tag{14}$$

Step 4: Calculate the distance between the ideal solution and each scheme (all constant).

$$\Delta P_i(t_k) = \left|\Delta Y^- \times \Delta V_i(t_k)\right| = \sum_{j=1}^{n} \Delta y_j^- \Delta v_{ij}(t_k). \tag{15}$$

Similarly, to get a better scheme, the ΔP_i will be smaller

Step 5: Find the standardized matrix ΔP_i^*. On the contrary, the larger the value is, the more reasonable the scheme is. Comprehensive evaluation value is obtained to $q_i(t_k) = \alpha P_i^*(t_k) + \beta \Delta P_i^*(t_k)$, in which $\alpha + \beta = 1$.

After determining the time weight, the comprehensive evaluation value of each scheme can be calculated, namely

$$g_i = \sum_{k=1}^{n} w_k q_i(t_k). \tag{16}$$

You can arrange them according to what you find.

5. Empirical Analysis

5.1. Evaluation Objects. The top 50 listed enterprises of China's new energy industry are selected as evaluation objects and evaluation samples. By repeatedly comparing and reading the materials of different new energy enterprises, detailed information on the input and output of carbon emissions of each enterprise is extracted. Finally, 30 comparable and comprehensive new energy enterprises are identified, including 12 solar energy enterprises, 7 wind energy enterprises, and 11 other new energy enterprises. The new energy enterprises' details are shown in Table 2.

5.2. Sample Data Acquisition

(1) Time range selection. Data in this paper are mainly obtained from the statistical results of the questionnaire survey of thirty new energy enterprises and the energy Bulletin of 1,000 enterprises from 2017 to 2021, China Statistical Yearbook, China Economic Network Industry database, Directory of China's new energy enterprises and other public information.

(2) Sample data acquisition of thirty new energy enterprises. The sample data in this study derive from thirty new energy-listed enterprises. The reasons for choosing new energy listed enterprises are as follows: First, the importance of data is considered. New energy is an important substitute for coal, and the data are representative. The second reason is to consider the reliability of the data. The selected Chinese new energy enterprises are all large listed enterprises, and the data obtained are true and reliable. Based on the orthogonal projection method, the dynamic evaluation method is used to study the dynamic evaluation of carbon emission performance of new energy enterprises. This study makes the scales of evaluation indicators into questionnaire, distributes the questionnaire with the printed paper editions, conducts and implements the actual field questionnaire survey and on-site questionnaire survey of thirty new energy enterprises to obtain data. There are six qualitative evaluation indicators in the evaluation indicator system, and all evaluation indicators are judged by using Likert 7-point scales. The Likert 7-point scales correspond to 7 levels of strong disagreement, disagreement, relative disagreement, general, relative agreement, agreement and strong agreement, *1* level stands for strong disagreement, 2 level stands for disagreement, 3 level stands for relative disagreement, 4 level stands for general, 5 level stands for relative agreement, 6 level stands for agreement, 7 level stands for strong agreement. The overall Cronbach's value of evaluation indicators scales are 0.902, which is greater than the threshold value of 0.7, the scales pass the reliability test. The overall KMO value of evaluation indicators scales is 0.861, which is higher than the threshold value of 0.7. The factor loadings of evaluation indicators scales are 0.882, 0.854, 0.831, 0.827, 0.792, and 0.778, respectively, which are all higher than the threshold value of 0.7. The overall KMO value and the factor loadings indicate that the scales pass the validity test.

5.3. Case Study. According to each indicator in Table 1, the carbon emission performance of 30 new energy enterprises in China from 2017 to 2021 is evaluated based on the orthogonal projection method. For parameters α and β, different values are taken to analyze the comprehensive evaluation value of each scheme, and at the same time, the data is weighted twice to make the analysis results more reliable.

(1) Only the differences among indicators are considered, without considering the growth degree of indicators, that is, when $\alpha = 1$, $\beta = 0$, the evaluation results and ranking of each new energy enterprise are shown in Table 3

(2) The difference between indicators is not considered, only the growth degree of indicators is considered, that is, when $\alpha = 0$, $\beta = 1$, the evaluation results and ranking of each new energy enterprise are shown in Table 4

Table 2: New energy enterprises.

Code	Name	Type
1	Wuxi Suntech Power Holding Co. Ltd	Photovoltaic industry
2	Byd Automobile Co. Ltd	New energy vehicle
3	Sinovel Wind Power Technology (Group) Co. Ltd	Wind power industry
4	Xinjiang Goldwind Technology Co. Ltd	Wind power industry
5	Yingli Green Energy Holdings Co. Ltd	The solar energy
6	LDK Solar Technology Co. Ltd	The solar energy
7	Huang Ming Solar Energy Co. Ltd	Solar-thermal industry
8	Avic Huiteng Wind Power Equipment Co. Ltd	Wind power enterprise
9	Guangdong Mingyang Wind Power Industry Group Co. Ltd	Wind power enterprise
10	Suzhou Atsi Sunshine Electric Power Technology Co., Ltd	Photovoltaic industry
11	Jiangsu Sunrain New Energy Group Co. Ltd	The solar energy
12	Hefei Sungrow Power Supply Co. Ltd	Photovoltaic (pv) power
13	Ja Solar Pv Technology Co. Ltd	Photovoltaic industry
14	Xemc Group Co. Ltd	Wind power industry
15	China Guangdong Nuclear Power Group Co. Ltd	Wind power, photovoltaic, clean energy
16	Enn Group Co. Ltd	Biomass energy, photovoltaic
17	Changzhou Trina Solar Energy Co. Ltd	Photovoltaic industry
18	China National Nuclear Corporation	Nuclear power, nuclear power industry
19	Longyuan Electric Power Group Co. Ltd	Wind power industry
20	Gcl-poly Energy Holdings Co. Ltd	Poly silicon, photovoltaic industry
21	Nanjing Gaojing Gear Group Co. Ltd	Wind power industry
22	China Datang Group Corporation	Biomass energy, photovoltaic, wind power
23	Zhejiang Chint Solar Energy Technology Co. Ltd	Amorphous silicon thin film cell
24	Zhongtong Bus Holding Co. Ltd	Hybrid large bus
25	China Huaneng Group Corporation	Wind and solar energy
26	Changzhou Yijing Photoelectric Technology Co. Ltd	Photovoltaic industry
27	Jiangsu Linyang New Energy Co. Ltd	The solar energy
28	China Power Investment Corporation	Clean energy, smart grid
29	Shengli Power Machinery Group Co. Ltd	Renewable energy generating set
30	China General Nuclear Research Institute Co. Ltd	Nuclear energy, nuclear power technology

Table 3: Evaluation results of carbon emission performance of 30 new energy enterprises from 2017 to 2021.

Code	Value of comprehensive evaluation ranking					Double weighted	
	2021	2020	2019	2018	2017	Comprehensive value	Evaluation value
1	21	20	20	20	20	−0.00106	20
2	14	14	14	14	14	−0.00091	14
3	3	3	3	3	3	−0.00057	3
4	14	14	14	14	14	−0.00091	14
5	23	23	23	23	23	−0.00114	23
6	9	9	9	9	9	−0.00071	9
7	7	6	6	6	6	−0.00061	6
8	20	20	21	21	21	−0.00106	20
9	14	14	14	14	14	−0.00091	14
10	25	25	25	25	25	−0.00133	25
11	24	24	24	24	24	−0.00116	24
12	6	6	6	7	7	−0.00061	6
13	13	13	13	13	13	−0.0009	13
14	17	17	18	18	18	−0.00095	17
15	28	28	28	28	28	−0.00185	28
16	8	8	8	8	8	−0.00064	8
17	11	11	11	10	10	−0.00078	11
18	1	1	1	1	1	−0.0004	1
19	26	26	26	26	26	−0.00153	26
20	22	22	22	22	22	−0.00109	22
21	10	10	10	10	10	−0.00076	10
22	12	12	12	12	12	−0.00082	12
23	5	5	5	5	5	−0.00057	3
24	3	3	3	3	3	−0.00057	3

Table 3: Continued.

Code	Value of comprehensive evaluation ranking					Double weighted	
	2021	2020	2019	2018	2017	Comprehensive value	Evaluation value
25	18	19	19	19	19	−0.00098	19
26	29	29	29	29	29	−0.00203	29
27	1	1	1	1	1	−0.0004	1
28	30	30	30	30	30	−0.00235	30
29	27	27	27	27	27	−0.00167	27
30	18	18	17	17	17	−0.00096	18

Table 4: Evaluation results of carbon emission performance of 30 new energy enterprises from 2017 to 2021.

Code	Value of comprehensive evaluation ranking					Double weighted	
	2021	2020	2019	2018	2017	Comprehensive value	Evaluation value
1	29	29	28	28	29	0.000272	29
2	13	13	14	12	14	0.00034	13
3	7	7	7	6	7	0.000366	7
4	12	12	12	11	12	0.000347	12
5	19	19	19	18	19	0.000319	19
6	6	6	6	5	6	0.000373	6
7	23	23	23	22	23	0.000304	23
8	8	8	8	7	9	0.000354	8
9	17	17	17	17	17	0.00033	17
10	30	30	30	30	30	0.000238	30
11	22	22	22	21	22	0.000313	22
12	11	10	9	8	8	0.000351	9
13	2	2	2	1	2	0.000402	2
14	13	13	13	12	13	0.00034	13
15	28	28	29	24	28	0.000275	28
16	3	3	3	2	3	0.000381	3
17	9	10	11	10	11	0.000351	9
18	4	4	4	3	4	0.000377	4
19	25	25	25	25	25	0.000291	25
20	24	24	24	23	24	0.000298	24
21	13	13	14	12	14	0.00034	13
22	9	9	9	9	9	0.000351	9
23	21	21	21	20	21	0.000316	21
24	16	16	16	15	16	0.000337	16
25	19	20	20	19	20	0.000318	20
26	27	27	26	26	26	0.000282	26
27	4	4	4	3	4	0.000377	4
28	1	1	1	29	1	0.000618	1
29	26	26	27	27	27	0.000281	27
30	18	18	18	17	18	0.000324	18

(3) At the same time, the difference between each indicator and the growth degree of the indicator are considered, that is, when $\alpha = 0.9$, $\beta = 0.1$, the evaluation results and ranking of each new energy enterprises are shown in Table 5. The ranking results of comprehensive evaluation value of carbon emission performance of all new energy enterprises with different values of parameter α are seen in Figure 1 and Table 6. All the values of parameter α and β are determined by the relevant literature results and achievements [1–5], which meet the actual situations, development tendencies, essential requirements, and standard criteria of new energy enterprises.

According to Table 3 and Table 5, the closer the parameter α is to 1, the smaller and negative the comprehensive evaluation value is; the closer the parameter α is to 0, the larger and positive the comprehensive evaluation value is. Quadratic weight is to reflect the overall level of enterprise carbon emissions performance in five years. Tables 3–5 and Figure 1 show that most of the comprehensive evaluation of enterprise value ranking change is small, one of the main solar new energy co. LTD and Jiangsu Linyang's main nuclear power industry of China national nuclear corporation value sorting difference is less than 1 At the same time, the comprehensive evaluation value difference between BYD Auto Co. LTD., which specializes in new energy vehicles,

Table 5: Evaluation results of carbon emission performance of 30 new energy enterprises from 2017 to 2021.

Code	Value of comprehensive evaluation ranking					Double weighted	
	2021	2020	2019	2018	2017	Comprehensive value	Evaluation value
1	21	20	20	20	20	−0.00092	20
2	15	14	14	14	14	−0.00078	14
3	3	3	3	3	3	−0.00047	3
4	13	14	16	16	14	−0.00078	14
5	23	23	23	23	23	−0.001	23
6	9	9	9	9	9	−0.0006	9
7	6	7	6	6	6	−0.00052	7
8	20	20	21	21	21	−0.00092	20
9	15	14	14	14	14	−0.00079	16
10	25	25	25	25	25	−0.00117	25
11	24	24	24	24	24	−0.00102	24
12	6	6	6	6	6	−0.00051	6
13	13	13	13	13	13	−0.00077	13
14	17	17	17	17	18	−0.00082	17
15	28	28	28	28	28	−0.00164	28
16	8	8	8	8	8	−0.00054	8
17	11	11	10	11	10	−0.00066	11
18	1	1	1	1	1	−0.00032	1
19	26	26	26	26	26	−0.00135	26
20	22	22	22	22	22	−0.00095	22
21	10	10	10	10	10	−0.00065	10
22	12	12	12	12	12	−0.0007	12
23	4	4	5	5	5	−0.00049	5
24	4	4	4	3	4	−0.00048	4
25	18	19	19	19	19	−0.00085	19
26	29	29	29	29	29	−0.0018	29
27	1	1	1	1	1	−0.00032	1
28	30	30	30	30	30	−0.00205	30
29	27	27	27	27	27	−0.00147	27
30	18	18	17	17	17	−0.00083	18

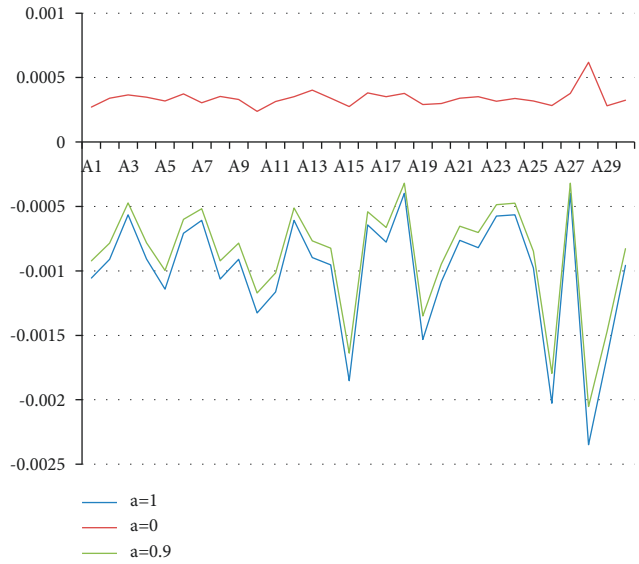

Figure 1: Comprehensive evaluation value of enterprises with different parameters.

Xinjiang Goldwind Technology Co. LTD., which specializes in wind power industry, and Guangdong Mingyang Wind Power Industry Group Co. LTD., which specializes in wind power industry, is also very small. Jiangxi LDK Solar High-tech Co. LTD. and Jiangsu Sunrain New Energy Co. LTD. are the main solar energy industry, and the comprehensive evaluation of new energy enterprises such as the ranking difference is large.

Table 6: Ranking of comprehensive evaluation value of carbon emission performance of all new energy enterprises with different values of parameter α.

Code	Comprehensive sort value				Maximum sort
	$\alpha = 0.2$	$\alpha = 0.4$	$\alpha = 0.6$	$\alpha = 0.8$	
1	25	24	25	25	1
2	14	15	13	15	2
3	3	3	4	3	1
4	15	14	14	16	2
5	19	21	21	21	2
6	6	6	6	6	0
7	11	10	11	11	1
8	18	18	17	18	1
9	16	16	16	14	2
10	27	27	27	27	0
11	24	25	24	24	1
12	5	5	5	5	0
13	8	8	8	8	0
14	17	17	18	17	1
15	30	29	29	29	1
16	4	4	3	4	1
17	10	11	10	10	1
18	1	1	1	1	0
19	26	26	26	26	0
20	23	23	23	23	0
21	12	12	12	12	0
22	13	13	15	13	2
23	9	9	9	9	0
24	7	7	7	7	0
25	20	20	20	20	0
26	29	30	30	30	1
27	1	1	1	1	0
28	22	22	22	22	0
29	28	28	28	28	0
30	21	19	19	19	2

It can be seen from Table 6 that with different values of parameter α, the ranking results of the comprehensive evaluation value of each new energy enterprise have slight differences, but the overall trend does not change greatly. In addition, Jiangsu Linyang New Energy Co. LTD., China National Nuclear Corporation, Sinovel Wind Power Technology Co. LTD., Zhongtong Bus Holding Co. LTD., and Zhejiang Chint Solar Energy Technology Co. LTD always occupy the top five in the comprehensive evaluation value of carbon emission performance. Through data analysis, it can be proved that the ranking result of comprehensive evaluation value of carbon emission performance of each new energy enterprise has little relationship with the value of parameter α. Therefore, it can be further proved that the sensitivity of parameters is low and the dynamic evaluation method based on orthogonal projection is stable.

6. Conclusions and Suggestions

Research and analysis of carbon emissions performance of new energy enterprises should be to reduce carbon emissions, reduce energy consumption and reduce the pollution to the atmospheric environment as the foundation. Through using the systematic, scientific, comprehensive integration methods of a series of indicators and requirements, carbon emissions performance evaluation indicator system of new energy enterprises is constructed. With new energy enterprises as examples, based on the construction of carbon emissions performance evaluation indicator system of new energy enterprises, orthogonal projection method is used to carry out an empirical analysis of the dynamic evaluation of carbon emissions performance of 30 new energy enterprises. Through the questionnaire survey of 30 new energy enterprises, the indicator weight of carbon emission performance evaluation of new energy enterprises was determined, and the carbon emission performance of new energy enterprises was analyzed. The results will reflect the actual situation of China's new energy enterprises, and provide the data support and references for the future research on carbon emission control by the country and enterprises. New energy enterprises carry out a complete study of the performance evaluation of carbon emissions, cannot leave the investor to the supervision of subsidies, positive incentives, reasonable and rational investment, make the carbon emissions performance situation appear in front of the followers, have certain powers of persuasion in order to promote the development and continuous improvement of new energy enterprises. The theoretical results and empirical analysis results will provide practical enlightenment and application value for enhancing carbon emission performance and reduce the carbon emission of new energy enterprises.

It is found that the comprehensive evaluation value of different new energy enterprises in the same evaluation indicator system is not the same. When evaluating and analyzing the carbon emission performance of different enterprises, it is necessary to adopt more targeted solutions for new energy enterprises with different development directions and speeds. Each enterprise has a large room for improvement and progress. Each enterprise has rich experience and advanced technology. They should actively make full use of their technical experience to formulate relevant plans and take effective measures. In this way, we can actively promote the orderly and healthy development of new energy enterprises, and at the same time, we can also coordinate the economic quality of enterprises and the ecological benefits of society to achieve a balanced state. Through analysis and research, enterprises can systematically identify the defects and deficiencies of their own development, clarify the ultimate goal of energy conservation and emission reduction at the current stage, and actively improve their own measures in energy conservation and emission reduction. The evaluation and research on carbon emission performance of new energy enterprises can not only provide a reference for the construction of industrial norms and standards but also serve as a guarantee for national and local government departments to actively respond to the carbon emission of new energy enterprises in the external environment. Facilitate the realization of energy saving and emission reduction targets of each enterprise mechanism optimization and the smooth implementation of national low-carbon policy. But at the same time, in the outbreak era, with various environmental resource constraints, new energy enterprises carry out the process of actively developing carbon reduction technology, which is

not perfect, there are still many defects that need to perfect, mainly in two aspects: first, hardware facilities, new energy companies in addition to advanced technology also need machine facilities and equipment, etc.; Second is soft technology, good management can make the effect twice the result with half the effort. Current research methods are not mature enough, and there are still deviations in data acquisition and processing, resulting in incomplete final evaluation results. Similar new energy enterprises can cooperate to take advantage of others to make up for their own shortcomings, to achieve mutual benefits and form win-win situations, work together to reduce carbon dioxide emissions, construct the low carbon society, and then reduce the carbon emissions of the whole country, and enter a new stage.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

It is declared by the authors that this article is free of conflict of interest.

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Research Article

Early Warning and Management Method of Abnormal Performance of Tourist Scenic Spots Assisted by Image Recognition Technology

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Scenic area is a product of the improvement of living standards and the improvement of economic level. Many types of scenic spots have been developed in most areas. The development of scenic spots will affect the economic development level of a region, and it will also affect the living standards of local residents because the construction of scenic spots will consume a lot of financial and human resources. If the scenic area can be managed well, it will bring greater economic benefits to the local area. However, if the scenic area fails to operate, it can affect the local finances. This requires local managers to be able to grasp the development of the scenic area, which will avoid abnormal performance. However, the performance management of scenic spots is more difficult for local managers, and more cumbersome data will be involved here. This study uses the convolutional neural network (CNN) method to realize the image recognition technology of the characteristics of the scenic area's flow of people and tourists' preferences, and these characteristics will be displayed to the managers in the form of images. In this study, the collaborative filtering algorithm can be used to complete the active recommendation of abnormal performance of tourist scenic spots. This also enables CNN to achieve collaborative monitoring. The research results show that image recognition technology can better assist managers to manage the abnormal performance of scenic spots. CNN also has good accuracy in predicting related features such as the flow of people in scenic spots. The similarity index of the three features exceeds 0.9. This has achieved a high accuracy for anomaly detection of tourist attractions. The largest similarity index has reached 0.963.

1. Introduction

With the improvement of economic level and people's pursuit of quality of life, the development of tourist attractions has been rapidly developed. However, the tourism industry is a relatively large investment industry [1, 2]. It needs to be effectively evaluated according to the local economic development level and local customs. Then, it can formulate a series of effective tourism industry programs. Therefore, for a tourism industry government, it needs to track the performance of the tourism industry according to the development of the tourism industry. Moreover, it needs to continuously update the projects of the tourism industry in real time according to the preferences of tourists and the flow of tourists [3, 4]. Each region will have different customs, and tourism that matches the customs will be more popular. However, it also needs to continuously formulate side jobs related to local customs according to the flow of people to continuously increase the income of the tourism industry. Therefore, the performance of a scenic area is more critical, and it is related to whether the scenic area will continue to develop and whether it will continue to bring considerable economic benefits to the local area [5]. At present, a large number of scenic spots have been developed in China, such as ancient villages or landscape gardens. However, it can be found that most of the scenic spots have been abandoned, which has resulted in a lot of waste of human and financial resources. This is because the

government does not take into account the local flow of people and the needs of tourists. A scenic spot wants to develop continuously, and it can bring economic benefits continuously. This requires the local government or managers to establish a performance early warning model for scenic spots. The scenic spot performance early warning mode can provide performance reference in real time according to the development of the scenic spot and the flow of people [6, 7]. However, the performance management of the scenic area is not like the enterprise performance management model. The performance management of scenic spots is a dynamic process, and it needs to formulate performance models in real time according to the preferences of tourists and the flow of people or seasons. This management model brings certain difficulties to local managers. Image recognition technology can monitor the development of scenic spots and the density of people in real time, which can provide better data for the managers of scenic spots. These data can then provide a reference for them to manage the performance of the scenic area.

Image recognition technology has been widely used in face recognition, traffic signal recognition, and other fields, and it has also achieved great success. Image recognition technology mainly uses convolutional neural network (CNN) methods to identify the features of images. The CNN algorithm has been successfully verified in many fields, and this algorithm is relatively mature. In the field of image recognition of abnormal performance of tourist attractions, researchers can only adjust relevant parameters and layers according to their needs, which have high stability and practicability. After it needs to learn the features of a large number of images, it will have the ability of image recognition. The advantages of CNN technology lie in feature recognition and mapping of nonlinear relationships [8, 9]. The key algorithm used in the field of image recognition is the CNN method. With the continuous improvement of computer computing power, the accuracy of CNN in the field of image recognition continues to improve, which is also conducive to its widespread promotion and application [10, 11]. The image is mainly composed of channel features of three colors of RGB, and its value range is mainly distributed between 0 and 255. The identification of grayscale images is easier than that of color images because the values of grayscale images are mainly 0 and 1. However, most of the current image recognition mainly focuses on the recognition of color images. This requires the CNN algorithm to go through the learning and training stages of knowledge before performing the image recognition task [12, 13]. Only in this way will the accuracy of CNN in the field of image recognition be improved. Moreover, the features of different objects also have the distribution of different color feature values, requiring CNN to undergo more training for different research objects. Although different research objects have different color characteristics, and different research objects have different distributions of color characteristics, CNN has allowed more network layers to train and learn. This increases the field of application of image recognition [14].

The relevant factors of abnormal performance monitoring of tourist scenic spots are all data forms related to images, and these images will contain a large number of data features. Image recognition technology can quickly and efficiently identify abnormal image features. It is reasonable and feasible to apply the image recognition method to the abnormal performance early warning of scenic spots. This is because managers can continuously collect the flow of people in scenic spots and the areas where tourists are concentrated through the image collection system. These data can be reflected to the managers of the scenic area in the form of images. Compared with cumbersome data, the form of images can more intuitively reflect the distribution of people flow in scenic spots. As long as the manager grasps the distribution of the flow of people, it can formulate a series of management measures for the scenic area. Only reasonable scenic area management measures can avoid the appearance of abnormal performance of scenic areas. Therefore, it is a feasible method to combine image recognition technology with early warning scheme of abnormal performance of scenic spots. Collaborative filtering algorithms can make active recommendations based on common characteristics of objects. If the collaborative filtering algorithm is applied to the abnormal performance monitoring of tourist scenic spots, it can actively push abnormal images to the staff, which will also save a lot of time.

This study uses the CNN method to realize the image recognition technology of the scenic area, which can reflect the abnormal performance of the scenic area through other image features such as the flow of people in the scenic area and the preferences of tourists. This study also uses the collaborative filtering algorithm to realize the active recommendation function of abnormal performance of tourist scenic spots, which will be used in the back of CNN. The significance of the research on abnormal performance of scenic spots and the development status of image recognition technology are introduced in Section 1. Section 2 introduces the current status of related research on scenic spots. Section 3 mainly investigates the research scheme of combining image recognition technology with abnormal performance of scenic spots and the working principle of big data technology such as CNN. The feasibility and accuracy of combining image recognition techniques with scenic abnormal performance are presented in Section 4. This section mainly analyzes and introduces some statistical parameters. In this study, the correlation index distribution, error scatter plot, and average error distribution are used to analyze the feasibility of CNN and CF algorithm in abnormal performance monitoring of tourist scenic spots. Section 5 is the summary part of the study.

2. Related Work

The development of scenic spots is a product of the economic and social development and the improvement of people's living standards. However, managers should also manage the related products of the scenic area reasonably according to the actual performance of the scenic area. The abnormal performance of scenic spots is an important

parameter and indicator for managers. Many researchers have done a lot of research on the relevant features of scenic spots. Wu and Chen [15] explored the interaction of human activities with associated features of scenic areas and the advantages that scenic areas bring to human activities. Through research, they found that there are important interactions between the three behavioral habits of people and the two characteristics of scenic spots. There is a strong correlation between the spatial characteristics of scenic spots and people's behavior. They used the random forest method to establish the relationship between people's behavior and the relevant characteristics of the scenic area, and they used the random forest method to predict the relevant characteristics.This method can provide certain suggestions for the optimal management of scenic spots and scenic spot planning. Cheng et al. [16] studied tourist preferences and the correlations that exist between external stimuli and tourist destinations. They first used the conditioned reflex relationship to establish a model that considers the relationship between habits and decision-making in scenic spots. Moreover, this study selected Jiuzhaigou Valley as the research object. The results of the study found that negative reports as well as negative characteristics of the scenic area can affect the performance and development of the scenic area. Beautiful scenery and unique ecological environment will promote the development of scenic area performance. This research can provide additional recommendations for the development and performance evaluation of scenic areas. Du et al. [17] studied Zhangjiajie Scenic Area as the research object to analyze the relationship between tourist characteristics and scenic spots. They used a fractal statistical model for analysis and wavelet analysis to analyze the nonlinear transformation of the tourist flow. The research results showed that the development of scenic spots is closely related to the flow of tourists. There is a great relationship between the flow of people in the scenic spot and the season. Wang et al. [18] mainly used the Delphi algorithm to study the impact of low-carbon behavior on the environment of the scenic area. At the same time, they also applied the AHP to study the impact of low-carbon behavior on the indicators of Zhangjiajie Scenic Area. The findings suggested that low-carbon behavior not only improves the environment of the scenic area, but also attracts more tourists, which improves the performance of the scenic area. At the same time, there is still much room for improvement in the low-carbon behavior of scenic spots. This research had certain reference value and warning effect for managers and tourists of scenic spots. Witkowski et al. [19] mainly studied the application of monitoring and evaluation methods in scenic areas. They mainly counted two different groups of travelers in Nigeria. The results of the study showed that there are small differences in the overall perception of KPIs by the traveler group. However, the environment has a greater significance for the scenic spot for tourists. Wang et al. [20] mainly studied the tourism structure network of 43 cities, and these studies were mainly conducted from three aspects of scenic environment, centrality, and community influence. The research results showed that the tourism centers of core cities will show relatively strong spatial concentration and temporal concentration. Scenic areas in the suburbs fared less well. In terms of network structure, there are clear boundaries between communities in the scenic area. From the above literature review, it can be seen that few researchers have studied the abnormal performance of scenic spots. This research mainly uses image recognition method and collaborative filtering algorithm to solve this problem. The CNN method used in this study can efficiently process a large number of images with features related to abnormal performance of tourist scenic spots. Collaborative filtering algorithms can actively recommend images with abnormal performance.

3. Application of Image Recognition Technology in Abnormal Performance of Scenic Spots

3.1. The Importance of Image Recognition Technology. If the abnormal performance of scenic spots is displayed to managers in the form of data, it will increase the difficulty of managers' work. This is because the data is complex and the amount of data is huge. If image recognition technology can be applied in the early warning of abnormal performance of scenic spots, it will not only reduce the workload of managers, but also reflect the situation of scenic spots to managers in a more intuitive way. The performance of the scenic area has a great relationship with the flow of people, the preference of tourists, and the development type of the scenic area [21]. However, the flow of people in the scenic area is more difficult to predict because the flow of people in the scenic area has a significant relationship with the time and what happens in the scenic area. Image recognition technology can use image acquisition technology for collection, and then it can display the real-time situation of scenic spots to managers in the form of a heat map. The application of image recognition technology in the early warning task of abnormal performance of scenic spots can help managers save a lot of human and material resources. This method is also more efficient.

3.2. Design Scheme of Image Recognition Technology and Principle of CNN. The present study is to use image recognition technology to achieve the task of forecasting and managing the abnormal performance of scenic spots. At the same time, this study mainly analyzes the influence of the three characteristics of the scenic area's traffic flow, the concentration of tourists, and the preferences of tourists on the performance of the scenic area. This method can not only intuitively display the characteristics of the scenic area to the manager, but also reflect the abnormal performance of the scenic area to the manager in the form of a heat map. This improves the timeliness of performance evaluation of scenic spots. Figure 1 shows the design scheme of image recognition technology in the early warning of abnormal performance of scenic spots. First, the manager needs to arrange the image acquisition system area to collect the flow of people, the concentration of tourists, and the preferences of tourists in the scenic area. The images of tourist scenic spots

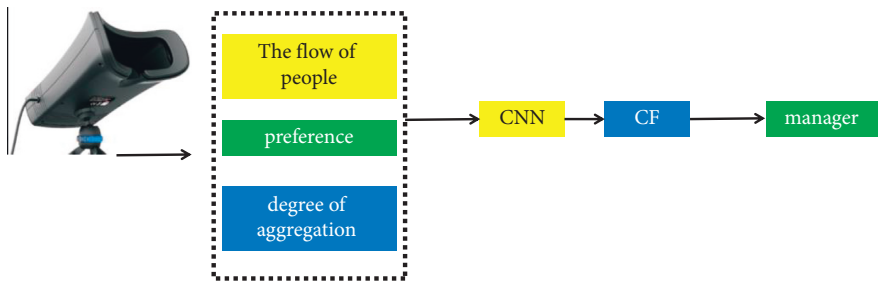

Figure 1: Image recognition and design scheme of CNN in abnormal performance early warning of scenic spots.

collected by the camera will be classified according to the distribution of weights. These images will be divided into images related to the flow of people and the degree of aggregation, and then these images will be input into the CNN. These data will be input into the CNN after preprocessing. CNN technology is mainly to assist managers to identify abnormal performance. The identification of abnormal performance of scenic spots is mainly based on the flow of people and the concentration of tourists in scenic spots. It can also use these images to establish a nonlinear relationship between images and abnormal performance. Then, these CNN-processed images and data will be sent to managers, who will identify and manage abnormal performance of scenic spots based on these images or data. The CF algorithm will transmit images related to abnormal performance of tourist attractions to managers. These images are jointly selected by CNN and CF algorithms. This scheme is a relatively intuitive and efficient scenic spot performance management mode. Not only can this solve a lot of time, it can also save the government's financial resources.

The images collected by the image acquisition system cannot be directly used by managers because the amount of image data is also huge. Managers only need to get images related to the abnormal performance of scenic spots. This requires intelligent algorithms to identify these images, which can only show the managers the images related to the abnormal performance of the scenic area. This study uses CNN technology to realize the image recognition technology of abnormal performance of scenic spots. Figure 2 shows how a CNN works. CNN technology is a flexible and changeable intelligent algorithm, which can be designed and built according to people's needs. The CNN technology used in this study mainly includes convolutional layers, pooling layers, and activation functions. The convolutional layer is mainly used to identify the features related to the performance of the scenic area, which can not only identify the related features efficiently, but also reduce the utilization of computing resources. The activation function is a necessary function for every neural network method, which can nonlinearize the data after the matrix operation. On the contrary, these data will be displayed to managers in the form of a linear operation. This fails to find areas of the image where abnormal performance exists. The number of CNN layers utilized in this study is 6, which will extract deeper abnormal performance features. The number of filters of CNN is 64. The sliding window is $3 * 3$.

The CNN algorithm is similar to other intelligent algorithms in that it has a forward propagation mechanism and a back propagation mechanism. Both propagation mechanisms require gradient descent methods to perform. The core of the gradient descent method is the derivative calculation of weights and biases. Equations (1) and (2) show how the derivation of weights and biases in a CNN is calculated.

$$\Delta\omega_{ji} = -\eta \frac{\partial E}{\partial \omega_{ji}}, \tag{1}$$

$$\Delta u_{ij} = -\eta \frac{\partial E}{\partial u_{ij}} \frac{\partial}{}. \tag{2}$$

The input calculation of CNN is quite different from other neural networks. The input data of CNN needs to perform Conv convolution operation before it can be output to the next layer of network. Equation (3) shows how the data convolution operation is calculated. b represents the bias and X represents the input data. Conv stands for convolution operation.

$$V = \text{conv2}\left(W, X'', \text{valis}''\right) + b. \tag{3}$$

Equation (4) shows the calculation method of the output layer of CNN, which is to nonlinearize the data after feature processing. Y is the output data. V represents the data subjected to the convolution operation.

$$Y = \phi(V). \tag{4}$$

Equation (5) shows the internal calculation method of the convolution operation, which mainly involves the calculation between each convolution layer. The rot180 represents the operation after the feature is flipped 180°.

$$\delta^{l-1} = \text{conv2}\left(\text{rot180}\left(W^l\right), \delta^l, 'full'\right)\phi'\left(v^{l-1}\right). \tag{5}$$

The loss function is a criterion for evaluating gradient descent. The loss function is to calculate the error between the actual value and the predicted value. The gradient descent method is to find the smallest error value. Equation (6) shows how the loss function is calculated. In this study, the calculation method of mean square error was chosen.

$$E = \frac{1}{2}\left(d_{\text{out}} - O_{\text{real}}\right)^2 = \frac{1}{2}\sum_{\kappa=1}^{t}\left(d_\kappa - O_\kappa\right)^2. \tag{6}$$

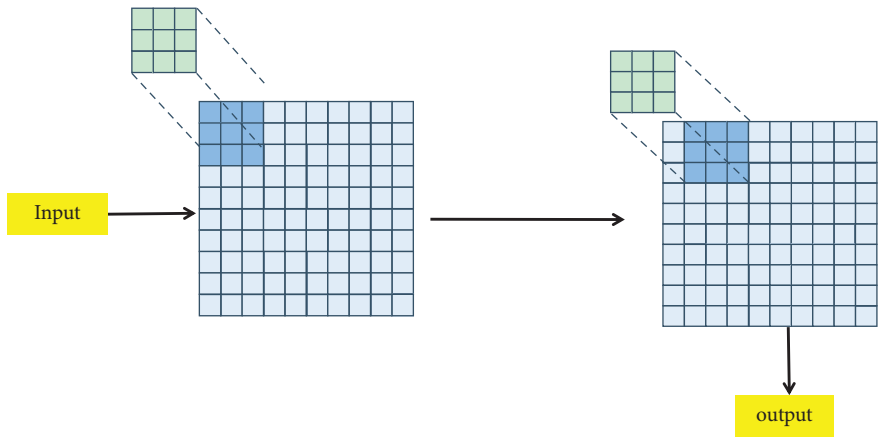

Figure 2: Application of CNN technology in image recognition technology related to scenic spot performance.

3.3. Recommendation Abnormal Performance of Coordinated Filtering Algorithm in Scenic Spots. After the relevant image of the scenic spot is collected by the image acquisition sensor, it needs to be extracted by CNN technology. After these images are recognized by CNN, it needs to be recommended by collaborative filtering algorithm. Coordinated filtering algorithms are mainly used in recommender systems. It is to recommend images with similar characteristics to users. This study uses a coordinated filtering algorithm to recommend abnormal performance of scenic spots with similar characteristics to managers. This method can more efficiently find where the abnormal performance of scenic spots exists.

Collaborative filtering algorithms are mainly divided into two types: object-based and item-based algorithms. This research mainly chooses the item-based collaborative filtering algorithm. This algorithm needs to group items with similar characteristics into one category for recommendation to related users. The common way to find the similarity between data is to calculate the distance between the data. In this study, the calculation method of the Jaccard similarity coefficient was chosen. Equation (7) demonstrates this method of calculating similarity.

$$J(A, B) = \frac{|A \cap B|}{|A \cup B|}. \tag{7}$$

Equation (8) shows a distance calculation method for the cosine of the included angle of the collaborative filtering algorithm. Equation (9) is a multidimensional generalization of equation (8).

$$\cos\theta = \frac{a \bullet b}{|a||b|}. \tag{8}$$

$$\cos\theta = \frac{\sum_{k=1}^{n} x_{1k} x_{2k}}{\sqrt{\sum_{k=1}^{n} x_{1k}^{2}} \sqrt{\sum_{k=1}^{n} x_{2k}^{2}}}. \tag{9}$$

Equation (10) demonstrates the association-based similarity method. This method computes the Pearson-r correlation between two datasets. Equation (5) shows how the adjusted cosine pair similarity is calculated.

$$\begin{aligned} \operatorname{sim}(i, j) &= \frac{\sum_{u \in U} \left(R_{u,i} - R_i\right)\left(R_{u,j} - R_j\right)}{\sqrt{\sum_{u \in U} \left(R_{u,i} - R_i\right)^2} \sqrt{\sum_{u \in U} \left(R_{u,j} - R_j\right)^2}}, \\ \operatorname{sim}(i, j) &= \frac{\sum_{u \in U} \left(R_{u,i} - R_u\right)\left(R_{u,j} - R_u\right)}{\sqrt{\sum_{u \in U} \left(R_{u,i} - R_u\right)^2} \sqrt{\sum_{u \in U} \left(R_{u,j} - R_u\right)^2}}. \end{aligned} \tag{10}$$

4. Result Analysis and Discussion

This research mainly uses collaborative filtering algorithm and CNN technology to realize the recommendation and image recognition technology of abnormal performance of scenic spots. The relevant images of scenic spots are collected in practical engineering applications using image sensor technology. The selection of the data set should include as many characteristics of factors related to abnormal performance of tourist scenic spots as possible, which requires it to contain more scenic spots and the distribution of different tourists. In the training process, this study uses relevant data from several large scenic spots in Hangzhou. It needs to classify the relevant data of these images. This study mainly analyzes the impact of three aspects of the scenic area's traffic flow, the degree of tourist aggregation, and the preferences of tourists on the performance of the scenic area. These three characteristics are also key factors affecting the abnormal performance of scenic spots. When the prediction stage of CNN is completed, it needs to use collaborative filtering algorithm to recommend abnormal performance for managers' reference.

In this study, the similarity index of collaborative filtering algorithm is an important parameter. The accuracy of similarity index will affect the accuracy of abnormal performance recommendation of scenic spots. If the similarity index is closer to 1, it means that the collaborative filtering algorithm has higher feasibility in recommending abnormal performance of scenic spots. Figure 3 shows the distribution of the correlation index of the collaborative filtering algorithm in the abnormal performance of recommended scenic spots. Overall, the collaborative filtering algorithm has good feasibility in the recommendation of abnormal performance

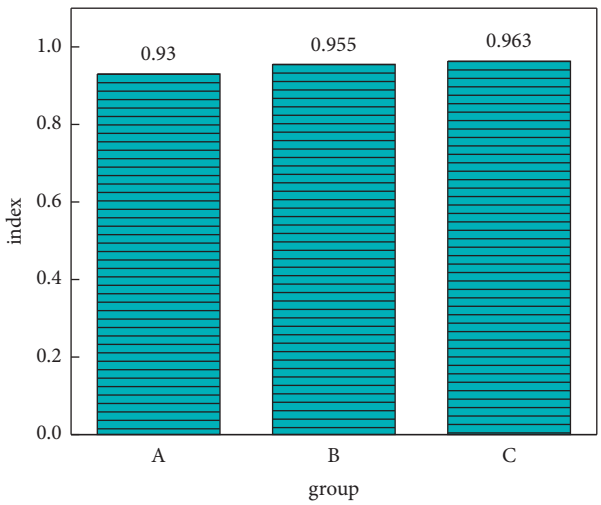

Figure 3: Similarity index distribution of three characteristics of abnormal performance of scenic spots.

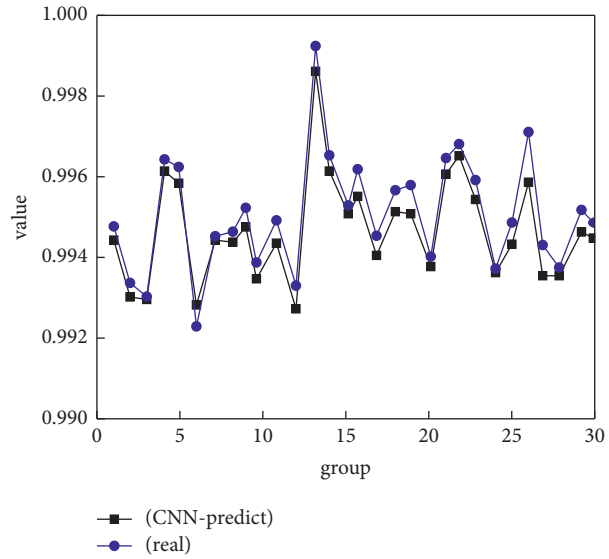

Figure 4: Recognition and prediction of people flow characteristics in scenic spots using CNN method.

of scenic spots because the similarity index of the three features exceeds 0.9. The largest similarity index has reached 0.963. The source of this part of the similarity index is the preference of passengers, which is relatively easy to recommend because the preferences of passengers have good volatility. The smallest similarity index also reached 0.93, and this part of the similarity index comes from the flow of people in the scenic area. The flow of people in the scenic area has great volatility, and this part of the characteristics has a great relationship with the abnormal performance of the scenic area. However, the similarity index of the flow of people in the scenic area has also reached the range that managers can trust.

The flow of people in the scenic area is one of the important factors affecting the performance of the scenic area. If there is a low flow of people in a scenic spot, this can seriously affect the performance of the scenic spot. Therefore, the flow of people is a key factor for the research on abnormal performance early warning of scenic spots. Figure 4 shows the distribution curve of the predicted and actual value of people flow in the scenic area using the CNN method. After the distribution of people flow in the scenic area is collected by the image acquisition sensor, it needs to use CNN for image recognition technology to identify the flow of people. Although there are large changes in the flow of people in the scenic area in different time periods, CNN can better identify the change trend of the flow of people. In general, the CNN method can better identify the value of the flow of people in the scenic area. Larger identification errors are mainly distributed in areas with large gradients of people flow in scenic spots. There is a smaller recognition error in the area with less change in the flow of people. The CNN method can also better predict and identify the changes in the flow of people in the scenic area, whether it is the peak or the trough of the change of people flow. Overall, CNN has good accuracy in the identification of people flow in scenic areas. This can help managers to reflect the abnormal performance of scenic spots.

Figure 5 shows the error distribution between the actual value and the predicted value of the scenic spot image features identified by the CNN method. Overall, CNN has high accuracy in predicting and identifying the flow of people in scenic areas. Most errors are distributed within 2%. Only a small number of traffic features have an error value of more than 2%. However, this part of the error is still within the acceptable range of 5%. This is helpful for managers to look for abnormal performance of scenic spots. Only by using CNN technology to detect the human flow images of scenic spots with low errors, can the abnormal performance of scenic spots be inferred and managed more effectively. Therefore, the prediction error of the flow of people in this scenic spot is an error distribution that can be trusted by managers.

Tourists' preference for scenic spots is also a key factor determining the performance of scenic spots. If most tourists have good preferences for the projects or humanistic culture in this scenic area, it will attract more customers. In turn, it can bring more considerable performance to the scenic area. On the contrary, it will bring abnormal performance crisis to the scenic area. Figure 6 shows the distribution of the predicted and actual values of the CNN method in predicting the tourist preferences of scenic spots. In general, the CNN method can effectively feedback the characteristics of tourists' preferences in scenic spots. Although the peak value of the passenger preference features predicted by CNN is smaller than the actual value, most of the feature values are in good agreement with the actual passenger preference feature values, especially the average value of the feature values. This shows that CNN can effectively identify the features of tourists' preferences from images. In general, this prediction effect can better guide the early warning task of abnormal performance of scenic spots.

Figure 7 shows the degree of tourist aggregation in the scenic area. Managers can formulate relevant marketing plans to improve the performance of scenic spots according

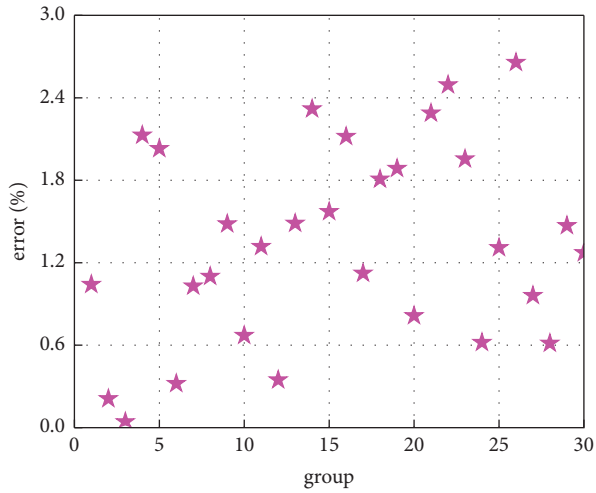

Figure 5: Prediction error distribution of people flow in scenic spots.

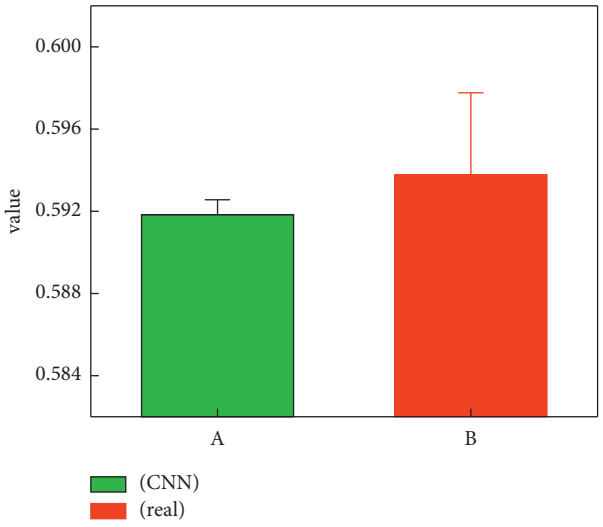

Figure 6: Predicted value and actual value distribution of tourist preference characteristics in scenic spots.

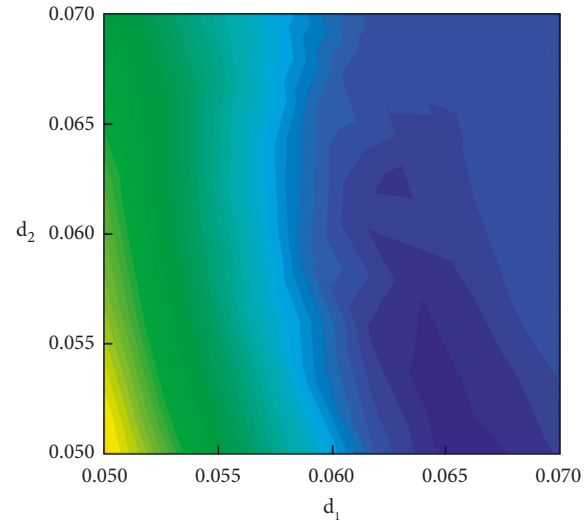

Figure 7: The distribution heat map of the characteristics of the tourist aggregation degree in the scenic area.

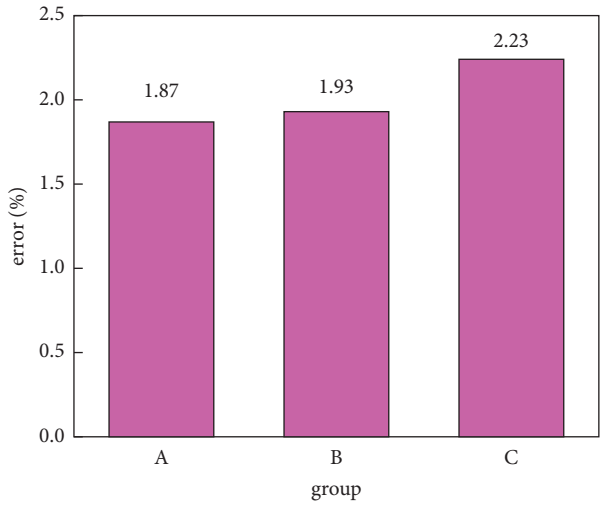

Figure 8: Prediction mean error of features related to abnormal performance of scenic spots.

to the concentration of tourists in scenic spots. It can be seen from Figure 7 that the CNN method can better reflect the aggregation degree of tourists in the scenic area. Most of the tourists will be concentrated in the fringes of the scenic area, which may be that more and more tourists prefer to participate in the activities rather than just watch the customs and other activities. This further illustrates the feasibility and accuracy of the CNN method in identifying the clustering degree of scenic spots. Figure 8 shows the average error of the CNN method in identifying three features related to scenic performance. A represents the flow of people in tourist scenic spots. B represents the preferences of tourists in the scenic spot. C represents the agglomeration degree of tourist scenic spots. Overall, CNN has high accuracy in predicting the three characteristics of abnormal performance of scenic spots. This is because most forecast errors are distributed within 3%. The largest prediction error is only 2.23%. This part of the prediction error mainly comes from the characteristics of the flow of people in the scenic area, which is a part of the characteristics with large fluctuations.

5. Conclusion

With the rapid economic development, the scenic area has also developed rapidly. However, managers should view the development and performance of the scenic area reasonably, and it cannot be developed blindly. The abnormal performance of scenic spots is a key parameter for managers, but the current form will be displayed to managers in the form of data, which increases the difficulty for managers. This study combines the CNN method to realize the image recognition technology of abnormal performance of scenic spots. It can identify pictures of scenic spots related to abnormal performance from a large amount of picture data.

The research results show that the CNN method used in this study has certain feasibility and preparation in the abnormal performance image recognition task of scenic spots. In order to achieve accurate recommendation after image recognition, collaborative filtering algorithm is also used in this study. Collaborative filtering algorithm also has a high similarity index. The lowest similarity also reached 0.93. This part of the lower similarity index comes from the identification and recommendation of the traffic characteristics of the scenic spots. Although there is a large mutation in this part of the characteristics, collaborative filtering algorithms may also better recommend images of abnormal performance of relevant scenic spots for managers. For CNN, the largest prediction error is only 2.23%. The smallest prediction error is only 1.87%. This part of the error is acceptable enough for image recognition of abnormal performance of scenic spots.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Research on Evolutionary Game of Value Co-Creation Behavior of Shared Private Charging Piles of Electric Vehicles

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To study the sharing behavior of private charging piles of electric vehicles, an asymmetric evolutionary game model is constructed based on the formation of respective investment costs and benefits of charging service operators and private charging pile owners; and considering the interactive factors such as the investment scale of shared charging platform construction and the number of private charging piles participating in sharing, this study explores the evolution process of value co-creation between the two parties in the private pile sharing mode, analyzes the evolution mechanism of their respective strategy choices, and explains the impact of sudden variable interference such as investment scale, sharing quantity, marginal cost, and income on the evolution results. The simulation results show that (1) the spillover effect of value co-creation between operators and private pile owners is the fundamental reason affecting the strategic choice of both sides. The initial willingness of both sides to cooperate will affect the evolution path of value co-creation, and the evolution speed of operators is the fastest; (2) under certain conditions, there is an optimal investment scale for both shared charging platform and the private pile, but the increase of marginal cost of both sides will lead to the dilemma of value co-creation, and the marginal cost of operation platform has a greater impact on value co-creation than the private pile; and (3) there is an optimal bearing quantity in the number of shared private piles, and the ratio of marginal cost to income is the key factor affecting value co-creation.

1. Introduction

The private charging pile discussed in this paper refers to other piles except for the public charging pile. The construction and operation of private charging piles for electric vehicles across China are facing dual problems. On the one hand, it is difficult to install, and on the other hand, many of them are idle. Private charging piles sit idle 70% of the time. The widespread phenomenon of "zombie pile" causes a waste of charging resources. Charging pile sharing can solve this dilemma. Charging pile sharing means that charging pile operators coordinate private charging piles by creating a sharing platform, fully using idle private charging piles, and befitting operating enterprises and private pile owners. According to the statistics of the charging alliance, by April 2022, there are 1.992 million private charging piles in China, of which less than 7% are shared. Assuming that only a quarter can be shared, if a single charging station can provide 15 piles, the supply of shared private charging piles is basically close to tens of thousands of public charging stations. Therefore, private charging piles have the potential to become another emerging business in the sharing economy industry. Star charging, State Grid, and China Southern Power Grid began to layout private pile sharing business, and the private pile intelligent charging sharing platform has been put into market operation.

The increasing electric vehicle market has brought huge market development space for private pile sharing. The success of the private pile sharing model lies in the joint participation of both parties, which is a typical "one-to-many" platform economy. Private charging piles can be regarded as a whole, and their participation ratio represents the behavioral decisions of this group. The operating enterprise creates a sharing platform, and the data value

generated by the platform far exceeds the charging value; The charging pile sharer gave up part of the private charging utility and reaped the charging value. Previous studies have shown that value co-creation is the key to the development of private pile sharing model. The inconsistency of profits and losses between the two sides may lead to both asymmetric and non-zero-sum games. Cooperation between the two sides may produce spillover effects, and neither side will benefit if they do not cooperate. Private piles change their private nature. Are they willing to provide charging-sharing services? What factors affect sharing decision-making, and what is the evolution trend? How can the two sides promote the sharing development of private piles? These are the questions to be answered in this paper.

Through the evolutionary game method, this paper analyzes the conditions for the evolution of value co-creation between operators and private piles towards the "win-win" strategy. Theoretically, it discusses the internal mechanism of value co-creation between operators and private piles to provide policy reference for promoting private pile sharing.

2. Literature Review

Most of the research literature on charging pile sharing regards the government as one of the essential subjects of operation. Wang et al. [1] used the ecosystem theory and grounded theory to find that consumers, platform service providers, charging pile manufacturers, and the government are the key actors in the operation of shared charging piles. Yue et al. [2] found that the optimal investment and construction quantity of new energy vehicle charging pile operators positively correlate with government subsidies. Zheng and Xu [3] found that government participation is the crucial factor in promoting the cooperation between charging operators and enterprises or individuals. Most of the literature suggests that charging facilities are invested and constructed by the market, the government plays a guiding role, and enterprises are the main body of investment and construction.

Private pile sharing is a user-driven charging pile operation mode. Shaobulina et al. [4] found that private piles sharing mode can be profitable. Gao et al. [5] studied the mechanism of shared charging piles based on users' social networks. Wu et al. [6] studied the private pile sharing trading strategy based on blockchain technology. Liu and Li [7] proposed a blockchain-based security supervision scheme to address information security issues. It shows that this model is feasible from the aspects of technology, economy, and security.

Private pile sharing is a typical platform economy. Value co-creation is the key to operation, and network effect and positive feedback will occur with the increase of the number of participants [8]. Wei and Liu define shared value as "improving the competitiveness of companies and the economic and social conditions of their communities" [9]. Xiao [10] believes that value co-creation is one of the core value processes. In the existing studies, Wang [11] believes that revenue is the main factor in the shared parking market. Yu and Li [8] found that the initial scale and income are the key factors for the operation of the sharing model.

As for the value and distribution of shared charging piles, the paper is mainly divided into three categories. The first is to study the value formation relationship of each subject in the operation mode. Zeng et al. [12] evaluated the comprehensive benefits of various subjects in the commercial operation mode of electric vehicle charging. Liu et al. [13] studied the network relationship among charging infrastructure manufacturers, charging service operators, and overall solution providers, as well as stakeholders, including users, from the network perspective. Huang and Lu [14] summarized the current typical business model of China's charging infrastructure industry and the value formation model of various participants. The second is to study the value change of each subject under the application scenario of information technology. Luo et al. [15] analyzed from the perspective of information technology application scenarios. The participating roles in each scenario of charging facility operation ecological construction tend to be diversified, and the value composition of each participating role in the business model is constructed. The third is to study the distribution of shared charging value from the pricing perspective. Li et al. [16] proposed a private pile sharing benefit distribution model from the perspective of charging pricing. Tong [17] and Hu et al. [18] studied the optimal behavior of all parties in the charging operation business model from a third-party operation platform perspective. Shi et al. [19] studied the charging price between charging stations and the optimal charging behavior of users to maximize the income of aggregators and select the optimal charging station.

Previous studies have regarded charging service as the primary shared value, but there are few studies on the spillover value effect caused by sharing. The spillover value shared by charging piles far exceeds the charging function. One end is connected to users, and the other is connected to the power grid. The charging network integrates big data from energy, payment, cars, users, and other aspects. The realization of the data value is greatly affected by uncertain factors, such as the technology and the market. At the same time, there is great uncertainty in the benefits from the decision-making of both sides. There is little analysis on the behavior selection process of each subject in the process of private pile sharing in the existing literature. Sharing a platform is a typical one-to-many feature. There is a dynamic value co-creation process between platform operators and private charging pile owners. Value co-creation is affected by the profit and loss of shared behavior of both parties. Value co-creation is the dynamic evolution result of the private pile owner and the operating platform learning from each other and constantly adjusting over time in the game process on the basis of bounded rationality. The game behavior between operators and private pile owners belongs to an asymmetric game. Information asymmetry is mainly reflected in the asymmetry of each subject's actual willingness to participate in the other party's information before the decision. Both sides need to consider the internal game of their own population and the impact of opponent population game on their population strategy.

3. Construction of an Asymmetric Evolutionary Game Model

Evolutionary game theory is usually used to study the dynamic evolution process of a group and analyze the reasons and paths to reach a particular state. This paper analyzes the interaction process between operators and private piles based on evolutionary game theory. The selection process of operators and private pile owners is a two-population evolutionary game process. If the expected return exceeds the average return, the evolutionary game process between the two sides will continue. There is information asymmetry between the two sides. So, it is a nonevolutionary game.

3.1. Model Assumptions. Suppose that, at a particular time t, the service provider and the private pile owner play the game simultaneously. Operators have two strategies of "create 1" and "do not create 0" shared platform. The variable Y indicates the proportion of operators and enterprises that select the "create 1" strategy at time t. It is assumed that the fixed investment scale for creating a shared charging platform is I_1, including investment costs such as workforce, equipment investment, and maintenance. The expected income from the operator's unit investment R_1 includes charging service cost, considerable data value, corporate image improvement, brand competitiveness, and market competitiveness. The expected return will increase with the investment scale, and the platform will obtain the spillover effect $R_1 I_1$. The investment cost of private pile owners is also a part of the investment scale of the platform. Set the investment cost I_2 paid by each private pile sharing, and the total number of private piles participating in the sharing is N, the larger the scale of N, the greater the value revenue $R_1(I_1+\mathrm{N}I_2)$ created by the platform. C_1 is the marginal cost of platform investment. The service provider can obtain the lowest rate of return L without creating a shared platform.

Private pile owners have two strategies: "share 1" and "do not share 0." Variable Z represents the proportion of private piles selected for "share 1" strategy at time t. If it is not shared, the utility value brought by the owner's free charging is U (including charging convenience value, pile maintenance, parking expenses, etc.). If participating in sharing, the unit investment will obtain the expected income R_2, including both charging services and parking income generated during charging. The marginal operation and maintenance cost C_2 of private piles includes maintenance, property communication, and information transmission to the platform. The private pile owner must pay the service usage fee I_2. If both parties choose (create and share) strategies, both parties will have spillover effects. At this time, the net income obtained by private piles is $U + R_2(I_1/N) + R_2 I_2 - C_2 I_2$, where (I_1/N) represents the proportion of the value-added brought by the platform investment scale spread equally, and $(R_2 I_1/N + R_2 I_2 - C_2 I_2)$ represents the value spillover effect brought by private piles through sharing cooperation. This spillover effect makes the profit and loss difference between the two sides of the game under different strategies, which is also the fundamental reason affecting the decision-making of operators and private pile owners.

Based on the above assumptions, to maximize their interests under the market mechanism, both sides of the game continue to play multiple games over time. The income matrix is shown in Table 1.

3.2. Replication Dynamics and Evolutionary Game. When expected return $R_{1,2} \geq C_{1,2}$, it can be seen that (create, share) is a dominant strategy equilibrium. At that time $R_{1,2} < C_{1,2}$, according to R, C, I and to judge the equilibrium strategy, the evolutionary game method is used to deal with this problem.

Operators choose to create the expected benefits of the platform $\pi_{11} = Z(L + R_1 I_1 + R_1 N I_2 - C_1 I_1) + (1 = Z)(L + R_1)$; the expected return not created is $\pi_{10} = L$, then the average expected return is the average expected return: $\pi_1 = Y\pi_{11} + (1 - Y)\pi_{10}$.

Expected income of private pile choosing "sharing platform" $\pi_{21} = Y(U + R_2 I_1/N + R_2 I_2 - C_2 I_2) + (1 - Y) \quad (U + R_2 I_2 - C_2 I_2)$, expected benefits of "nonshared platform" $\pi_{20} = U$, and the average expected return is $\pi_2 = Z\pi_{21} + (1 - Z)\pi_{20}$.

According to the dynamic replication principle of strategy selection in evolutionary game theory, the strategy whose expected return is higher than the average expected return can spread among operators and private pile owners. Then, the dynamic replication equations of operators and private piles are, respectively, as follows:

$$\begin{aligned} f(Y) &= \frac{dY}{dt} \\ &= Y(\pi_{11} - \pi_1) \\ &= y(1 - y)\left(ZR_1 N I_2 + R_1 I_1 - C_1 I_1\right), \end{aligned} \tag{1}$$

$$\begin{aligned} f(Z) &= \frac{dZ}{dt} \\ &= Z(\pi_{21} - \pi_2) \\ &= Z(1 - Z)\left(\frac{YR_2 I_1}{N} + R_2 I_2 - C_2 I_2\right). \end{aligned} \tag{2}$$

The differential equations composed of dynamic replication equations (1) and (2) are the dynamic replication system of the asymmetric game between operators and private piles. This equation system represents the population proportion of both sides over time t dynamic change speed. The solution curve of differential equations is a dynamic evolution process, and its stable solution is the equilibrium point, which can resist the disturbance of small mutation.

3.3. Analysis of Evolutionary Stability Strategy. According to the stability theorem, the operator's evolutionary stability strategy condition is $F(Y) = 0$ and $F'(Y) < 0$.

Table 1: Income matrix of operators and private pile owners.

Service provider	Private pile owner	
	Share proportion Z	Unshared Proportion $(1-Z)$
Create shared platform proportion Y	$(L+R_1I_1+R_1NI_2-C_1I_1, U+R_2I_1/N+R_2I_2-C_2I_2)$	$(L+R_1I_1-C_1I_1, U)$
Do not create shared platform proportion (1-Y)	$(L, U+R_2I_2-C_2I_2)$	(L, U)

(1) At that time $Z=((C_1I_1-R_1I_1)/R_1NI_2)$, be $F(Y)=0$. It shows that the operator's strategy is stable regardless of the value of the private pile Z.

(2) At that time $Z\neq((C_1I_1-R_1I_1)/R_1NI_2)$, make $F(Y)=0$, get $Y=0$ and $Y=1$ are the two stable points for the operator's strategy to copy the dynamic equation. At this time, there are two cases:

① If $ZR_1NI_2+R_1I_1-C_1I_1>0$, there are $F\prime(Y)|Y=0>0$, $F\prime(Y)|Y=1<0$, indicating that the operator's choice of creation strategy is stable, and the choice not to create is unstable.

② If $ZR_1NI_2+R_1I_1-C_1I_1<0$, there are $F\prime(Y)|Y=0<0$ and $F\prime(Y)|Y=1>0$, indicating that the operator's choice not to create the policy is stable and the choice to create is unstable.

Similarly, the conditions for private piles to choose the shared stability strategy are $F(Z)=0$ and $F\prime(Z)<0$.

(1) At that time $Y^*=NI_2((C_2-R_2)/R_2I_1)$, $F(Z)=0$, indicating that the operator selects the creation strategy in any proportion Y, and the private pile strategy is stable.

(2) At that time $Y^*\neq NI_2((C_2-R_2)/R_2I_1)$, let $F(Z)=0$, get $Y=0$ and $Y=1$, which are the two stable points for the private pile strategy to copy the dynamic equation. At this time, there are two cases:

① If $YR_2I_1/N+R_2I_2-C_2I_2>0$, there are $F\prime(Z)|Z=0>0$, $F\prime(Y)|Z=1<0$, indicating that the private pile selection sharing strategy is stable and the selection not to share is unstable.

② If $(YR_2I_1/N)+R_2I_2-C_2I_2<0$, there are $F\prime(Z)|Z=0<0$, $F\prime(Z)|Z=1>0$, indicating that the private pile selection sharing is unstable and the not sharing strategy is stable.

Let $F(Y)=0$, $F(Z)=0$, get 5 equilibrium points (0, 0), (0, 1), (1, 0), (1, 1), and (Y^*, Z^*), and $Y^*\neq NI_2((C_2-R_2)/R_2I_1)$, and $Z^*\neq((C_1I_1-R_1I_1)/R_1NI_2)$. According to the Lyapunov stability theory, the stability is analyzed according to the Jacobian matrix of the evolutionary game system.

Substitute the equilibrium point into the above matrix, J is the Jacobian matrix corresponding to the copied dynamic equation. If the determinant $\mathrm{Det}(J)>0$, $tr(J)<0$ is satisfied, the equilibrium point is a locally asymptotically stable fixed point, that is, the evolutionary stability strategy. According to the local stability analysis method of the Jacobian matrix, the stability of the above five Nash equilibrium points is analyzed. The Jacobian matrix of this model is as follows:

$$J=\begin{vmatrix}(1-2Y)\left(ZR_1NI_2+R_1I_1-C_1I_1\right) & Y(1-Y)R_1NI_2\\ Z(1-Z)\left(\dfrac{R_2I_1}{N}\right) & (1-2z)\left[\dfrac{YR_2I_1}{N}+R_2I_2-C_2I_2\right]\end{vmatrix}. \tag{3}$$

The specific values of 5 local equilibrium points in the corresponding $\mathrm{Det}(J)>0$, $tr(J)<0$ are shown in Table 2.

Because $0\le Y^*\le 1$, $0\le Z^*\le 1$, we can deduce the existence of inequality conditions: $R_1\le C_1\le R_1(1+NI_2/I_1)$, $R_2\le C_2\le R_2(1+I_1/NI_2)$.

Under these two conditions, there are (0,0) and (1,1) two stable evolutionary solutions at the same time, resulting in the problem of chicken laying eggs and egg laying chickens: operators are willing to build platforms when private piles are willing to participate in sharing; on the contrary, private piles are willing to participate if operators are willing to build platforms.

As for what kind of stable state and critical point will the strategic choice between the operating enterprise and the private pile owner evolve $E=[(NI_2(C_2-R_2)/R_2I_1), (I_1(C_1-R_1)/R_1NI_2)]$; therefore, we study the changes of some variables to observe the changes of the critical point E and then analyze the evolution track of operating enterprises and private pile selection. At the same time, affected by inertia, the initial proportional value selected by both parties also greatly impacts the results.

4. Case Analysis and Model Parameter Setting

4.1. Case Analysis. Next, combined with the actual situation of existing private pile sharing, set the main parameters in the asymmetric model constructed, and then explore the dynamic evolutionary process of value creation between the two sides.

The values of each variable are as follows:

(1) Investment scale. To simplify the processing, the scale of the operator's investment in the sharing platform and the expenses incurred by private pile sharing are

Table 2: Equilibrium points and eigenvalues of the Jacobian matrix.

Equilibrium point	Det(J) expressions and symbols		$tr(J)$ expressions and symbols		Result
(0, 0)	$(R_1I_1 - C_1I_1)(R_2I_2 - C_2I_2)$	+	$R_1I_1 - C_1I_1 + R_2I_2 - C_2I_2$	−	ESS
(0, 1)	$[R_1(I_1 + NI_2) - C_1I_1]I_2C_2I_2 - R_2)$	−	$R_1(I_1 + NI_2) - C_1I_1 + C_2I_2 - R_2I_2$	+	Unstable point
(1, 0)	$[R_2(I_1/N + I_2) - C_2I_2]C_1I_1 - R_1I_1)$	+	$R_2(I_1/N + I_2) - C_2I_2 + C_1I_1 - R_1I_1$	+	Unstable point
(1, 1)	$[C_2I_2 - R_2(I_1/N + I_2)]C_1I_1 - R_1(I_1 + NI_2))$	+	$C_2I_2 - R_2(I_1/N + I_2) + C_1I_1 - R_1(I_1 + NI_2)$	−	ESS
(Y^*, Z^*)	$-(C_1 - R_1)(C_2 - R_2)(R_2NI_1 + I_1R_1 - I_1C_1)(R_2I_2 + NI_2R_2 - NI_2C_2)/R_1R_2N$	−	0	0	Saddle point

measured in currency (assuming that the unit is 10,000 yuan). When providing shared services, operators should be responsible for the platform's design, construction, operation, and maintenance, and the investment scale is generally much higher than that paid by a single private pile to participate in the platform. For this purpose, it is assumed that the operator invests $I_1 = 1000$. Different private pile investments, construction and maintenance costs vary greatly, and private piles are set to participate in the cost expenditure $I_2 = 1$.

(2) Expected return. Expected revenue of sharing platform $R_1 = 1.06$, which means the net return on unit investment is 6%. According to the private pile sharing scheme of the State Grid, the income sharing is "minimum income 30 yuan/month +70% sharing proportion," and the shared slow charging price is about 1 yuan–1.2 yuan/kWh, while the State Grid changes the private pile price at the household price of 0.475 yuan/kWh; that is, 1 kWh of electricity is consumed for each "sharing," and the pile owner can earn about 0.5 yuan. Since most private piles are installed in private parking spaces, the instability of shared income is large, so the expected rate of return is also high, set at 3%, i.e., $R_2 = 1.03$.

(3) Marginal cost. The marginal cost is higher than the expected investment income, which is mainly based on the following considerations: for operators, the construction, operation, and maintenance costs include many hidden costs, such as human investment and manager talent. For private piles, when adopting the sharing strategy, in addition to paying the use fee, it may also incur other costs, such as the cost of communication with the property, the penalty of nonsharing of equipment, and the opportunity cost of normal private use. Combined with the analysis in the theoretical model, it is assumed that the operator invests in the marginal cost of the sharing platform $C_1 = 1.5$. In addition, it is assumed that the marginal cost of participating in sharing is lower than that of the operator $C_2 = 1.3$.

(4) Share private pile scale. For simplicity, it is assumed that the private piles involved in the shared platform are homogeneous, and the number of private piles in the benchmark analysis is set as $N = 1000$.

4.2. Parameter Setting and Description. From the above analysis, the initial value setting of parameters needs to reach the optimal evolutionary stability point [1], that is, it needs to meet $R_2 \le C_2 \le R_2(1 + I_1/NI_2)$, $R_1 \le C_1 \le R_1(1 + NI_2/I_1)$; therefore, the initial values of each parameter are set as shown in Table 3.

Table 3: Initial values of parameters.

Game participants	Main variables	Value
Operator	Investment scale I_1	1000
	Expected rate of return R_1	1.06
	Marginal cost C_1	1.50
Private pile owner	Expenses I_1	1.00
	Expected rate of return R_2	1.03
	Marginal cost C_2	1.30

5. Economic Subject Behavior and Value Co-Creation

The decision-making results of private stake owners and charging operators directly affect the size of value co-creation, and the factors that affect the decision-making directly affect the possibility of value co-creation. The derivation above also proves this point. MATLAB simulates the evolutionary game model of both parties, and the initial participation intention, cost, and income of both parties are analyzed.

5.1. Impact of Investment Scale on Evolution Results

5.1.1. Changes in Operator Investment Costs. Operators create operation-sharing platforms. Generally, the larger the investment cost, the larger the investment scale, and the greater the probability of private pile sharing value profit. Private pile owners will choose operators with the large investment scales to cooperate. The initial values of each parameter are set in Table 3, $T = 10$. On this basis, the influence of the change of the investment costs of the operators I_1 on the evolution path of the asymmetric game is investigated.

As shown in Figure 1, the initial scale is $Y = Z = 0.5$, $T = 10$, and $I_1 = 1000$. Other situations evolved from situation 2. Case 1: when the operator's investment cost is low ($I_1 = 500$), the platform provides limited ability to create value together, and the profit of a single pile is limited. Therefore, most private piles gradually choose the sharing strategy, and the change speed is slow. Scenario 2: operators increase investment ($I_1 = 1000$), the co-creation value spillover effect increases, and private piles will choose the sharing strategy. In case 3, when the investment increases to 1500, the willingness to share private piles gradually decreases, and both parties' strategies gradually evolve into (no creation, no sharing). In summary, it shows that when other conditions remain unchanged, there is an optimal value of shared platform investment, which is in line with the law of economies of scale. No matter how the investment changes, the operator's strategy can always choose in the shortest time, while the private pile response lags.

5.1.2. Influence of Private Pile Investment Scale on Evolution Results. As shown in Figure 2, case 2 is the basic case, and the initial ratio is $Y = Z = 0.5$, $I_2 = 1$. In reality, the installation and maintenance subjects of charging piles are inconsistent, so the investment shared by private piles is quite different. The investment I_2 changes are from 0.5, 1, and 1.5, as shown in cases 1–3, respectively. The lower the scale of private pile investment, the value created by both parties is not enough to attract private pile owners to participate in sharing, so the proportion of nonsharing intention will gradually decrease (see case 1); on the contrary, the higher

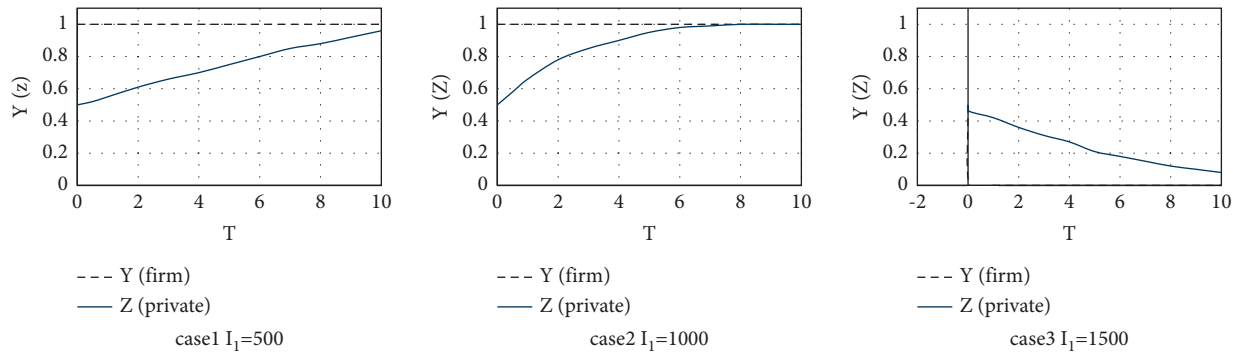

Figure 1: I_1 impact of changes on the evolution of co-created value.

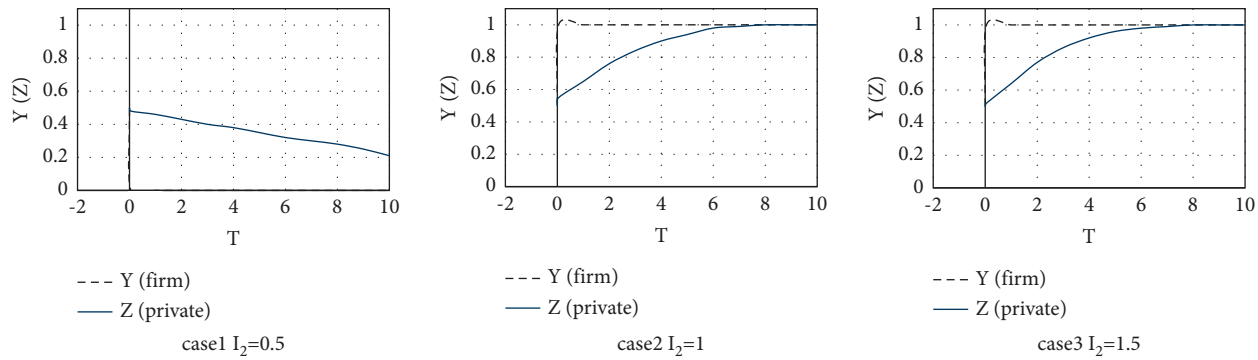

Figure 2: I_2 impact of changes on the evolution of co-created value.

the investment scale, the higher the value created by both parties, so the proportion of private pile owners' willingness to share will increase (see case 3). Compared with case 2, the curve of case 3 is relatively flat, indicating that the increase rate of private pile sharing intention is relatively slow and also indicating that there is an optimal investment scale for the realization of the value of both parties.

5.2. Impact of the Number of Private Pile Sharers on the Evolution Results. The realization of value creation requires a sufficient number of private piles to be shared. The choice of single pile strategy has little impact on the co-creation of value, once the number or proportion of shared piles adopting the same strategy reaches a certain scale; if the investment scale remains unchanged, there must be a crowding effect; even if there is spillover effect in the value co-creation of both sides, then the proportion of private piles adopting the sharing strategy will continue to decrease. With $Y = Z = 0.6$ as an example, in case 1, the share proportion of private piles is small and gradually tends not to be shared. In figure 3 case 2, when N = 1000, the private piles with an initial proportion value of 0.6 is starred as a sharing policy, and the private piles with a proportion value of 0.3 is starred as a nonsharing policy. In Figure 3 case 3, as the number of private piles is increasing, when N = 1500, The reason is that the number of participants increases, and the co-created value apportioned to a single pile increases first and then decreases. The initial share ratio is 0.3. At this time, the share intention ratio increases rapidly, indicating that both parties have created an immense value-added.

5.3. Impact of Marginal Cost on Evolution. Once private piles are installed, the parking and installation costs have been formed, and the marginal cost mainly includes maintenance and operation costs. The marginal cost of charging operators mainly includes platform information collection, transmission, feedback, maintenance, etc. The level of marginal cost affects the decisions of both parties. As shown in Figure 4, other conditions remain unchanged. Case 2 is the benchmark case. Case 2 is the reference case with an initial ratio of 0.6. With the increase of C_1 from 1.05 to 2.3, the net income decreases, and the value of CO-creation decreases. The evolution of the game between the two sides is stable (0, 0), and the proportion of operators that choose not to create changes quickly. As shown in Figure 5, similarly, the marginal cost of private piles gradually increases, the income decreases, and the proportion of private piles selected for sharing decreases, and the decline rate is fast. Whether it is a private pile or an operator, with the increase of marginal cost, if the initial proportion is 0.3, the proportion of both parties' choice (not create, not share) will increase rapidly, as shown in Figure 4 (case 3) and Figure 5 (case 3), indicating that the change of initial value will affect the value co-creation choice strategy of both parties.

Compared with benchmark case 2, if C_1, C_2 increase or decrease at the same time and change separately, the private piles with an initial value of 0.3 tend to be shared, but with the simultaneous increase of C_1 and C_2, the two sides evolve into (not created and not shared) (see Figure 6 case 3).

If C_1 increases and C_2 decreases, both parties evolve into (not created and not shared) (see case 4); if C_1 decreases and

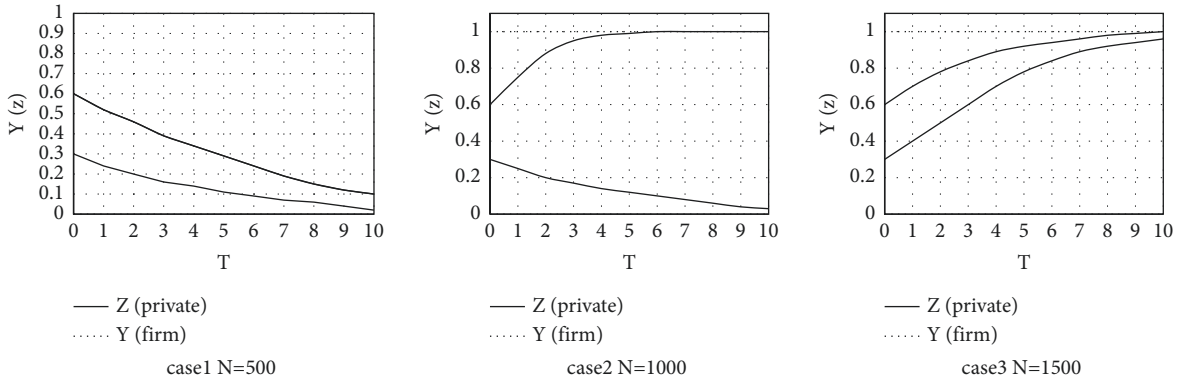

Figure 3: N impact of changes on the evolution of co-created value.

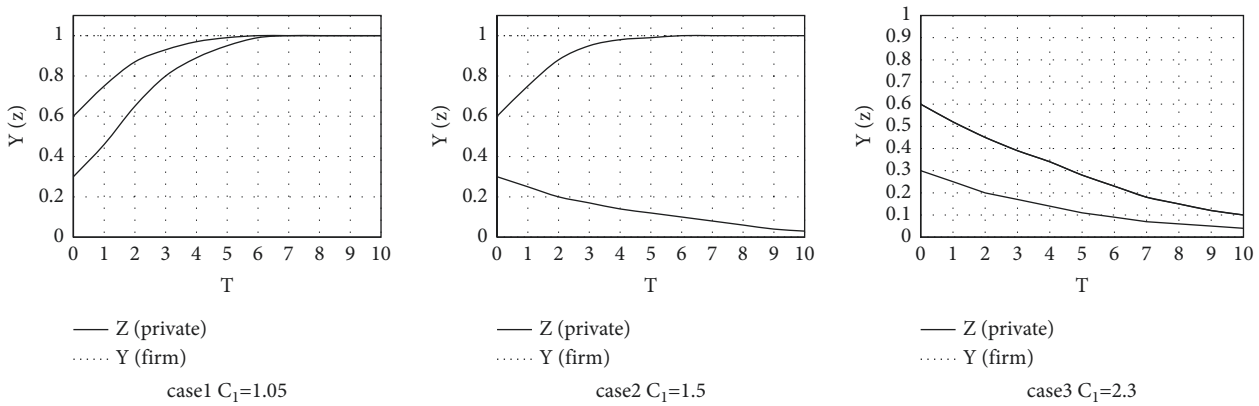

Figure 4: C_1 impact of changes on the evolution of co-created value.

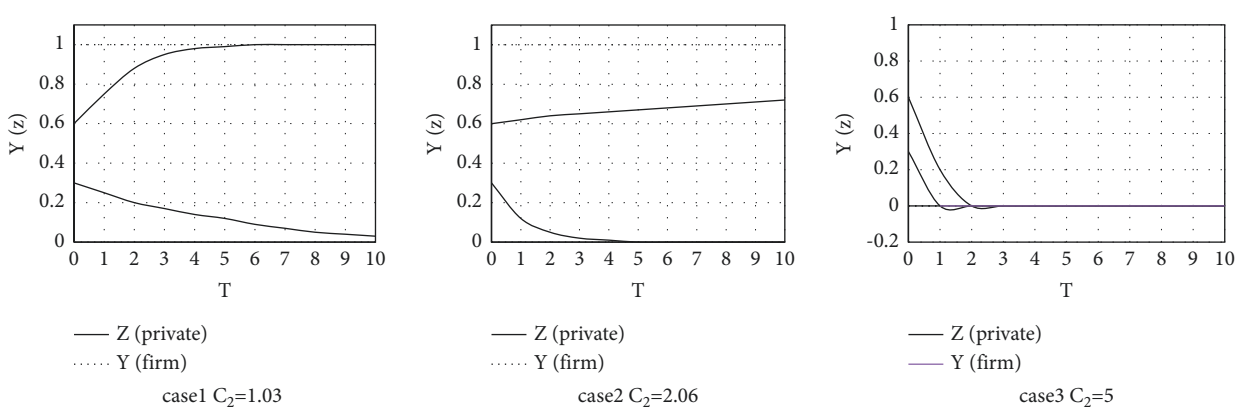

Figure 5: C_2 impact of changes on the evolution of co-created value.

C_2 increases, both parties form (create, share) a combination strategy (Figure 6 case 5). It shows that the marginal cost of operators has a greater impact on the evolution results than private piles.

5.4. Impact of Income Change on the Evolution. Revenue can increase the proportion of operating enterprises and private pile selection (create, share) strategies to a certain extent.

As shown in Figures 7 and 8, R_1 increases, and the initial proportion is 0.6. Both sides gradually evolve into (create and share) combination strategies. With an initial probability of 0.3, private piles still evolve to nonsharing, but the rate gradually decreases, and operators still choose not to create them. The results show that increasing the operators' revenue can effectively enhance enterprises' willingness to choose the strategy of "creating a shared charging pile platform." R_2 increases, and the initial probability is 0.6. The proportion of private pile sharing intention gradually increases with the increase of yield. The initial probability is 0.3, and the private pile still evolves to nonsharing, but the speed slows down. It shows that the initial intention greatly

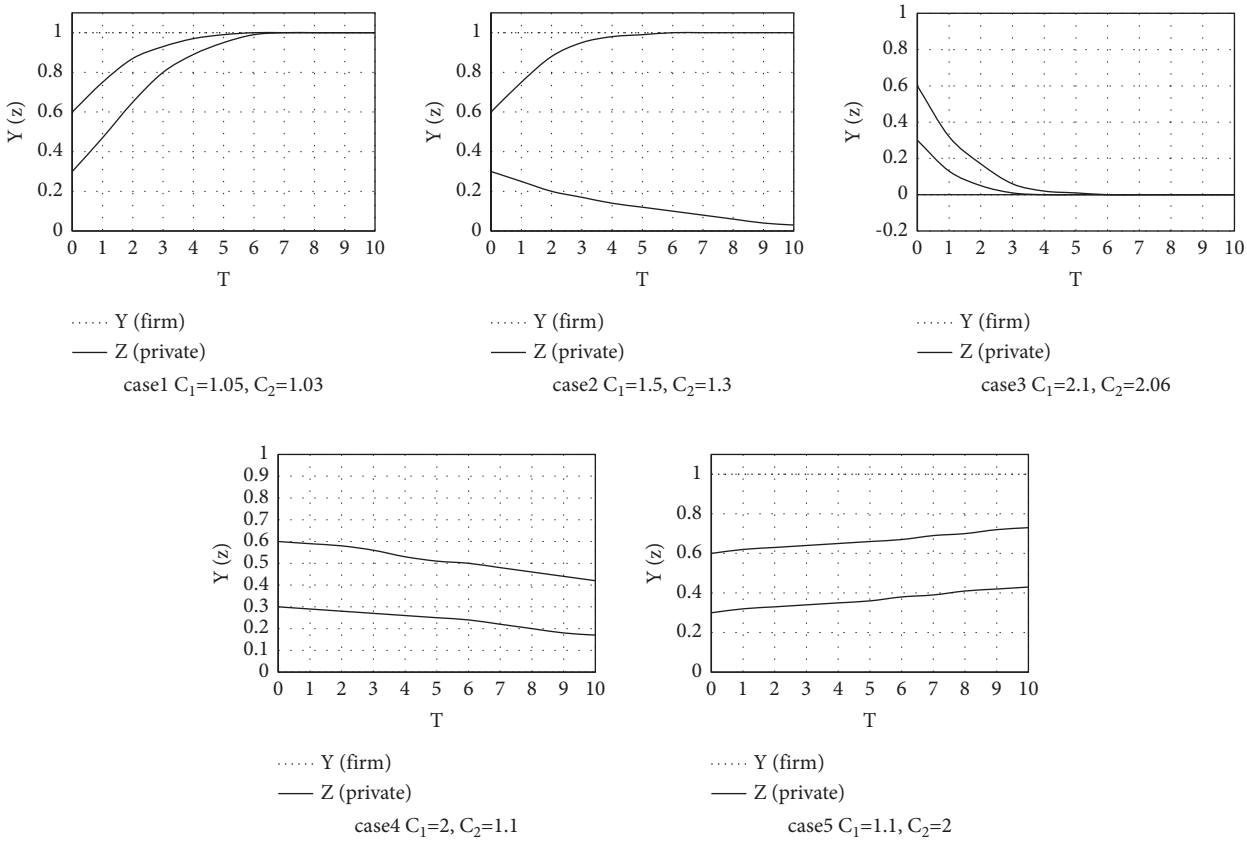

Figure 6: C_1, C_2 impact of changes on the evolution of co-created value.

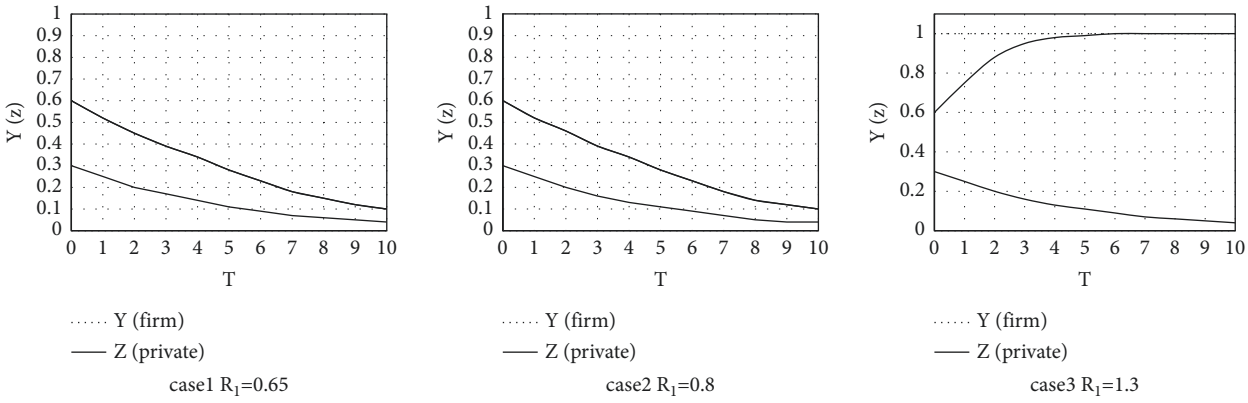

Figure 7: R_1 impact of changes on the evolution of co-created value.

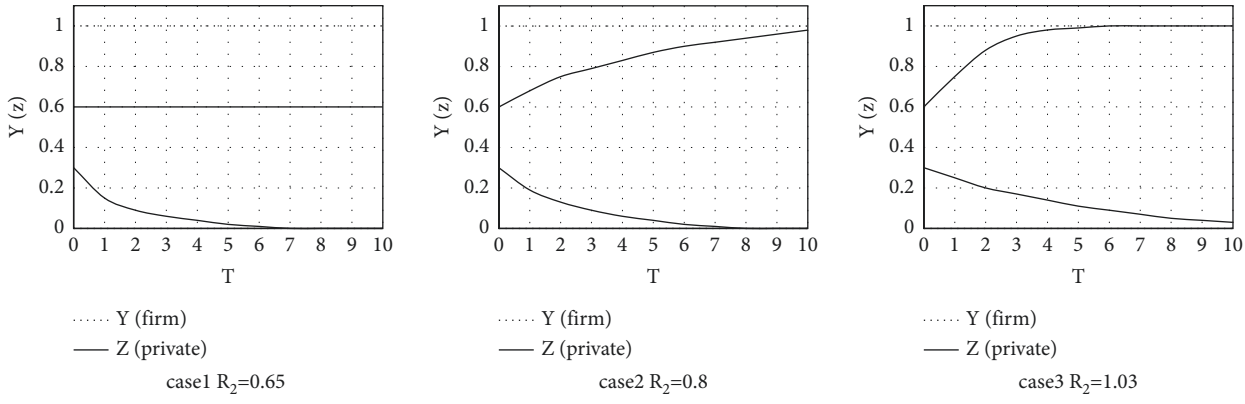

Figure 8: R_2 impact of changes on the evolution of co-created value.

impacts the choice (create, share) of both parties. R_1 has more influence on evolution than R_2.

6. Conclusions and Suggestions

This paper studies the asymmetric game in the value creation process between operators and private piles. The paper shows that (1) the probability of initial intention will affect the strategic choice of both sides. Improving the initial creation and sharing probability will help both sides create value together; (2) there is an optimal scale for operators to invest in creating a shared charging platform; (3) the change in the proportion of marginal cost and income will affect the strategic choice of both parties. The private pile yield has a more significant impact on the evolution results of both parties than operators. The marginal cost change of operators has a more significant impact on the evolution results of both parties than private piles; (4) due to the "one-to-many" relationship between operators and private piles, there is an optimal bearing scale for the number of private piles on the shared platform under certain conditions. Too few or too many may make the value co-creation of both sides evolve to (not created or shared) combination; (5) private piles and operators have a "chicken lays eggs" cycle. Operators can make decisions in time. Operators' decisions are more timely affected by private pile operation decisions.

To guide operators and private piles to create value together and avoid the dilemma of both sides (not creating or sharing), combined with the research conclusions, the following enlightenment can be put forward.

First, encourage the initial probability of operators and private piles (creation, sharing). Strengthen the efficiency of the pilot operation of shared charging piles, encourage more private piles to participate in sharing, and encourage more social resources to participate in the construction of charging infrastructure. Reasonably, set the charging and parking prices of shared private piles, balance the benefits of both operating enterprises and those sharing private piles, and make them in a balanced possession equilibrium strategy.

Second, improve the probability of operators creating a shared platform strategy. Currently, the operation mode of private pile sharing by Chinese operators still needs continuous innovation and perfection. To promote the orderly development of this industry, operators need to enhance their awareness of creating a sharing platform. Regarding the occurrence of the "egg" problem, operators are encouraged to pilot first and then promote it in a large area.

Third, reducing the marginal cost of private pile sharing is conducive to private pile sharing. The charging company bears the maintenance fee in the star charging method, which is conducive to increasing the possibility of private pile sharing strategy. It is suggested to learn from this experience. Property management should adapt to the development of private pile sharing and make appropriate management measures in time.

Fourth, it is suggested that government departments guide social charging pile resource sharing to prevent value co-creation from getting into trouble: ① when operators adopt the "creation" strategy, government departments will appropriately subsidize according to the development of the electric vehicle demand market, reduce the construction and operation cost of sharing platform, and increase the possibility of adopting the "creation" strategy; ②encourage the management environment of private pile sharing in the community, make it possible for private pile sharing in the community, and increase the possibility of adopting the "sharing" strategy.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis on the Influence of Urban and Rural Economic Differentiation on the Development of Art Design Teaching

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Art design education in China has nearly 30 years of development history. Due to China's vast territory, a large population, regional economic development, and social resources are extremely unbalanced, resulting in the uneven development of art design education in various regions. Art design is not only a practical and artistic comprehensive discipline, it also spans more majors. It contains almost all aspects of urban and rural construction, beautification, so its scientific and effective design scheme indirectly affects the future development process of urban and rural economy. First, this paper analyzes the impact of urban and rural economic development on art design teaching. The research results show that it has a great influence and a wide range of influence on art design teaching, including enhancing the naturalness of art discipline, promoting the creativity of art design discipline, and promoting the historicity of art discipline. Second, this paper also analyzes the role of art design in promoting regional economic development. For example, we should make full use of regional cultural differences, expand regional historical elements, pay attention to art design talents, and ensure the supply of funds.

1. Introduction

Innovation is the driving force of a country's economic growth. Renowned economist Romer made this prediction 20 years ago. However, in today's world, the development of innovative industries is more closely linked to the development of a country. It is of great significance for China to pay attention to the current development status of the world's innovative industry and accurately grasp the development trend. And innovative industry has become one of the most important quintessences of urban competitiveness. In order to speed up the adjustment and upgrading of industrial structure, enhance the image and status of the city, improve the comprehensive competitiveness of the city, and realize the soft path of innovative industries, the key is to have the system and talents as the guarantee and backing. We should not only ensure platform construction, but also include personnel training and system innovation. As an important force in the innovation industry, the great art discipline plays a major role in the adjustment and upgrading of the industrial structure. At the same time, how to play a more active role in the tide of innovative industry is also worth thinking [1, 2]. As an important part of quality education, art education is an important means to implement quality education.

At the beginning of the 20th century, due to the continuous expansion of industrial production scale in European countries, some schools for training design talents have been unable to adapt to the new requirements of design education. Therefore, with a series of new reforms to promote the development of German modern design, it has also established a decisive position in the field of modern design [3, 4]. Nowadays, China's art design education in colleges and universities has a lot in common: many companies are reluctant to recruit fresh art design graduates. This reflects the fact that the practical operation ability of students does

not meet the market demand. It can be seen that the current art design education has been difficult to adapt to the new situation. First, there is a certain gap between the old teaching system and the new situation and environment. Second, there is a big gap between traditional arts and crafts education and modern design in concept and thought [5, 6].

The quality of students is a prerequisite to determine the quality of teaching. At present, art students in China are mainly enrolled according to arts and sciences, which has broken the current situation that art students only have arts. It has also greatly expanded the scope of enrollment, and the proportion of science and technology students is gradually increasing. Besides, it should be said to adapt to the current trend of social development. However, under the current situation of art enrollment in China, many art students only pay attention to the basis of painting, thus neglecting the study of cultural courses [7, 8]. Most of the students' parents also lack knowledge and understanding of art design professional. They failed to discover the child in all aspects of the talent, just think it is easy to learn at the fine arts college, and even some students sit for the college entrance examination in time at the request of the parents to choose art. Reference [9]. "To study art for college entrance examination" has become a shortcut in today's society, so modern middle schools have added art classes, special classes, so as to improve the enrollment rate they pursue. A large number of targeted training classes as well as all kinds of fine arts training institutions are organized in response to the college entrance examination. The serious influence of the arts class examinee's artistic accomplishment also brings higher art education, affecting the overall quality and level of the art design education in China [10, 11]. The development of art education is not only conducive to promoting the all-round development of individuals, but it also enriches people's spiritual and cultural life, promotes the development of cultural diversity, and promotes social harmony.

In Shandong province, for example, the number of applicants for the fine arts examination broke through 100,000 in 2007. In the following four years, the number of examinees declined continuously [12]. In 2011, the number of applicants was only 39683, nearly 60000 fewer than the peak. The decrease of students makes some colleges and universities unable to recruit high-quality art students. Compared with some developed big cities, this phenomenon is more obvious in remote local colleges and universities, and even enrolled students do not register or drop out.

The government's emphasis on art education directly affects its investment. The government's investment in education mainly focuses on some hardware facilities or it is based on meeting the needs of exam-oriented education. Therefore, under the condition of a certain total amount, the investment in art education is insufficient. It is mainly manifested in the lack of necessary equipment for art education, the lack of professional site construction, and the weakness of teachers [13, 14]. Many local governments often reduce or even ignore the budget of resources needed for art education when they are planning school districts, purchasing equipment, or introducing talents. In addition to the premise of meeting the needs of exam-oriented education, the lack of finance at the township level is an important source of the lack of investment in art education [15, 16]. In China's rural areas, there is a serious imbalance between administrative and financial power, which is also an important factor that makes it difficult to improve the public service level in rural areas in a short period of time. The absence of public finance in rural areas has already brought restrictions to the work of the government at the township level, while the reduction and exemption of agricultural tax has cut off the main source of public finance in rural areas, which has caused more tension in the rural public finance, which is not rich at first, and thus insufficient investment in education on the whole [17]. However, art education is specialized in manpower and material resources, which make the cost of carrying out art education high. In addition, the government's understanding of "dispensable" art education cannot provide a large amount of manpower, material resources, and financial resources. This has become the main factor restricting the development of art education in rural areas [18, 19].

In view of the fact the development of art education is not ideal in practical work, especially at the primary level in rural areas. It can be seen that in every period of social development, there are relations between economy, culture, and politics, and economic development is always the most basic and fundamental factor. Economic development promotes the development of politics and culture, while the development of politics and culture also acts on economic development. As a manifestation of cultural ideology, art design also has a certain relationship with economic development. This paper takes artistic design as the main research object and analyzes the profound relationship between it and economic development, in order to make the development of artistic design better adapt to the development of social life.

2. Differences of Art Design Teaching between Urban and Rural Areas

This paper also discusses the feasible path to promote the development of art education in rural areas from the aspects of policy support, school positioning, resource allocation, and teacher construction, so as to achieve the purpose of improving the level of art education in rural areas. Students from both urban and rural areas are very fond of art design teaching, believing that art design teaching is a relaxing course without the pressure of examination. High school students said that art design teaching is one of their favorite classes, so they do not have to concentrate on lectures.

Urban and rural students generally believe that art design teaching is a minor subject, which does not need to be studied seriously, and they think that art design teaching content will not be used in the future. Due to the long term, art design teaching is "less important," so that the course is conducted without having to learn. Even if they learned later in life, it will not be used in this kind of idea.

Students in both urban and rural areas know that learning arts can be a shortcut to college. Over the years, the number of art examinees has become larger and larger, and

their influence has expanded year by year. Learning art has become a shortcut for students to enter college. Part of it is due to the talents and hobbies, and part is to study for college entrance. It can be said that this is also meets a lot of college students' dream. Figure 1 shows the phenomenon of cultural classes crowding out music classes in urban area and it was investigated, accounting for the fact that 32% is often, 45% is sometimes, and 23% is never. Besides, Figure 2 shows the phenomenon of cultural classes crowding out music classes in urban area was investigated, of which 49% of students said they were often, 38% said they were sometimes, and 13% said they were never.

In addition, urban students can fully realize and benefit from the new curriculum reform. Rural students have not realized the impact of the new curriculum reform and have no great experience of the reform of art design teaching. After the new curriculum reform, the urban high school teachers closely follow the pace of reform, which makes the students feel the vitality injected by the new curriculum reform.

Therefore, from the perspective of an art educator, this study uses the theory of public service and combines relevant national policies to discuss the problems existing in art education in rural areas. Urban students can not only relax their body and mind, but also receive ideological and moral education in the teaching of art design. Rural students directly experience the entertainment of art teaching, not other functions. Urban high school teachers not only teach art knowledge for students in art class, but also teach moral education. Rural teachers have traditional classes and dare not innovate.

Urban students have a deep understanding of artistic specialties, and there are many convenient learning opportunities and space to showcase themselves. However, rural students have little understanding of artistic specialty, and there are many misunderstandings. Besides, there is no perfect teaching equipment and there is also teacher shortage. In addition, urban high school students have many opportunities to showcase themselves and exercise themselves, and almost all students can get the opportunity to exercise. Abundant campus activities have built a good platform for students, and professional teachers have laid a solid foundation for students' growth, providing fertile soil. However, only a few students in rural high schools study art and have few opportunities to showcase themselves. A survey on how much the students liked the art design lesson was conducted, as shown in Figure 3. Sixty-five percent of students said they liked it very much, 21% students said they liked it, 10% students said they did not care for it, and only 4% students said they did not like it.

2.1. Economic Differences Lead to Inadequate Introduction and Training of Teachers. A good teacher is the premise for students to learn, he or she is a strong guarantee for students to acquire knowledge and improve skills. With the rapid expansion of art design education in all parts of the country and the subsequent expansion of college enrollment, the number of art design students has increased, and there is a

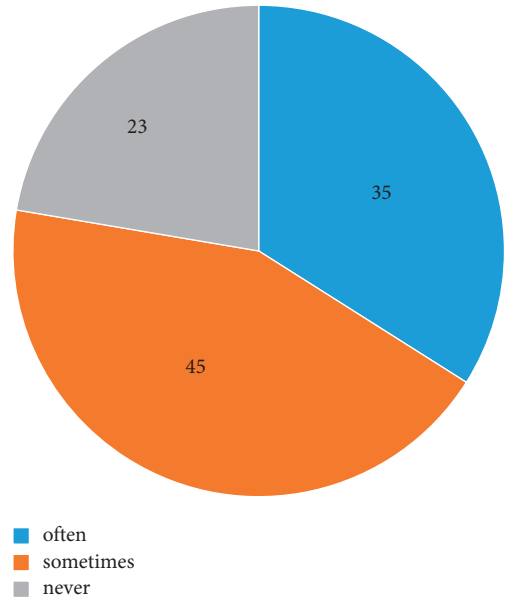

Figure 1: The phenomenon of cultural classes crowding out music classes in urban area.

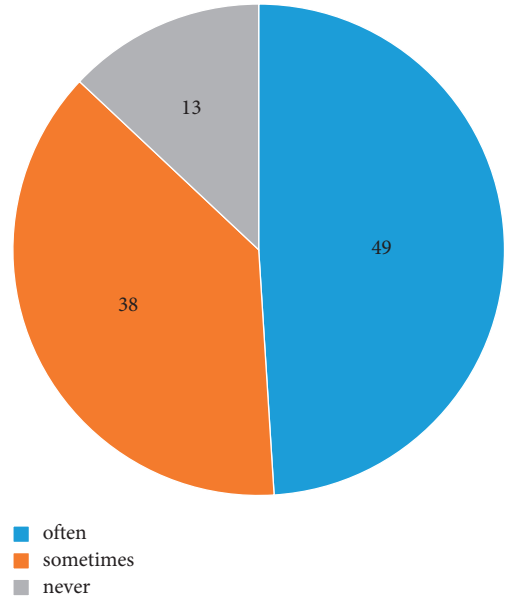

Figure 2: The phenomenon of cultural classes crowding out music classes in rural area.

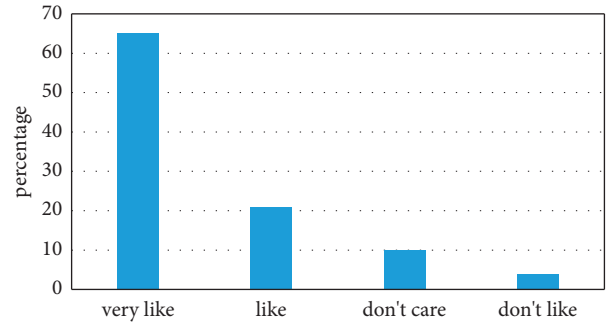

Figure 3: The degree to which the students enjoy their art design lessons.

general shortage of teachers. It is also due to the limitation of local environment that excellent graduates and high-level talents cannot be attracted. This situation makes the teacher-student ratio in many schools far exceed the allowable level of art design education. No matter what professional courses are taught, there are only a few teachers repeatedly, which brings too much burden on professional teachers. Thirty to forty percent of students in a class are like herding sheep, so it is difficult to ensure the quality of teaching and even more difficult to have time for scientific research. Even more absurd is that in order to balance the teaching, some schools let many people who are engaged in pure art education such as Chinese painting and oil painting fill the art design teacher team to take the basic course of design. The teaching quality can be imagined due to the lack of design literacy and professional knowledge.

Second, local colleges and universities recruit students, who had just done the test on short-term training in painting. It will be only slavish and they even do not know that the understanding of their own professional deficiencies enough. For the unceasing transformation, it promotes the creative design more at a loss. Some of the students after admission were disconsolate, they did not understand the lecture without the teacher's correct guidance, and so learning interest is not high. Over time, they have formed the situation of modern art design college students with poor artistic imagination and creativity and more concrete and conservative way of thinking. In order to study the effect of urban and rural location on study resources, the data are investigated and the corresponding predicted value is shown in Figure 4. As can be seen, the urban students have a better condition of study resources.

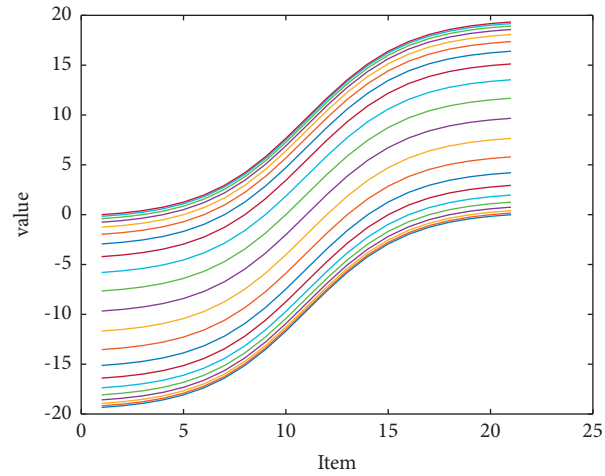

Figure 4: Predicted value.

2.2. Economic Differences Lead to Inadequate Teaching and Experimental Facilities and Imperfect Social Market. Art design is a profession with strong practicality and high requirements for hands-on ability. However, due to various reasons, some local colleges and universities do not pay attention to the art design major, and lack of investment in experimental equipment, let alone update, making the art design experimental teaching become the weakest link in the teaching of design education. Such relatively backward experimental equipment cannot meet the innovative design concept of art design, as a result students cannot personally participate in the production process of the art design major, and the students trained by these colleges can only be "armchair."

Conversely, regional economic development will also affect art design. It can enhance the naturalness of the discipline of environmental art. With the acceleration of economic development in various regions, the scale of urban construction is getting larger and larger. Therefore, the discipline of environmental art design has been innovated in concept in this era. In order to satisfy the urban resident population life and aesthetic requirements, the modern environmental art design personnel to afforest, humanities, sculpture, water, and fitness to join in the planning scheme, at the same time, combined with the feature of regional development in time and factors such as natural environment condition in environmental art design, in the city under the background of the original culture, natural and social organization, can make economic and environmental development sustainable.

Second, regional economy can also enhance the creativity of art design disciplines. People living in modern large cities have higher and higher requirements for comfort. Therefore, environment art designers must timely enrich their professional knowledge, and on this basis, constantly improve innovation, use science and technology to make environmental art design more innovative and diversified. While meeting people's needs, it also accelerates the development of environmental art design discipline and improves its knowledge system. At the same time, innovative design will become bolder and more unique with the development of discipline and technology.

Third, regional economy can enhance the history of environmental art discipline. In the process of urban development, social activities make our cities more modern, but the improvement of urban infrastructure should also preserve the unique culture formed in the process of urban development. These humanistic histories are of very high research value and should be preserved. Therefore, in environmental art design, the historical and cultural background of urban development should be presented more comprehensively through the integration of historical elements. For example, Suzhou's urban gardens are not only full of cultural deposits, but also make people's life and nature harmonious and unified, adding natural and cultural beauty to basic life. These distinctive cultural features distinguish cities from each other.

There are some problems in art design courses in urban and rural areas. Both urban and rural high schools have ignored the importance of art design courses. The professional skills of art design teachers are reduced. Due to the lack of attention from the school, the status of art design teachers is also reduced. Art design teachers relax their self-discipline and their professional skills are gradually

weakened. The understanding of modern educational technology is not profound and cannot be well applied to teaching.

The existing problems have been accumulated over a long period of time and cannot be solved overnight. Many of the problems are left over from history, and many need the intervention of the government and other relevant departments to alleviate them, such as the lack of teachers in senior middle schools in counties. Art design courses have long been regarded as "minor subjects." These problems are "difficult and complicated diseases" and cannot be solved once they are discovered. It requires long-term persistence and strong support.

The status of art design courses in Chinese schools is generally not high, and art design courses are not valued. The importance of thinking can be reflected in the saying, "As far as the thought is, so far can go." If we continue to hold the idea that art design is a "minor subject" and a useless minor subject, we cannot reverse the status of art design. It is necessary to establish a new ideology to further promote the development of art design courses.

Urban teaching facilities are relatively perfect. The art design teaching equipment in urban schools is much superior compared with other schools. No classroom is equipped with projectors and sound, which can make students experience the charm and fun of multimedia art design teaching. Art design teachers have a certain professional level. All art design teachers have bachelor's degree and graduated from professional colleges. And they have many years of teaching experience. The art design curriculum system is not perfect. Chinese high schools do not have a profound understanding of the art design curriculum reform, and cannot complete the art design teaching well in accordance with the requirements, which leads to the absence of teaching modules, the lack of entertainment and integrity of art design courses, and the lack of fun for students.

Art design appreciation classes in urban middle schools have been fully covered; Rural high schools only open for the first year of high school. Abundant resources of urban art design teachers; Rural senior high school art design teacher resources shortage. Although the teaching equipment is very perfect, the teaching equipment of urban high schools is newer, higher level, and more comprehensive than that of rural high schools. Urban art design teachers are more skilled in multimedia teaching operation and have innovative consciousness for PPT production; Rural high school art design teachers are more conservative. Comparatively, the campus art activities in urban high schools are more abundant. Influenced by the number of students, there are more students with special abilities in urban high schools.

Then, the correlation study is studied as follows. We establish a regression analysis using the number of students per 10,000 population ($\hat{x}_1$) as the dependent variable and per capita GDP(x_2) as the independent variable to calculate the logarithmic regression equation:

$$\begin{aligned} \hat{x}_1 &= -700 + 85 \ln x_2, \\ F &= 1281, p < 1\%. \end{aligned} \tag{1}$$

Taking the cubic root of index X_3 into consideration, perform regression analysis on the transformed data, and we can get the regression equation

$$\begin{aligned} \sqrt[3]{x_3} &= 47 - 3 \ln x_2, \\ F &= 18, p = 5\%. \end{aligned} \tag{2}$$

The logarithm curve model is fitted by natural logarithm transformation of X_4,

$$\hat{x}_2 = 336000 - 262500 \ln x_4 + 52003 (\ln x_4)^2. \tag{3}$$

Through the regression analysis program, we obtained the fitting curve model as follows:

$$\hat{x}_2 = 29100 - 7048 x_5 + 496 x_5^2. \tag{4}$$

In addition, we can also obtain:

$$\begin{aligned} \hat{x}_2 &= 2700 + 130 x_6, \\ R^2 &= 1, F = 185, \\ \hat{x}_8 &= e^{x_2 + 3}. \end{aligned} \tag{5}$$

The regression model is obtained through iterative operation of nonlinear regression program:

$$\begin{aligned} \hat{x}_2 &= -18000 + 5900 \ln x_8, \\ \hat{x}_2 &= 3615 + 74 x_9, \\ \hat{x}_2 &= -1200 + 270 x_{10}. \end{aligned} \tag{6}$$

3. Art Design Promotes Regional Economic Development

3.1. We Should Make Full Use of Regional Cultural Differences. In the rural areas of China, due to the influence of the economic and cultural environment, the government and other public departments pay less attention to education, especially art education, and the burden of educational development and reform is mainly provoked by schools. China is a vast country with a wide span from east to west and distinct climate differences from north to south. In the course of historical development, each region has formed its own unique cultural history and social environment, and there are also great cultural differences between different regions and different ethnic groups. Therefore, in order to highlight the uniqueness of each city, environmental art designers must make full use of regional cultural differences, take geographical and climatic environmental factors of the north and south into consideration, and integrate more national characteristics and elements into the design scheme through scientific design and combination, so as to enhance the cultural vitality of urban development. At the same time, in order to highlight the modern development of the city, it is necessary to integrate more scientific and technological means and make innovations on this basis while preserving the history. Following the design principle of adapting measures to local conditions, so that human society can live in harmony with the natural environment and promote each

other. We can promote the regional economic development of the city without wasting natural resources. As can be seen in the colorful map of the results shown in Figure 5 that the shortcomings of rural areas are mainly manifested in the lack of necessary equipment for art education, the lack of professional site construction, and the weakness of teachers. Many local governments often reduce or even ignore the budget of resources needed for art education when they are planning school districts, purchasing equipment, or introducing talents. However, education is related to the future, the national economy, and people's livelihood, and is an important part of China's basic public services.

3.2. We Should Incorporate and Expand Regional Historical Elements. Unique regional development history has created unique local conditions and customs, cultural customs, therefore, in the process of urban economic development, we should pay attention to provide a more perfect and modern economic environment for the urban population. We should also pay attention to preserve the original historical buildings and cultural practices of the city, because the development of the region is based on the human spirit. Only by respecting the history of urban development and paying attention to the protection of traditional culture can the city develop efficiently without losing its individuality. At the same time, the protection of historical development marks is tantamount to the protection and development of urban culture, so it is necessary to integrate new ideas into these traditional cultures and innovate on the basis of historical integration. Only in this way can urban development based on regional historical and cultural elements become more scientific and more vigorous. The radar map is shown in Figure 6. It can be concluded that local governments should build teaching places where there is a shortage of teaching places and purchase teaching equipment to diminish the insufficient teaching equipment. Besides, schools with poor development should strengthen supervision and guidance to provide advice on art education in schools.

3.3. We Should Attach Importance to Environmental Art Design Talents and Ensure Funding Supply. A successful environmental art designer not only requires the designer with high artistic accomplishment, but also one who has a strong sense of social responsibility. He may also have rich knowledge reserves and can accurately grasp the public's aesthetic consciousness, keeping up with the trend of the opportunities. At the same time, he may not forget to include innovation, bold practice, so as to establish a unique regional environment. Of course, regional construction is also inseparable from the strong economic backing, without economic security all plans and decisions are empty talk. All design and construction are subject to the constraints of funds, only sufficient funding sources, coupled with an excellent artistic design scheme. There can also be finally collision-independent, excellent environmental design cases. That is the more excellent urban construction planning, the more beneficial to the development of regional economy.

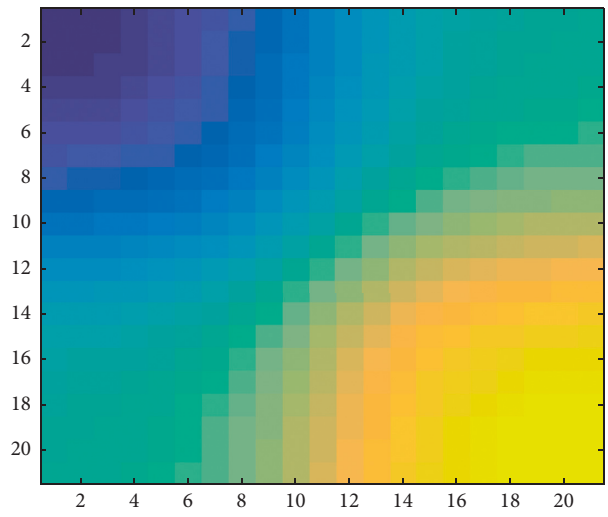

Figure 5: Colorful map of the results.

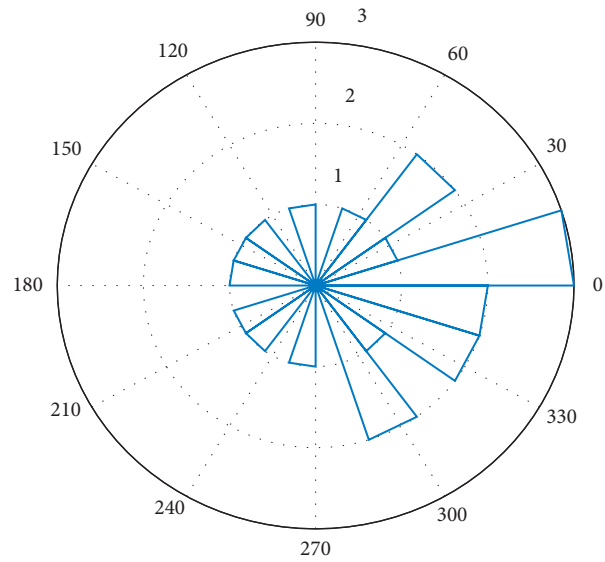

Figure 6: Radar map.

The time versus frequency is plotted in Figure 7. That is, in terms of finance, the government may consider giving corresponding support, purchasing corresponding teaching equipment and resources for rural schools, and providing basic tools or equipment for the development of their art education. Therefore, the development of education is not only the responsibility of schools, but also an important responsibility of the government.

In a word, people's continuous pursuit of practical beauty is the source power for the development of art design, and this source power is also the biggest power to promote social and economic development, which is exactly the saying that "science and technology is productivity." The level of science and technology can most effectively promote the progress of social and economic level. It is not difficult to find the development course of science and technology, art

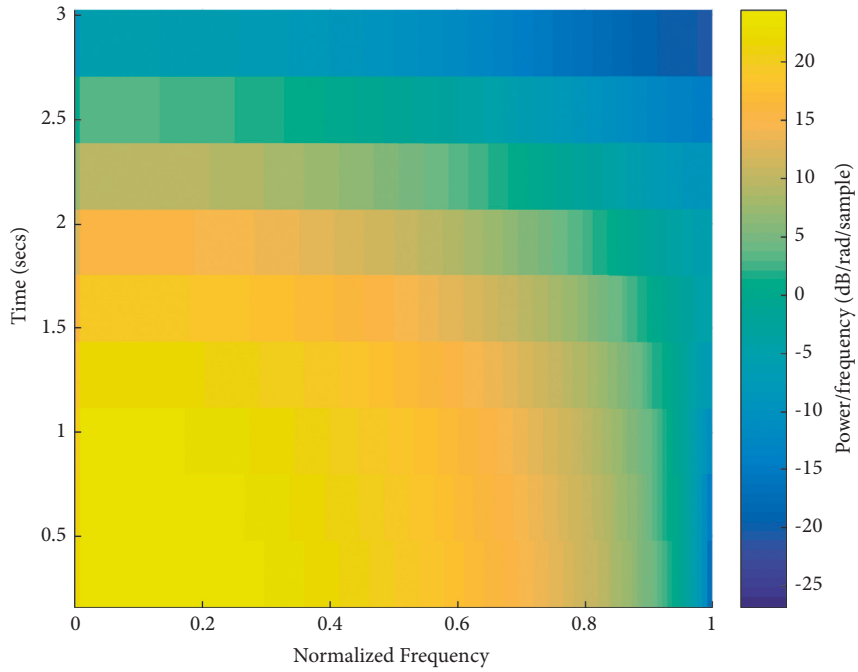

Figure 7: Time vs frequency.

and economy. Technological life is also a combination of various forms of art and serves the real life of human beings. To put it in the simplest terms, in the development of today's society, if a commodity not only has certain practicality but also has certain artistry, otherwise it will be widely welcomed by the public, and the economic value of the commodity will inevitably increase, and the specific income will continue to increase. In this case, artistic design can be regarded as having certain economic value. To rise to the social level, the prosperity of art design on the one hand, that all the things on the social level increase at a certain artistic value, makes its overall value higher, at the same time, the continuous development of art design also brings our country a multitude of creativity, the creativity for the economic development of China has played a huge role in promoting, it has brought about tremendous innovation. Therefore, we can think that art design can promote the development of China's social economy to a certain extent.

In the development of recent years, the new era of development characteristics is the revolution of knowledge economy, the economic development of all aspects needs to rely on the knowledge content and knowledge as the main social labor main reference standards, at the same time, it is knowledge economy that provides opportunities for the development of art design and the basis of further development. In the development process of art design, it does not simply pursue the projection of the real world, but requires the harmonious and unified expression of creativity and emotion, which is one of the most indispensable factors in the current social and economic development. Therefore, we will incorporate the art design into the social and economic development when they need to be consistent with the direction of development of the knowledge economy, pay attention to the creative design in the art design and emotional expression, not blindly to show off the objective world, in the process of the design of concrete should be positive to join their ideas, we should try to be different, only then can it have a certain position in the knowledge economy and obtain certain economic benefits. The prediction of the results is shown in Figure 8.

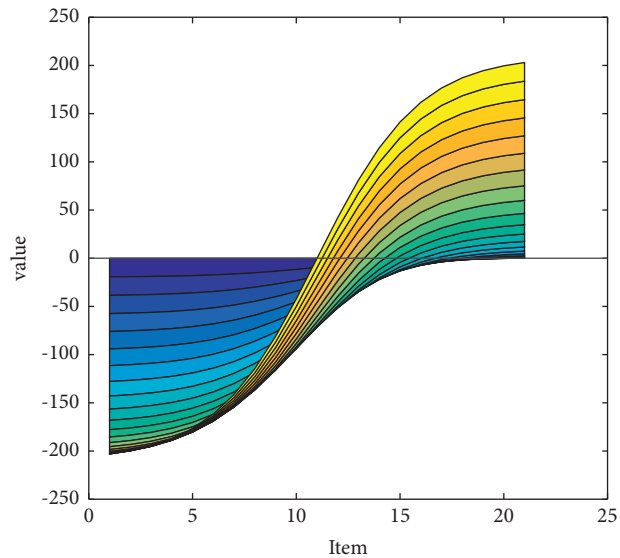

Figure 8: Prediction of the results.

In the current social development, the art design should bring in innovation with the aid of certain means of science and technology, software, computer peripherals, such as computer, plot, and so on. At the same time, the

development of art design is not isolated and one-sided, it needs to constantly absorb and draw lessons from existing scientific achievements, making the whole design better fit with the time development, really meeting the main needs of the people. For example, in the ancient times of mankind, only stone chisel technology, and red clay as the material so the production of rock paintings. The murals have a certain bold and unrestrained style. The generation of oil extraction technology so that the Van Eyck brothers invented oil paint, Da Vinci could leave Mona Lisa eternal smile. In the process of the development of contemporary society, the continuous popularization of information technology makes art design reflect more modern science and technology elements. Therefore, in the future design development process, we should actively combine art design with advanced science and technology. At the same time, art design can have certain innovation and can also adapt to the development, so that it can better meet the pursuit and the real needs of consumers.

4. Conclusion

It can be seen from this paper that the difference between urban and rural areas has an impact on art design education. Thus, it is the common responsibility of schools and society to narrow this gap and speed up the construction of local social spiritual civilization. The research results show that it has a great influence and a wide range of influence, including enhancing the naturalness of art discipline, promoting the creativity of art design discipline, and promoting the historicity of art discipline. Besides, it is also found that regional economic development has enhanced the naturalness of art, promoted the creativity of environmental art design, and promoted the historicity of art.

Although this paper studies the difference between economic level and urban and rural art education, the factors considered by the author on urban and rural differences are not comprehensive enough and need to be further improved in future work.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Impact of Digital Inclusive Finance on Rural High-Quality Development: Evidence from China

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Digital inclusive finance not only reduces the threshold of rural financial services but also plays an important role in promoting the rural economy. Under the background of the digital economy in China, we studied how digital inclusive finance affects the high-quality development of the rural economy. For this purpose, we assembled the provincial panel data from 2009 to 2018 and constructed an index system of rural high-quality development and then calculated its index using the entropy weight method. FE regression model and RE regression model were employed for empirical analysis, and we constructed a nonlinear regression model to investigate the nonlinear relationship as well. Furthermore, systematic GMM and iterative GMM were used to solve the endogenous problem. We found that digital inclusive finance plays a significant and positive role in promoting rural high-quality development, mainly through the channel of economic efficiency, urban and rural structure, green ecological development, harmony of people's livelihood, and innovative development potential. Each subdimension of digital inclusive finance has a positive impact on rural high-quality development to different degrees. There is also a direct nonlinear relationship between the core variables, which act as a disincentive in the initial stage and boost after reaching a certain inflection point. Therefore, it is recommended to increase the construction of rural digital infrastructure, improve the digitalization of inclusive finance with the help of digital technologies such as cloud computing, and expand the breadth and depth of digital inclusive finance services in rural areas, especially in economically underdeveloped provinces and cities, to effectively promote the comprehensive and high-quality development of rural areas.

1. Introduction

The 19th CPC National Congress clearly judged that China's economy has shifted from high-speed growth stage to high-quality development stage. High-quality development (HQD) means that the traditional economic model should gradually transition to an innovation-driven economic growth model dominated by smart economy and industrial upgrading. HQD is not only a requirement for economic development but also a general requirement for all aspects of society, culture, and ecology [1]. A series of national policies and measures emphasize not only the comprehensive HQD but also urban-rural integration. Among them, the rural high-quality development (RHQD) is the key point, because China made a major policy of giving priority to the development of industry and cities based on the domestic and international situation in the early stage of reform and opening-up. After 40 years of development, although industrialization and urbanization have been developed, it has objectively led to the widening gap between agriculture and industry and rural areas and cities, which are inconsistent with the concept of achieving common prosperity for all people at this stage. RHQD is also the development goal of "agriculture, rural areas, and farmers" as clearly stated in No. 1 central document. It is an important factor for the high-quality implementation of the rural revitalization strategy

and the improvement of the urban-rural integration development mechanism. Therefore, more attention should be paid to the high-quality development of rural areas under the new situation.

How to promote the RHQD has become the focus of academic circles. Digital inclusive finance (DIF) has become a "lubricant" to promote economic efficiency. Supported by information technology and big data, the digital transformation has driven innovation in traditional financial institutions and sectors, introducing new financial services such as online credit, mobile payment, and e-commerce supply chain finance, reshaping the business model and format, and greatly improving economic efficiency and productivity [2]. DIF, a new financial model, has increasingly become an indispensable part. On the one hand, with the help of Internet technology, DIF can promote economies of scale, reduce cross-regional supply-demand mismatch, and make the economy develop continuously. On the other hand, it can promote the balanced development of financial services in remote areas. It can also reduce the financing threshold of vulnerable groups [3]. DIF received national attention at the G20 Summit in 2016, and then, the Digital Industry Research Institute of Peking University released China's provincial DIF index. At the same time, many other developing countries also attach great importance to relevant research. For example, some studies have proved that DIF enables people to expand access to financial services and advances economic progress in rural areas [4]; Myovella et al. have proved that digitalization positively contributes to economic growth in sub-Saharan Africa (SSA) as well [5]. DIF plays an important role in economic growth and promotes economic development in developing countries and emerging economies. DIF can help to improve the social welfare of loan groups, provide a wide range of employment opportunities for society, and promote sustainable economic growth [6, 7].

Most of the studies focus on the impact of DIF on macroeconomic growth. People distributed in vast rural areas lack access to digital financial services. Hence, the key direction of DIF should be in rural areas. Serving rural long-tail people who really need financial services should become the due meaning of academic research, which is also a relatively neglected research field at present. Therefore, we attempt to study these questions.

2. Literature Review

The literature review is mainly carried out from three aspects: digital inclusive finance, high-quality development, and the impact of DIF on HQD.

2.1. Digital Inclusive Finance. (1) Development and Reform of DIF. In recent years, breakthroughs in computer, cryptography, big data, and other technologies have promoted the rapid development of DIF [8]. DIF means that a series of advanced information technologies are used in the financial area to improve the original way of information exchange, so that all social groups can enjoy financial products and services equally and efficiently, to achieve the purpose of inclusive finance. Breakthroughs in disruptive technologies such as computers and cryptography have promoted the rapid development of DIF [9]. DIF has changed the business processing of traditional finance, reduced the threshold and transaction cost of financial services, expanded the scope of financial services, improved the profits of financial institutions, and made refinancing market more active [10]. With the innovation of financial products, services, and systems, DIF solves the mismatch of fields, stages, and attributes of traditional finance and improves the efficiency of the financial industry [11]. (2) Influencing Factors of DIF. The study found that rural financial infrastructure, development of digital technology, social environment, personal characteristics, and financial literacy of farmers will have an impact on DIF [12]; the level of financial education, trust, and preference transparency of farmers will affect their use of DIF [13]; social media software and applications have promoted farmers' participation, depth, and breadth of use of DIF [14].

2.2. High-Quality Development

2.2.1. Connotation of HQD. New agricultural production factors such as technology and labour capital should be introduced to make modern agriculture the driving force of economic growth. Resource-based areas should reflect the requirements of "quality" in the process of realizing the growth of "quantity." High-quality growth should consider factors such as residents' income and health in addition to economic efficiency. Modern agricultural diversity system can help HQD. In the period of economic transformation, attention should be paid to the economic quality growth. High-quality development should consider the dimensions of supply-demand, efficiency, and openness. After the proposal of China's rural revitalization strategy, several scholars shift their research perspectives to rural areas. Most of them believe that we should deeply understand the strategic connotation of rural revitalization and strengthen rural industry, infrastructure, ecological environment, civilization, and government governance from the internal relationship of central policy and major goals [15–20].

2.2.2. Level Measurement of HQD. In terms of research methods and index construction, Mlachila et al. construct the economic growth quality index of developing countries, which included the internal and social aspects of growth. Zou Yinan and Zhao Junhao use Delphi and entropy method to measure China's level of ED from the five aspects of "innovation, coordination, green, openness, and sharing" based on the connotation of changing the mode of economic development. Liu Huajun measures total factor productivity and empirically explored its impact on the HQD of regional economy using the secondary assignment procedure. Tang

Juan et al. analyse the difference in economic development quality among provinces using the DG coefficient model. Sun Yan and others construct the index of HQD of agriculture using the multi-objective comprehensive evaluation model from the perspective of agricultural industry innovation, coordination, green development, and openness. Zhang Hong et al. use micro-survey data to measure the HQD level of rural areas in Shaanxi Province from the aspects of employment quality, education environment, pension security, food safety, health care, and ecological environment [21–25].

2.3. Impact of DIF on HQD

2.3.1. IF Affects Economic Development. In terms of specific research, Kassi uses PCA to measure China's inclusive finance index; Ana et al. measure the level of IF in 30 provinces and cities. The results show that China's provincial inclusive finance level was generally low. Some scholars hold the opposite view. For example, Evans and Alexis measure the level of IF in various regions of China using subdivision indicators and found that the level is different [26–28].

2.3.2. DIF Affects Economic High-Quality Development. In terms of DIF, Ozili believes that DIF promotes the economic development of developing countries and emerging economies. DIF has a positive role in improving technological innovation and broadening employment channels; Yu Chaoyi et al. empirically verify that DIF can ultimately improve QED by reducing the income gap and improving the efficiency of capital allocation; Hu, Liu, and Peng believe that DIF can help to improve the living standards and social welfare of loan groups, provide a wide range of employment opportunities for society, and promote sustainable economic growth. Technological innovation has promoted traditional financial services and the launch of emerging digital financial services such as online loans, which makes the target customers directly point to the socially vulnerable groups, improves the transaction frequency and convenience in remote areas, increases the possibility of saving, and increases the bank credit of small- and medium-sized enterprises [29–33].

Previous literature has achieved fruitful results, which has important reference significance. However, there are still some problems not involved, which is also the direction of our further research. Therefore, we will proceed from the following aspects: (1) starting from the latest national development concept, based on the connotation of common prosperity, we will comprehensively define the "comprehensive and high-quality rural development" and build a comprehensive index system covering five dimensions from the theoretical level. All index data are drawn from various yearbooks, making the data highly available and easy to measure and compare. It is also convenient to depict regional differences; (2) using the provincial macro-panel data, the entropy weight method is used to calculate the overall RHQD index of 31 provinces and cities in China to compare the provincial development trend and regional differences; (3) building panel econometric model (FE and RE model) is used to analyse the impact and mechanism of DIF on RHQD; (4) further instrumental variables are introduced, and systematic GMM estimation is used to solve the endogenous problem; and (5) from the perspective of innovative rural DIF development, we propose recommendations to promote the development of rural areas.

3. Theoretical Framework and Hypothesis

3.1. Impact of DIF on RHQD. Impact of DIF on RHQD comes from five aspects. First, DIF simplifies the cumbersome business process of traditional finance, enhances the mobilization of savings in rural areas, speeds up the formation and accumulation of rural capital, provides financial support for rural enterprises, reduces the financing constraints of farmers and enterprises, improves the efficiency of financial institutions serving the rural economy, stimulates rural consumption and investment, and thus promotes the quality and efficiency of rural economic development. Second, DIF has optimized the allocation of resources in rural areas and alleviated the imbalance of urban and rural development. DIF reduces threshold and cost of financial services by alleviating the information asymmetry in financial transactions, covering rural areas and low-income people. By meeting the needs of long-tail people, namely remote rural customers, it effectively improves the imbalance between supply-demand and resource mismatch in the financial market and realizes the flow and full utilization of financial resources. Third, DIF has improved rural ecological capital and rural environmental quality through the path of technological progress and income increase effect. The "IPAT" model verified the three influencing factors of capita environment: population size, technical level, and affluence. On this basis, DIF has achieved remarkable results in governing the environment through financial technology [34]. At the same time, DIF has increased farmers' income, reduced the negative impact on per capita environment, and then improved environmental quality; therefore, DIF promotes the green ecological development. Fourth, the improvement of rural medical care, health care, minimum living security, and pension cannot be separated from the support of funds. Although financial funds have made transfer payments in these fields to a certain extent, they have only achieved basic security. If we want to further improve the rural situation, we must have the support of external funds. Based on its inclusive characteristics, DIF has widened the financing channels of township governments, so that the funds can be used to improve rural people's livelihood in time and then promote harmony. Fifth, through the introduction of advanced digital technology, DIF has changed the traditional types of financial products and service modes, promoted the transformation and upgrade of rural enterprises, provided financial support for enterprise innovation and R&D, and improved the innovation of rural areas.

Based on the above analysis, we will develop the following hypotheses:

(1) H1: DIF plays a positive role in promoting RHQD
(2) H11: DIF can promote the quality and efficiency of rural economic development
(3) H12: DIF optimizes the urban-rural structure
(4) H13: DIF can promote the green ecological development of rural areas
(5) H14: DIF has improved the rural style and the harmony of people's livelihood
(6) H15: DIF has improved the innovative development potential of rural areas

3.2. Analysis on the Impact of Different Dimensions of DIF on RHQD. The development of DIF is multidimensional, which can be reflected not only in the coverage, depth, and digitization of finance but also in payment, insurance, and credit services [35]. Different dimensions of DIF play different roles in RHQD. Unlike traditional finance, DIF has cross-regional restrictions. With the help of the Internet, rural users can get financial services by binding electronic accounts of bank cards; after the guarantee of hardware facilities, the types, total amount, and activity of rural users using financial services are gradually increasing; the enrichment of third-party payment functions has broadened the financial management and financing channels of rural users; the degree of credit has better reflected the value of DIF and improved the efficiency of financial services in rural areas; insurance business not only makes the economic losses caused by accidents compensated but also enables the applicant's idle funds to obtain the payment of expected insurance benefits, increases investment channels, promotes the stable development of rural areas, and maintains friendly social order. The above factors have promoted the RHQD in their respective fields.

Based on the above analysis, we will develop the following hypotheses:

(1) H21: coverage of DIF has a positive impact on RHQD
(2) H22: depth of the use of DIF has a positive impact on RHQD
(3) H23: digitization degree of DIF has a positive impact on RHQD
(4) H24: payment business of DIF has a positive impact on RHQD
(5) H25: credit business of DIF has a positive impact on RHQD
(6) H26: insurance business of DIF has a positive impact on RHQD

3.3. Nonlinear Effect of DIF on RHQD. Financial theory research shows that role of financial development on economic growth is not invariable. Developing countries often have the phenomenon of "financial repression" of interest rate regulation, which makes funds unable to effectively support economic growth. The path of deregulation of interest rates and financial liberalization is conducive to increasing the savings rate and investment, so as to promote economic growth. However, developing countries do not have the conditions of complete information and complete market [36]. Financial liberalization cannot achieve the effect of optimal allocation of resources, but increase financial risks. Combined with the theory of "scale effect" and "diminishing marginal utility," we believe that the effect of DIF on RHQD at different stages is also nonlinear. In the early stage of DIF, the infrastructure of digital finance was imperfect, the intermediary function was underdeveloped, the social idle funds absorbed by financial institutions were limited, the capital cost was high, and the small-scale funds leads to the slow accumulation of material capital, human capital, and technological progress, which has a limited role. In the process of development, due to the existence of "diminishing marginal utility," role of financial development in promoting high-quality growth first increases and then decreases. When digital financial capital reaches a certain scale, the marginal utility of input capital is the largest, which has the effect of less input and more output.

Based on the above analysis, we develop the following hypotheses.

H3: there is a nonlinear relationship between the impacts of DIF on RHQD.

4. Methods and Models

4.1. Entropy Weight Method. We use the entropy weight method to measure the overall high-quality development level of rural areas. The specific calculation steps are as follows.

(1) Standardized Treatment of Indicators. The extreme value method is used to deal with the indicators of the RHQD level in a dimensionless way.

$$\begin{cases} \dfrac{X_{ij} - \min\left(X_{ij}\right)}{\max\left(X_{ij}\right) - \min\left(X_{ij}\right)}, X_{ij} \textit{ is a positive indicator}, \\ \dfrac{\max\left(X_{ij}\right) - X_{ij}}{\max\left(X_{ij}\right) - \min\left(X_{ij}\right)}, X_{ij} \textit{ is a negative indicator}, \end{cases} \tag{1}$$

where i and j denote the province and year, respectively, X_{ij} denotes the original index data, Y_{ij} denotes the standardized data, $\max(X_{ij})$ denotes the maximum value of X_{ij}, and $\min(X_{ij})$ denotes the minimum value of X_{ij}.

(2) The information entropy (E_{ij}) of Y_{ij} is calculated as follows:

$$E_{ij} = \ln(n) \sum_{i=1}^{n} \left[\left(Y_{ij} / \sum_{i=1}^{n} Y_{ij} \right) \ln \left(Y_{ij} / \sum_{i=1}^{n} Y_{ij} \right) \right]. \tag{2}$$

(3) The weight W_j of Y_{ij} is calculated as follows:

$$W_j = \left(1 - E_j\right) / \sum_{j=1}^{m} \left(1 - E_j\right). \tag{3}$$

(4) Dimension layer index is calculated. The target weighting method is used to calculate the indexes of different dimensions.

$$Z_{is} = \sum_{i=1}^{q} W_j Y_{ij}, \tag{4}$$

where Z_{is} denotes the index of s criterion layer in the ith province and city, and q is the indicators contained in the criterion layer.

(5) The comprehensive RHQD index F_i of each province is calculated.

$$F_i = \sum_{s=1}^{s} Z_{is}, \tag{5}$$

where F_i denotes the RHQD level in different provinces and cities, and the larger the F_i, the higher the RHQD.

4.2. Models. Fixed-effects regression model (FE model) and random-effect regression model (RE model) are employed for empirical analysis, and we also construct a nonlinear regression model to investigate the nonlinear relationship between DIF and RHQD. Furthermore, the system GMM is used to solve the endogenous problem [37].

4.2.1. Regression Model Selection. We take RHQD as explanatory variable, DIF as core explanatory variable, labour resources, natural disasters, openness, and financial support as control variables, build panel model, and use robust standard error method for modelling. The panel model involves three models: mixed pool model, FE model, and RE model. First, the model test is carried out to find out the optimal model. It can be seen from Table 1 that F test shows a significance of 5% level, $f\ (30208) = 38.303$, and $P < 0.05$, which means that the FE model is better than the pool model. The BP test shows a significant level of 5%, chi (1) = 218.441, and $P < 0.05$, which means that the RE model is better than the pool model. The Hausman test shows a significant level of 5%, chi (5) = 77.487, and $P < 0.05$, which means that the FE model is better than the RE model (see Table 2).

Based on the above analysis, we adopt FE model, and model is set as follows:

$$\begin{aligned} Rhq_{i,t} = {} & \alpha_0 + \beta_1 Di\ f_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{it} + \mu_i + \varepsilon_{i,t}, \end{aligned} \tag{6}$$

where i refers to the individual, i.e., all provinces and cities; t denotes time; α_0 is a constant term; $\mu_{\mathbf{i}}$ indicates individual fixed effect and time effect; and $\varepsilon_{\mathbf{i,t}}$ is the error term.

4.2.2. Subindex Regression Model Selection. DIF covers three secondary dimensions: financial coverage breadth (BRE), financial use depth DEP), and digital degree DIG). The secondary dimension also includes different forms such as payment PAY), insurance INS), and credit (CRE). To deeply investigate the heterogeneous role of different subindexes, we empirically verified the effects of financial coverage breadth, financial use depth, digitization, payment, insurance, and credit on the RHQD. Taking 6 subindexes as explanatory variables, the panel model was constructed using robust standard error. Specific model settings are as follows:

$$\begin{aligned} Rhq_{i,t} = {} & \alpha_0 + \beta_1 Bre_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t} \\ Rhq_{i,t} = {} & \alpha_0 + \beta_1 De\ p_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t} \\ Rhq_{i,t} = {} & \alpha_0 + \beta_1 Di\ g_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t} \\ Rhq_{i,t} = {} & \alpha_0 + \beta_1 Pay_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t} \\ Rhq_{i,t} = {} & \alpha_0 + \beta_1 Ins_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t} \\ Rhq_{i,t} = {} & \alpha_0 + \beta_1 Cre_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t}. \end{aligned} \tag{7}$$

4.2.3. Regression Model Selection of Different Channels. RHQD index was constructed from five dimensions. Considering differences in different dimensions affected by DIF and to investigate different action channels and provide targeted differentiated policies for decision-makers, we took economic development (ECO), urban-rural structure optimization (STR), green ecological development (GRE), people's livelihood harmony (CIV), and innovative development potential (INO) as the explanatory variables. Specific model settings were as follows:

$$\begin{aligned} Eco_{i,t} = {} & \alpha_0 + \beta_1 Di\ f_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t} \\ Str_{i,t} = {} & \alpha_0 + \beta_1 Di\ f_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t} \\ Gre_{i,t} = {} & \alpha_0 + \beta_1 Di\ f_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t} \\ Civ_{i,t} = {} & \alpha_0 + \beta_1 Di\ f_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t} \\ Ino_{i,t} = {} & \alpha_0 + \beta_1 Di\ f_{i,t} + \beta_2 Lab_{i,t} + \beta_3 Gov_{i,t} + \beta_4 Ope_{i,t} \\ & + \beta_5 Nat_{i,t} + \mu_i + \varepsilon_{i,t}. \end{aligned} \tag{8}$$

Table 1: Variable definition and sample descriptive statistics.

Variable category	Variable name	Definition and assignment
Explained variable	Digital inclusive finance (DIF)	Coverage, depth, and digitalization of finance
Explanatory variable	High-quality rural development (RHQD)	ECO, STR, GRE, CIV, and INO
Control variables	Labour resources (LAB)	Employment of township enterprises
	Government support (GOV)	Proportion of investment in agricultural comprehensive development projects in GDP expenditure
	Open program (OPE)	Proportion of foreign investment in GDP
	Natural disaster (NAT)	Number of natural disasters in the region

Table 2: Model test.

Test type	Test purpose	Test value	Test results
F Test	Comparison between FE model and pool model	$F\ (30,\ 208) = 38.303,\ p = 0.001$	FE model
BP test	Comparison between RE model and pool model	$\chi^2\ (1) = 218.441,\ p = 0.001$	RE model
Hausman test	Comparison between FE model and RE model	$\chi^2\ (5) = 77.487,\ p = 0.001$	FE model

4.2.4. Selection of Nonlinear Regression Model. We add the quadratic term variable of DIF on the basis of the linear model, i.e., model (6), and constructed the following nonlinear model:

$$Rhq_{i,t} = \alpha_0 + \beta_1 Di\ f_{i,t} + \beta_2 Di\ f_{i,t}^2 + \beta_3 Lab_{i,t} + \beta_4 Gov_{i,t} + \beta_5 Ope_{i,t} + \beta_6 Nat_{it} + \mu_i + \varepsilon_{i,t}. \quad (9)$$

4.2.5. Model Estimation of Endogenous Problems. Considering the limitations of short panel and the endogenous problems caused by the correlation between explanatory variables and disturbance terms, we constructed the instrumental variable Lag_Dif as shown in formula (10). Instrumental variables were strongly correlated with endogenous variable, DIF, and weakly correlated with the explained variable, RHQD.

$$\text{Lag_Dif} = Di\ f_{t-n} \times Di\ f_{t-n}, \quad (10)$$

where $Di\ f_{t-1}$ denotes the digital inclusive financial index lagging by one order, $Di\ f_{t-1}$ represents the first-order difference in time of the digital inclusive financial index. Systematic GMM and iterative GMM in the panel model were used for regression estimation. The specific model is shown in the following formula:

$$Rhq_{i,t} = \alpha_0 + \beta_1 Di\ f_{i,t-1} + \beta_2 Di\ f_{i,t} + \beta_3 Lab_{i,t} + \beta_4 Gov_{i,t} + \beta_5 Ope_{i,t} + \beta_6 Nat_{i,t} + \varepsilon_{i,t}. \quad (11)$$

4.3. Data. We selected macro-panel data of 31 provinces and cities in China from 2009 to 2018 for our research. The DIF data were adopted from the second issue of "Peking University Digital finance index"; most data of RHQD came from China Statistical Yearbook, Regional Economic Statistical Yearbook, Local Statistical Yearbook, and China Rural Statistical Yearbook, and some data were obtained from the State Food Administration, Wind database, and EPS database. The empirical part adopts Stata 16.0 and SPSS for data and graphics processing.

5. Index System, Variables, and Results

5.1. Index System of DIF. Due to the availability of relevant economic data, Chinese scholars mostly use DIF index jointly prepared by Peking University Digital Financial Centre and Ant Financial Services Institution. The index has been published in two issues. To ensure the scientific of index selection, we adopt the second phase of the index for the construction of DIF index system, which is prepared by Guo Feng and other (2020) scholars. This index system is more comprehensive and objective, including the dimensions of finance coverage, use depth, and digitization, with a total of 33 three-level indicators. See Table 3 for details.

In terms of index calculation, firstly, the logarithmic efficacy function was used to deal with the initial index value dimensionless, secondly, the weight of each index was determined by the analytic hierarchy process, and then, the final digital inclusive financial index was calculated by layer-by-layer arithmetic weighted average synthesis model.

5.2. The Overall Development Trend of DIF in China. China's digital inclusive financial index and primary dimension index from 2011 to 2018 are shown in Figure 1. It can be seen that related business of China's digital inclusive fund has achieved rapid development in 8 years. The composite index increased from 40 in 2011 to 300.21 in 2018, an increase of 86.7%.

As to the subindex, from 2011 to 2015, the digital degree index increased the fastest, but decreased in 2016 and then increased again; the growth rate of digital finance coverage index is moderate; the growth rate of digital finance use depth index was the slowest, but it increased rapidly from 2014 to 2017, which became an important driving force for

Table 3: DIF index system.

First-level dimension	Secondary dimension	Specific indicators
Coverage breadth (54.0%)	Account coverage	The number of Alipay accounts, the percentage of Alipay card users, and the average bank account of each Alipay account
Use depth (29.7%)	Payment (4.3%)	The number of payments per capita, amount paid per capita, and the number of active users with high frequency account for one or more times of activity
	Monetary fund (6.4%)	The number of Yu Ebao purchases per capita, the amount of Yu Ebao purchased per capita, and the number of Yu Ebao purchases per 10000 Alipay users
	Credit (38.3%)	The number of Internet consumer loans per person, the number of loans per person per capita, and the amount of loans per person per 10000 Alipay adult users
	Insurance business (16%)	The number of Internet small and micro-business loans of every ten thousand Alipay adult users, the average number of loans for small and micro-operators, and the average loan amount of small and micro-operators
	Investment	The number of insured users, the number of per capita insurance pen, and the insured amount per 10000 Alipay users
	Business (25%)	The number of Internet users who invest in the Internet, the number of investment pens, and the amount of investment per person per 10000 Alipay users
	Credit business (10%)	The number of credit calls per natural person, the number of users using credit-based services per 10000 Alipay users
Digitization (16.3%)	Mobility (49.7%)	Proportion of mobile payment transactions and mobile payment amount
	Affordable (24.8%)	Average loan interest rate of small and micro-operators, average individual loan interest rate
	Credit (9.5%)	The proportion of Ant Credit Pay, the proportion of Ant Credit Pay amount, proportion of sesame credit-free deposit, transactions, proportion of credit-free amount
	Facilitation (16%)	Proportion of user QR code payments, proportion of user QR code payment amount

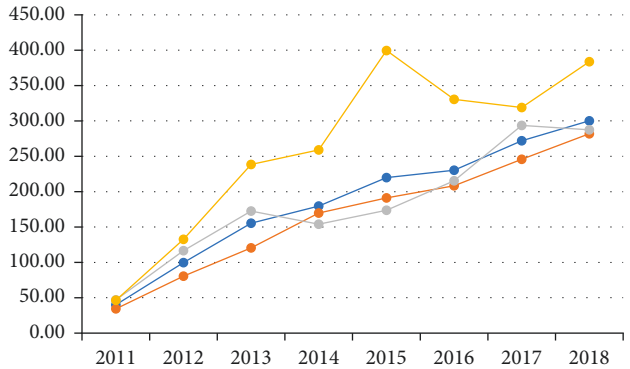

Figure 1: DIF index and subindex from 2011 to 2018. (Data source: Peking University DIF index).

the growth of DIF. It decreased in 2018 due to the decline of Monetary Fund Index and investment index caused by policy factors. Overall, the DIF index and subindex have maintained a high growth trend.

5.3. Construction of Comprehensive Rural High-Quality Development Index System. "Comprehensive" means that we should pay attention not only to the economic fields that we used to focus on but also in the comprehensive fields such as political, economic, cultural, and social innovation fields. Combining with the connotation of rural revitalization strategy and common prosperity, taking into account the hierarchy of indicators and the availability of rural data, we selected RHQD index as the explanatory variable. The index system specifically includes five dimensions: rural economic development quality and efficiency (ECO), urban-rural structure optimization (STR), green ecological development (GRE), rural style and people's livelihood harmony (CIV), and innovative development potential (INO), with a total of 34 three-level indicators. See Table 4 for details.

5.3.1. Quality and Efficiency of Economic Development. The foundation of common prosperity is economic development. We use "rural residents' per capita income," "rural per capita GDP growth," "rural primary industry growth," "rural residents' consumption level," and "rural residents' living standard" to measure the quality and efficiency of economic development. Among them, "per capita income of rural residents" is measured by "actual per capita net income of rural residents"; "rural per capita GDP growth rate" is measured by "the ratio of GDP added value of primary industry to rural population"; "growth rate of primary industry" is measured by "the proportion of added value of primary industry in regional GDP"; "consumption level of rural residents" is measured by "consumption price index of rural residents (last year = 100)"; and the "living standard of rural residents" is measured by "Engel coefficient of rural residents' families," specifically by "the proportion of total rural food expenditure in total personal consumption expenditure". "Living standard of rural residents" is a negative indicator, and the rest are positive indicators.

5.3.2. Optimization of Urban-Rural Structure. Goal of common prosperity proposes that in view of the current situation of unbalanced urban-rural development in China, indicators representing optimization of urban-rural

Table 4: Rural comprehensive and high-quality development index system.

Dimension	Measure index	Data sources
ECO	Per capita income of rural residents (yuan/person) Rural per capita GDP growth (100 million yuan) Growth rate of primary industry (%) Consumption level of rural residents Living standard of rural residents (%)	Agricultural Statistical Yearbook China Statistical Yearbook Regional Statistical Yearbook EPS database
STR	Per capita disposable income ratio of urban and rural residents Industrial and agricultural output rate Population urbanization rate Urban-rural consumption level rate	Agricultural Statistical Yearbook National Statistical Yearbook Regional Statistical Yearbook
GRE	Forest coverage (%) Water-saving irrigation area (1000 HA) Area of nature reserve (10000 hectares) Sown area of crops (1000 HA) Afforestation area (HA) Agricultural fertilizer input (10000 tons) Total gas production of biogas digester (10000 m3) Solar water heater (10000 m2) Rural carbon emissions (thousand tons of carbon dioxide)	State Administration of Grain China Statistical Yearbook Wind database Agricultural Statistical Yearbook
CIV	Rural population (10000) Township (town) health centres Village doctors and health workers (person) Township cultural stations (nos.) Sanitary toilet penetration rate (%) Number of elderly care institutions Minimum living security expenditure (100 million yuan) Per capita road area (M2)	Agricultural Statistical Yearbook China Rural Statistical Yearbook China Statistical Yearbook
INO	Investment in fixed assets (100 million yuan) Number of village committees Education years per capita (years) R&D expenditure intensity (%) Per capita turnover of technology contracts (10000 yuan) Number of patent applications accepted per capita (PCs) Number of employed persons (10000)	China Statistical Yearbook Regional Economic Statistical Yearbook Local Statistical Yearbook China Rural Statistical Yearbook

structure must be incorporated into the RHQD system. We mainly measure the optimization level of urban and rural structure through "ratio of per capita disposable income of urban-rural residents", "ratio of industrial and agricultural output value", "rate of population urbanization," and "the ratio of urban and rural consumption level". Among them, "ratio of per capita disposable income of urban and rural residents" is measured by "ratio of per capita disposable income of urban residents to per capita disposable income of rural residents"; ratio of industrial and agricultural output value "is measured by "ratio of output value of secondary industry to that of primary industry "; "population urbanization rate" is measured by "ratio of urban resident population to rural resident population"; and "urban-rural consumption level ratio" is measured by "ratio of the consumption level of urban residents to that of rural residents," and consumption level of rural residents = 1. All indicators are positive indicators.

5.3.3. Green Ecological Development. The following indicators are adopted for consideration: total sown area of crops, area of nature reserves, afforestation area, water-saving irrigation area, forest coverage, total gas production of biogas digesters, and solar water heaters; negative indicators are as follows: chemical fertilizer input and carbon emission. Among them, "forest coverage" refers to the percentage of regional forest area in land area, which reflects the richness of regional ecological environment resources; "chemical fertilizer input" is measured by "amount of agricultural chemical fertilizer (converted into pure amount)," which refers to the amount of chemical fertilizer actually used for agricultural production in a year; and "carbon emission" refers to the carbon emission of each province counted by "rural" as the subdepartment.

5.3.4. Harmonious of Rural and People's Livelihood. We use "rural population, health centres in town, rural doctors and health workers, township cultural stations, sanitation toilet penetration rate, number of elderly care institutions, minimum living security expenditure, per capita road area, and water penetration rate" to measure the harmony of rural style and people's livelihood. Among them, "rural doctors and health workers" refers to "the average village health room personnel per 1000 rural population"; "road area per capita" and "water penetration rate" use county-level data. All indicators are positive indicators.

5.3.5. Innovation and Development Potential. We use "the completed amount of fixed assets investment, the number of village committees, the number of years of education per capita, the investment intensity of R&D funds, the turnover of technology contracts per capita, the number of patent applications accepted per capita, and the number of employed persons" to measure the innovation and development potential. Among them, "fixed asset investment completion" is measured by "rural household fixed asset investment completion"; "R&D expenditure intensity" is measured by "the ratio of R&D expenditure of industrial enterprises above designated size to GDP of primary industry"; "per capita technology contract turnover" is measured by "the ratio of technology contract turnover to the GDP of the primary industry"; "number of patent applications accepted per capita" is measured by "ratio of number of patent applications accepted to rural population"; and "number of employed persons" refers to "number of employed persons in rural private enterprises." All indicators are positive indicators.

5.4. RHQD Index and Growth Rate. To further investigate the specific indexes and growth rates of RHQD, Table 5 lists the indexes and growth rates of 31 provinces and cities and the whole country in 2011 and 2018, respectively (due to limited space, the specific indexes in other years are not listed). It can be seen that the average value of RHQD index increased from 0.972 in 2011 to 1.255 in 2018, with a growth rate of 29.2% and an average annual growth rate of 4.2%. Shanghai and Beijing had a high level of RHQD in the initial 2011, with indexes reaching 1.647 and 1.257, respectively, indicating that Shanghai and Beijing played a leading role in RHQD; Hainan, Liaoning, and Xinjiang are more prominent in other provinces, with the index reaching 1.215, 1.125, and 1.122, respectively; the provinces with poor performance are Tibet and Qinghai, with indexes of 0.630 and 0.736, respectively; the performance of Guangdong is more unusual, with an index of only 0.985. As an economically strong province, its RHQD level ranks only 15 in the country, indicating that RHQD is ignored in the process of pursuing high-speed economic development. By 2018, only Shanghai's development index is greater than 2, significantly higher than other provinces and cities, indicating its rapid and high-quality rural development. The development index of 17 provinces and cities in China is below the average of the national index.

In terms of growth rate, from 2011 to 2018, the growth rate of RHQD index was faster, including Heilongjiang, Jiangsu, and Shanghai, which were 49.7%, 47.4%, and 43.2%, respectively; Jilin, Gansu, and Liaoning have a slower growth rate. Among them, Jilin and Liaoning have formed a sharp contrast with Heilongjiang, the same three northeastern provinces. Heilongjiang ranks first in growth rate, while Jilin and Liaoning rank last; the growth rate of 16 provinces and cities is lower than the national average, indicating that there is still a long way to go for the comprehensive and high-quality development of rural areas in many provinces and cities.

5.5. Control Variables. In addition to core explanatory variables, there are other variables that will affect the RHQD. Based on the existing literature, we set the following variables as the control variables: labour resources (LAB), government support (GOV), degree of external development (OPE), and natural disasters (NAT). See Table 1 for specific variables and descriptive statistics.

6. Empirical Results

6.1. Basic Regression Results. In our study, the FE model was used for basic estimation. To facilitate comparative analysis, the estimation results of time fixed effect and two-way fixed effect were given at the same time (see Table 6).

From the above table, the core explanatory variable DIF shows the significance of 0.01 level ($t = 3.547$, $P = 0.001$), and the regression coefficient value is $0.113 > 0$, indicating that DIF has a significant positive impact on RHQD. From control variables, labour resources show a significant level of 0.05 ($t = 2.272$, $P = 0.024 < 0.05$), and coefficient is $0.189 > 0$, indicating that labour resources have a significant positive impact on RHQD. Natural disasters show a significant level of 0.05 ($t = -2.170$, $P = 0.031 < 0.05$), and coefficient is $-0.036 < 0$, indicating that natural disasters have a significant negative impact on RHQD. The opening-up process shows a significant level of 0.01 ($t = -7.017$, $P = 0.001$), and coefficient is $-0.388 < 0$, indicating that it has a significant negative impact on RHQD. In terms of government support, it does not show significance ($t = -0.559$, $P = 0.577 > 0.05$), which shows that government support will not affect RHQD.

6.2. Regression Results of DIF Subindex. From Table 7, the regression coefficients of the six subindexes of DIF on the impact of rural comprehensive and high-quality development are significantly positive, with coefficients of 0.109, 0.107, 0.053, 0.160, 0.056, and 0.169, respectively. Credit has the strongest driving force on rural comprehensive and high-quality development, followed by payment, coverage, and use depth, and the weakest is insurance and digitization, and it shows that these subdimensions play different roles.

6.3. Results of Different Channels of DIF Affecting RHQD. From Table 8, the regression coefficients of DIF on quality and efficiency of rural economic development, green ecological development, rural style, people's livelihood harmony, and innovative development potential are significantly positive, with coefficients of 0.222, 0.051, 0.102, and 0.167, respectively, indicating that driving force of DIF on the quality and efficiency of economic development is the strongest, followed by innovative development potential, rural style, people's livelihood harmony, and green ecological development that are the weakest. Through these channels, DIF has effectively promoted the all-round and high-quality development of rural areas. Meanwhile, the impact of DIF on optimization of urban and rural structures is not significant, and the coefficient is very small, only 0.007, indicating that DIF needs to be further developed.

Table 5: RHQD index and growth rate of 31 provinces and cities in 2011 and 2018.

Province	2011	2018	Growth rate	Province	2011	2018	Growth rate
Beijing	1.257	1.790	0.424	Hubei	1.025	1.357	0.324
Tianjin	1.180	1.545	0.310	Hunan	0.923	1.146	0.242
Hebei	0.965	1.188	0.231	Guangdong	0.985	1.269	0.288
Shanxi	0.767	1.015	0.324	Guangxi	1.013	1.255	0.240
Inner Mongolia	1.087	1.372	0.262	Hainan	1.215	1.542	0.269
Liaoning	1.125	1.322	0.176	Chongqing	0.926	1.141	0.232
Jilin	0.942	1.043	0.108	Sichuan	0.980	1.195	0.219
Heilongjiang	1.027	1.538	0.497	Guizhou	0.820	1.175	0.432
Shanghai	1.647	2.358	0.432	Yunnan	0.885	1.152	0.303
Jiangsu	1.050	1.548	0.474	Tibet	0.630	0.866	0.375
Zhejiang	1.058	1.416	0.339	Shanxi	0.974	1.164	0.194
Anhui	0.952	1.121	0.178	Gansu	0.846	0.994	0.175
Fujian	0.943	1.374	0.456	Qinghai	0.736	0.996	0.354
Jiangxi	0.864	1.092	0.263	Ningxia	0.803	1.143	0.423
Shandong	1.095	1.380	0.261	Xinjiang	1.122	1.318	0.174
Henan	0.989	1.177	0.190	China	0.972	1.255	0.292

Table 6: Basic regression results.

		FE model		Time FE model		Two-way FE model	
		Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Explained variable	DIF	0.113** (3.547)	0.032	0.893* (2.062)	0.433	0.400 (1.710)	0.234
	LAB	0.189* (2.272)	0.083	0.269** (4.122)	0.065	0.212* (2.519)	0.084
	GOV	−0.096 (−0.559)	0.172	−0.026 (−0.351)	0.073	−0.034 (−0.178)	0.193
	OPE	−0.388** (−7.017)	0.055	0.144 (0.934)	0.154	−0.391** (−6.488)	0.060
	NAT	−0.036* (−2.170)	0.017	0.046 (0.955)	0.048	−0.019 (−1.405)	0.014
	CONS	0.259** (7.641)	0.034	−0.247 (−1.327)	0.186	0.104 (0.947)	0.110
$\mathbf{R}^2$ sample test		0.751		−7.219		−0.495	
		244		244		244	
		F (5,208) = 103.980 p = 0.001		F (5,231) = 25.098 p = 0.001		F (5,201) = 11.891 p = 0.001	

Note. ***, **, and *, respectively, indicate significance at the level of 1%, 5%, and 10%; T value is in parentheses.

Table 7: Impact of DIF subindex on RHQD.

	BRE FE model	DEP FE model	DIG FE model	PAY RE model	INS FE model	CRE RE model
	0.109** (3.426)	0.107** (3.938)	0.053** (2.740)	0.160** (2.617)	0.056** (3.032)	0.169** (3.235)
LAB	0.180* (2.176)	0.199** (2.658)	0.285** (4.538)	0.201 (1.838)	0.271** (4.175)	0.199* (2.090)
GOV	0.020 (0.513)	0.062* (2.056)	0.004 (0.085)	−0.030 (−0.546)	0.039 (1.183)	0.003 (0.067)
OPE	−0.392** (−6.485)	−0.407** (−6.824)	−0.447** (−6.782)	−0.088 (−1.176)	−0.461** (−6.792)	−0.149* (−2.400)
NAT	−0.037* (−2.177)	−0.043* (−2.492)	−0.049** (−2.968)	−0.034* (−2.058)	0.054** (−2.872)	−0.030* (−2.081)
CON	0.246** (11.738)	0.233** (13.333)	0.245** (11.465)	0.192** (4.891)	0.246** (11.723)	0.178** (4.985)
R^2 (w)	0.751 (5,208) =	0.752 (5,208) =	0.725 (5,208) =	0.693 $\chi^2(5)$ =	0.594 $\chi^2(5)$ =	0.718 $\chi^2(5)$ =
TEST	95.315 p = 0.001	106.460, p = 0.001	113.696, p = 0.001	484.759 p = 0.001	45.600 p = 0.001	512.670, p = 0.001

Table 8: Impact of DIF on different dimensions of RHQD.

	ECO RE model	STR RE model	GRE RE model	CIV RE model	INO RE model
DIF	0.222** (6.331)	−0.007 (−0.169)	0.051* (2.391)	0.102** (4.719)	0.167** (3.988)
LAB	0.649** (8.448)	−0.216* (−2.266)	0.021 (0.454)	0.012 (0.316)	−0.107 (−1.084)
GOV	−0.112* (−2.066)	−0.057 (−1.350)	0.046 (0.870)	−0.036 (−1.679)	−0.061 (−1.083)
OPE	−0.154** (−5.095)	−0.134** (−2.862)	−0.046 (−1.104)	−0.136** (−2.997)	−0.364** (−4.740)
NAT	−0.060* (−2.176)	0.004 (0.394)	−0.036 (−1.716)	0.062* (2.008)	−0.043* (−2.254)
CON	0.154** (5.248)	0.240** (5.728)	0.427** (9.279)	0.378** (8.408)	0.326** (6.347)
R^2 (w)	0.857	0.522	0.356	0.493	0.594
TEST	$\chi^2(5)$ = 1066.164 p = 0.001	$\chi^2(5)$ = 159.469 p = 0.001	$\chi^2(5)$ = 48.365 p = 0.001	$\chi^2(5)$ = 105.211 p = 0.001	$\chi^2(5)$ = 45.600 p = 0.001

Table 9: Nonlinear regression results.

	Coef	Std. Err	t	p	95% CI
DIF	−0.091	0.038	−2.389	0.018*	−0.167–0.016
Dif^2	0.275	0.086	3.194	0.002**	0.106 ~ 0.444
LAB	0.183	0.099	1.850	0.066	−0.011 ~ 0.378
GOV	0.035	0.036	0.978	0.329	−0.035 ~ 0.106
OPE	−0.051	0.083	−0.609	0.543	−0.214 ~ 0.112
NAT	−0.032	0.017	−1.854	0.065	−0.067 ~ 0.002
CON	0.206	0.039	5.322	0.001***	0.130 ~ 0.282
	$R^2 = 0.334$	R^2 (w) = 0.742	$\chi^2(6) = 505.236$ p = 0.001		

Table 10: GMM estimation results.

		Systematic GMM				Iterative GMM			
				95% confidence interval				95% confidence interval	
		Estimate	S.E.	Upper limit	Lower limit	Estimate	S.E.	Upper limit	Lower limit
Endogenous explanatory variable	DIF	0.376 *** (0.000)	0.106	0.167	0.584	0.83 *** (0.00)	0.16	0.52	1.14
Exogenous variable	LAB	0.219 *** (3.959)	0.055	0.111	0.328	−0.02 ** (0.02)	0.01	−0.03	0.00
	GOV	0.06 (0.12)	0.37	−0.01	0.13	0.04 ** (0.05)	0.02	0.00	0.08
	OPE	0.82 * (0.06)	0.44	−0.04	0.13	0.75 *** (0.00)	0.23	0.28	1.21
CONS		−1.73 (0.15)	1.21	−4.10	0.64	−0.26 (0.68)	0.63	−1.49	0.97

6.4. Empirical Analysis of DIF and RHQD from a Nonlinear Perspective. If the coefficient of $\mathbf{Dif}_{i,t}^{2}\beta_2$ is not 0 and significant, there is a nonlinear relationship between DIF and comprehensive and high-quality development. β_1 is negative, when β_2 is positive, the relationship between the two may be U-shaped. The regression results are shown in Table 9.

In Table 9, DIF and $Di\ f_{i,t}^{2}$ have passed the significance test, which shows that there is a nonlinear relationship between DIF and RHQD, and DIF coefficient is less than 0, and the quadratic term coefficient $Di\ f_{i,t}^{2}$ is greater than 0, indicating that there is a U-shaped relationship between DIF and RHQD, which first inhibits and then promotes after reaching the inflection point.

7. Endogeneity Test

We used systematic GMM and iterative GMM to solve the endogeneity problem. In Table 10, the R-square value of model is 0.562, which means that DIF, natural disasters, openness of labour resources, and government support can explain 56.2% of the reasons in the variation of RHQD.

The regression coefficient of DIF is 0.376 ($P < 0.01$), which means that DIF will affect MMS_ RHQD. The regression coefficient of natural disasters is 0.155 ($P = 0.011 < 0.05$), which means that natural disasters will have a significant positive impact on RHQD. The regression coefficient of labour resources is 0.219 ($P < 0.01$), which means that labour resources will have a significant positive impact on RHQD. The regression coefficient of the degree of opening to the outside world is 0.341 ($P < 0.01$), which means that the degree of opening to the outside world will have a significant positive impact on RHQD. The regression coefficient of government support is -0.061 ($P = 0.189 > 0.05$), which means that government support will not have an impact on RHQD.

8. Conclusions, Suggestions, and Discussion

8.1. Conclusions

(1) From 2011 to 2018, China's DIF index and rural comprehensive high-quality development index showed an upward trend, and the development of 31 provinces and cities showed regional heterogeneity.

(2) DIF has a significant positive effect on the overall and high-quality development of rural areas. DIF can promote the overall and high-quality development of rural areas, which confirms hypothesis 1. Rural labour resources also have a positive impact on the overall high-quality development of rural areas. The degree of opening to the outside world and natural disasters has a negative impact on the overall high-quality development of rural areas. The role of government support is not significant.

(3) The coverage, depth, digitization, payment, insurance, and credit of DIF have a positive impact on RHQD, which confirms hypotheses H21– H26. The impact of credit is the strongest.

(4) DIF has a positive impact on the dimensions of economic development quality and efficiency, green ecological development, rural style, and people's

livelihood harmony and innovative development potential, which confirms hypotheses H11– H15. We also found that DIF has different effects on RHQD through different channels.

(5) There is a nonlinear U-shaped relationship between the impacts of DIF on RHQD. In the early stage of the development of DIF, its role in promoting RHQD is not strong and may even be inhibitory. However, when the further development of DIF reaches a certain inflection point, it begins to promote the RHQD.

8.2. Suggestions

(1) The construction of digital inclusive financial infrastructure in rural China should be improved. The laying of communication networks in rural areas should be expanded, the promotion and coverage of DIF should be strengthened, and the development level of DIF in all provinces and cities should be improved to improve the quality and efficiency of DIF in serving the high-quality development of rural areas.

(2) Support for rural financial institutions should be increased. More rural financial institutions should be encouraged and guided to carry out digital inclusive financial services, their level of providing digital financial products and services should be improved, and the digitization of finance should be improved; at the same time, the financial literacy of rural residents should be improved, the knowledge of DIF in rural areas should be widely popularized widely to enhance the depth of the use of DIF in rural areas.

(3) The construction of payment and insurance credit systems in rural areas should be accelerated. Relying on digital technologies such as cloud computing and big data, the construction of electronic payment and insurance credit systems in rural areas should be accelerated, payment levels should be improved, and information asymmetry should be alleviated. Risks through credit platform should be monitored to promote the stable and healthy development of DIF, which in turn promotes the all-round and comprehensive development of rural economy, culture, politics, and ecology, gradually narrowing the gap between urban-rural areas, and making continuous progress towards the goal of common prosperity.

8.3. Discussion. Finally, we discussed two limitations of this study. (1) Because we use the DIF index constructed by existing scholars, we only had the data from 2011 to 2018. Without a longer sample period, we cannot analyse the long-term spillover effect of DIF on RHQD. Therefore, we consider building our own index to extend the sample period in future studies. (2) We only used the panel models for empirical research, without considering the possible spatial effects. Spatial effects need to be further investigated due to spatial dependence or heterogeneity among Chinese provinces and cities.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Performance Evaluation of Laboratory Management System Based on BP Neural Network

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Due to the lack of scientific performance evaluation methods and effective performance management, many tax authorities' performance evaluation and performance management are not perfect. The BP neural network has strong nonlinear mapping, self-learning, and self-adaptive abilities. It has been widely used in the field of numerical prediction and pattern recognition. Based on the exploration of neural network, this paper combines BP neural network with performance evaluation and applies BP neural network to the performance evaluation of university laboratories. Data envelopment analysis (DEA) is mainly used to evaluate the performance of other fields. This paper selects key laboratories as the research object. The performance evaluation of university laboratories based on BP neural network is studied. The existing laboratory evaluation system is scientifically and reasonably revised, reasonable scientific methods are introduced, and a complete and scientific evaluation scheme suitable for the current evaluation requirements is explored. This paper perfects the evaluation method system, so as to scientifically and reasonably allocate research resources, which can maximize the enthusiasm of research departments.

1. Introduction

In recent years, with the further standardization and improvement of university laboratory management system, higher evaluation requirements have been put forward for the performance of experimental equipment [1]. At present, in order to cultivate applied innovative talents and excellent engineers, many universities have increased the proportion of practical and experimental teaching in their teaching plans and encouraged students to actively participate in various innovative activities, discipline competitions, and teachers' scientific research [2]. This requires that experimental teaching and laboratory management should be more of a top priority for educational equipment, but in practice, it appears to be significantly lagging behind, and many schools still use manual bookkeeping for management [3]. The shift in the focus of public personnel management from the defense of abstract meritocratic principles to a focus on maximizing productivity and measurable output outcomes, the result-oriented approach to administrative control, the simplification of burdensome regulations, and the expansion of autonomy for public organizations and personnel have all contributed to a preference for greater use of performance evaluation techniques [4].

Institutional laboratory performance assessment can make a more comprehensive evaluation of laboratories, can objectively give the advantages and shortcomings of each laboratory in the teaching of the college, and can provide an adequate theoretical basis for the construction of laboratories in the college [5]. Laboratories are not only an important support for the development of weapons and equipment but also an important carrier of the core capabilities of the military industry, providing an important technical basis for building an innovative national defense science and technology industry and enhancing the independent research and development capability of weapons and equipment [6]. Laboratory management system is a complex system operation process, which is

affected not only by internal aspects such as quality, cost, schedule, and safety but also by external environmental factors such as social, economic, legal, technological, political, and natural factors. An intelligent laboratory management system consists of three components: a hardware platform, a management software system, and a laboratory management control system based on information control technology [7]. The impact of internal and external factors on performance is very complex due to different management objectives and variable project environments [8]. The experimental users can directly access the laboratory to use the instruments and equipment within the authority to realize the full opening of the laboratory to students and further improve the laboratory management and experimental teaching quality [9].

BP artificial neural network is an important branch in the field of artificial intelligence, and this technique can compensate for the errors judged by the subjective aspect and make the assessment performance to a more accurate degree [10]. Performance evaluation is a very important and necessary part of the laboratory management system, which enables the laboratory to have a proper grasp of all aspects of future project execution, schedule control, budget adjustment, cost assessment, etc., and to improve the effectiveness and efficiency of the evaluation. Through performance evaluation, the organization's strategy and performance expectations are implemented to individuals, while employees improve their value through continuous communication with supervisors and the process of performance improvement. Laboratory management mainly includes planning and design of laboratories, institutional adjustment, implementation and reform of experimental teaching, laboratory team building, use and management of instruments and equipment, construction and implementation of rules and regulations, information collection and management, technical safety management, and environmental construction and maintenance. It is an important part of the scientific research management reform to establish a scientific research evaluation system and to develop practical evaluation methods, to change the old method of management by administrative means alone, to strengthen science, to reduce blindness, to strengthen the sense of competition, and to stimulate the vitality of scientific research work.

This paper revises the existing laboratory evaluation system scientifically and reasonably, introduces reasonable scientific methods, and explores the establishment of a complete and scientific evaluation scheme to meet the current evaluation requirements. The existing research performance evaluation literature mainly uses data envelopment analysis technology to evaluate the performance of other fields. This paper selects key laboratories as the research object. Relying on the strong learning ability of BP neural network, it can realize multifactor data fusion, output more accurate performance evaluation values after nonlinear transformation, reduce and overcome the limitations of traditional performance evaluation, and provide effective decision support for managers.

2. Performance Evaluation of Laboratory Management System Based on BP Neural Network

2.1. Calculation Index of Performance Analysis. The laboratory is an important base for teaching and scientific research. The safety management of the laboratory is the basic guarantee for the normal operation of the experiment. All personnel working and studying in the laboratory must abide by the relevant rules and regulations of the laboratory. Laboratory staff and personnel participating in the experiment must carefully study relevant safety regulations and safety technical operation procedures. Facing the historical opportunities and new challenges at the same time, in the new period, in order to further strengthen the laboratory construction in colleges and universities, to grasp the laboratory work comprehensively, and especially to strengthen the overall common management of school laboratories, it is necessary to establish a set of scientific and reasonable performance appraisal system for laboratory construction. At the same time, this is also an important and urgent task for workers engaged in laboratory construction and management at present. The traditional model can only evaluate the relative effectiveness of decision units and classify them into two categories—effective and noneffective—but cannot rank the decision units. With the gradual stabilization of the large-scale search and the slowing down of the update, the coefficients of the velocity v_i^t at the time of t are adjusted by using the property that the inverse cosine function has monotonically decreasing on $[0, 1]$ as follows:

$$w(t) = sqrt\left[\frac{4}{7} * \arccos\left(\frac{t}{t} - \max\right)\right] * \left[\frac{(t - \max - t)}{(t - \max - 1)}\right]. \quad (1)$$

Call $w(t)$ the inverse cosine function speed adjustment factor, where the velocity update equation is transformed as follows:

$$v_i^{t+1} = w(t) * v_i^t + \left(x_i^t - x^*\right)F_i. \quad (2)$$

At present, it is common for universities to purchase or develop their own laboratory management system to improve the informationization level of laboratory management. However, most of the laboratory management systems are aimed at the laboratories with mainly networked PCs. Therefore, a better solution is found by using the calculation index of performance analysis, and then the network parameters are used as the initial parameters of the algorithm at this time and then trained, and finally the optimal network parameters are searched. The current laboratory assessment uses a combination of quantitative assessment by experts (qualitative assessment) and quantitative calculation by assessment organizations (quantitative assessment). The basic relationship between the indicators in the indicator system can form a recursive hierarchical structure, which is shown in Figure 1.

First, the capacity of the laboratory to accommodate students and the rated number of laboratory hours are calculated based on the available laboratory area, and the

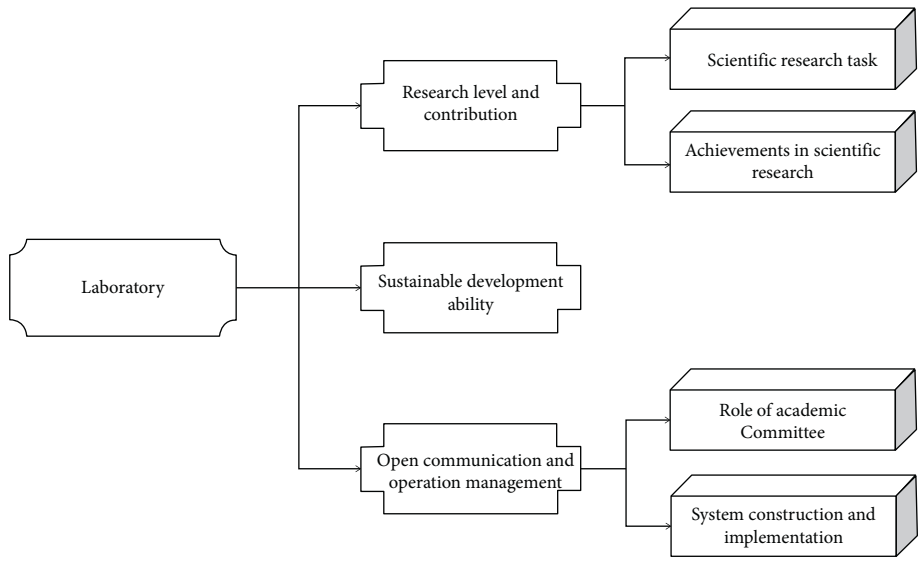

Figure 1: Hierarchical structure of indicator system.

college laboratory utilization rate is calculated based on the actual number of man-hours of students doing the laboratory. Performance can generally be defined at three levels: organizational, group, and individual. The dimensions of performance differ in terms of what they include, what they influence, and how they are measured. By calculating the correlation between different granularity N-gram features, the different granularity features are correlated with each other, and the corresponding weights are assigned to the different granularity features, and the performance is obtained by weighting and summing:

$$\alpha_i^t = \frac{\exp\left(U_i^{tT} u_w\right)}{\sum_t \exp\left(U_i^{tT} u_w\right)}. \tag{3}$$

c_i^t is the i word characterization of the t-th feature.

BP networks can both learn and stock numerous input-output pattern of mapping relations, while eliminating the need to express mathematical equations that describe such mapping relations. The parameters of the laboratory's operational status are then measured both from the student perspective and from the internal business perspective, fully linking the school's long-term strategy with the school's short-term actions and transforming the visionary goals into a systematic set of performance measurement indicators. The advantage of BP neural network is that it can find the rules of data in the knowledge pattern and deal with various types of data. Therefore, the performance evaluation of university laboratories uses the theory of artificial neural network, which overcomes the problem of traditional evaluation procedures to create complex mathematical models and mathematical analytical formulas. It also makes the assessment more accurate. Therefore, making full use of neural network theory to establish laboratory performance evaluation model is an effective method of performance evaluation. The evaluation objectives are decomposed into elements, and a hierarchical structure of evaluation elements is established. Based on the basic data collected by the intelligent laboratory management system, the performance analysis mathematical model is applied to analyze the performance of laboratories in each college. Since the three-layer structure of the BP neural network can fit to approximate any desired nonlinear (or linear) continuous function with any desired accuracy, here, a three-layer BP neural network is used to do quantitative analysis, and the three-layer BP neural network model is shown in Figure 2.

Second, the average utilization rate of the machine-hours used is calculated for the number of machine-hours used for large instruments and equipment in the college laboratory over 50,000 yuan. Experimental teaching performance is the output performance of the organization or individual after the input of human, material, time and other resources in the input-output period. In the late search phase of the algorithm, the discovery probability is reduced in order to increase the speed of convergence of the algorithm. Thus, the discovery probability is improved as follows:

$$pa_t = \exp\left(\frac{t}{t_{\max}}\right) * \cos\left(\frac{t}{t_{\max}}\right) * pa_{\text{begin}}. \tag{4}$$

pa_t is the discovery probability of the t-th iteration and $\exp(t/t_{\max}) * \cos(t/t_{\max})$ is the function dynamic decreasing factor.

The online data is captured by the IOT, and the consistent requirements are obtained after communication and exchange with the school management users. In the forward propagation stage, the propagation of neurons is not reversible, but if the error between the output variables and the predicted values is beyond the allowed range, then the error signal will be backward propagated to find out the error of the numerical variables in the implied layer and adjust the weights or thresholds of each layer. Finally, the teacher provides a statistical data model that can form a data information report, which can be used to visualize the performance values of i colleges, so as to assess the efficiency of

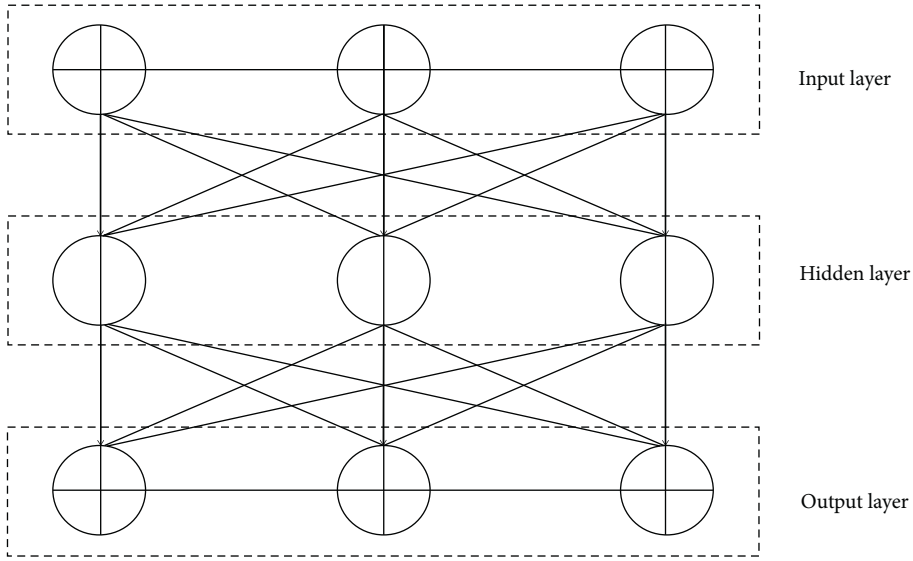

Figure 2: Three-layer BP neural network model.

laboratory management and laboratory teaching. Then, the number of nodes is increased sequentially until the minimum error value is recorded. The formula for determining the number of nodes in the hidden layer using the trial-and-error method:

$$m = \sqrt{k + l} + a. \tag{5}$$

m is the number of hidden layer nodes, k is the input node, and l is the output node.

Finally, the number of person-hours per full-time laboratory manager to receive students and faculty is calculated, which mainly assesses the workload of full-time laboratory managers as well as their work efficiency. The BP algorithm is essentially an algorithm that uses the sum of squared errors of a neural network as the objective function and seeks its objective function to achieve the minimum value according to the gradient descent method. The successful management methods and competitive mechanisms of the private sector are advocated to be widely adopted in the public sector such as the government; e.g., the private sector is organized in a form that can flexibly adapt to the environment rather than a rigid section hierarchy. The knowledge base is supported by both tools and content, and a BP neural network model based on the knowledge base and database is developed.

2.2. Build an Evaluation Model Based on BP Neural Network. This evaluation model, as it involves the construction and management status of educational technology equipment of the evaluated school and the quality of school education teaching, is screened by selecting the modules in the educational equipment management system that can respond to the status of school experimental teaching in real time and the input-output index system for the cost-effectiveness of experimental teaching. In order to obtain more reasonable and reliable evaluation results and achieve the expected research objectives, certain working steps must be followed in using BP neural network evaluation, and this step is presented in Figure 3.

First, according to the principle of multiobjective planning, a satisfactory value and an impermissible value are determined for each evaluation index. DEA is a decision-making method to evaluate the relative effectiveness of the same conditions, the same objectives, the same tasks, and the same input and output indicators. Relying on the data collected by the intelligent management platform of experimental training, the data of the input part of laboratory work and the data of the output part of laboratory work are compiled, and the performance of the laboratory is analyzed accordingly. A filter with the initialization window of k is used for the convolution operation, and its width is consistent with the dimension of the word vector. The convolution operation is shown in the following equation:

$$c_i^k = \sigma\left(\sum\left(C[i, i+k] \circ H_k\right) + b\right). \tag{6}$$

σ is the sigmoid activation function, $C[i, i+k]$ is the word vector sequence, and H_k is the convolution kernel.

The learning of BP neural network consists of four processes: pattern propagation, error back propagation, memory training, and learning convergence. It can be used to analyze and evaluate multiobjective, multistage, and multi-indicator algorithms according to the requirements of performance evaluation and provide an effective basis for performance evaluation of laboratory management. The features are expanded sequentially, where the aggregated features at each moment are obtained by splicing the feature words of different granularity at that moment, and the results are shown in the following equation:

$$c_i = \left[c_i^1; c_i^2, \ldots c_i^k\right]. \tag{7}$$

c_i^k is the convolution window of the i word is the characteristic representation of k.

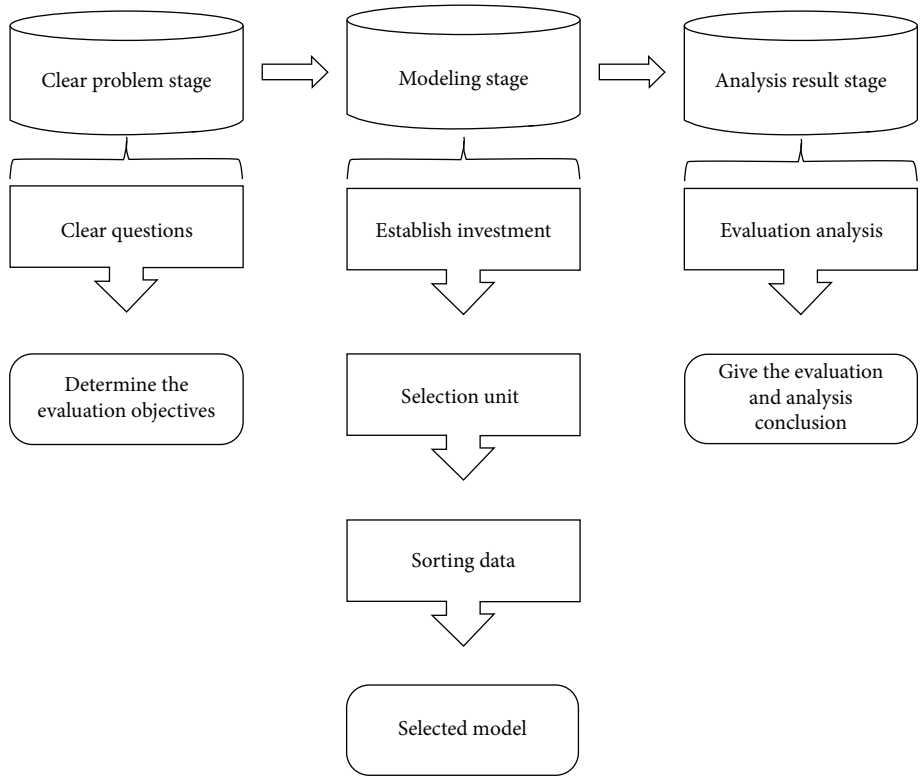

Figure 3: Working steps of BP neural network evaluation method.

Next, the scores of each index are determined by the degree of satisfaction value. The analytical instruments in the laboratory are connected through a computer network, and a distributed management system centered on the laboratory is established. According to the scientific laboratory management theory and computer database technology, a perfect quality assurance system is established and data are shared in a network. Choosing too many decision units will result in too many effective units because they have the same nature. If too few decision units are selected, the assessment objects will all be valid units, so that the real assessment results cannot be obtained. Therefore, most of the daily work of the laboratory (including performance data collection, report generation, etc.) is carried out on the client side, and the server side is only responsible for the processing and exchange of data in the background, while some data that need to be published can be made public through dynamic Web technology using the B/S model. The number of training samples is defined as L, the neural network weights are w_j, the number of neural network connection weights is 1, and the neural network training function is the mean squared difference objective function F:

$$F = \alpha E_w + \beta E_D. \tag{8}$$

α and β are the regularization coefficients.

Decompose a complex problem, after which the constituent elements are classified by attributes, which in turn form different levels. And these factors are further decomposed by dominance relationship and arranged by objective layer, criterion layer, and indicator layer to form a multiobjective, multilevel model, forming an ordered recursive hierarchy. The outputs of each neuron in the implicit layer and output layer of the network are calculated:

$$O_{Pj}^{l} = fi\left(\sum_{j} w_{ji}^{l} O_{i}^{l-1} - \theta_{j}^{1}\right). \tag{9}$$

The BP algorithm is the same, the process is to give several sets of sample data and then continuously use these sample data to train the network; the signal is constantly back and forth inside the network. The network is trained by the database with the sample data according to the index system formed by the knowledge base processing, and the correct output is obtained through the adaptive learning of the BP network, and the trained BP network can make objective and fair evaluation and analysis according to the samples to be identified provided by the database. In most cases, the sum of squared errors (SSE) is used to express the SSE as follows:

$$\mathrm{SSE} = \sum_{i=1}^{k} \sum_{\lambda \in c_i} \mathrm{dis}\left(v_i, x\right), C_i = \frac{1}{m_i} \sum_{\lambda \in c_i} x. \tag{10}$$

k is the cluster number, c_i is the class i, m_i is the the number of samples, v_i is the central point, and x is the cluster sample.

Finally, a weighted average was synthesized to evaluate the overall status of the studied subjects. In terms of hardware, we configured a server in the central lab and installed SQLSERVER2020 as the backend network database, and each hardware lab client computer accessed the

server directly through the campus high-speed LAN. The learning of the BP neural network was successfully completed when all the training patterns met the expectations. For the elements on each layer in the recursive hierarchy, a series of judgment matrices can be constructed based on a two-by-two comparison judgment of the importance to the previous level. The BP algorithm is trained and learned to adjust the weights of the network connections in a systematic way so that the network can obtain the desired output for any input after a systematic adjustment. According to the objectives and requirements of laboratory management, the analysis and evaluation of the processing results of the samples to be identified can serve to continuously enrich the knowledge base and database, and improve the training effect of the neural network.

3. Application Analysis of BP Neural Network in Performance Evaluation of Laboratory Management System

3.1. Derivation and Analysis of BP Algorithm in Performance Evaluation. The BP algorithm is mainly used for the learning of neural network weights and thresholds, and its learning process is composed of two processes: forward propagation of signals and backward propagation of errors. Therefore, the performance evaluation of university laboratories using artificial neural network theory overcomes the problem of traditional evaluation procedures to create complex mathematical models and mathematical analytic formulas and also makes the evaluation more accurate. After setting the parameters of the management system model, the optimization of the BP neural network weights and thresholds is then performed. Through the operation of the management system, we obtain the comparison of the error change and the change of fitness function graphs of the BP neural network training in this paper with the traditional assessment procedure, as shown in Figures 4 and 5.

First, in forward propagation, the input signal is transmitted from the input layer to the output layer through the hidden unit, and the output signal is generated at the output end. The BP neural network-based performance evaluation method requires a certain number of known samples to train the network before the system to be evaluated can be evaluated, and the normalized composite evaluation score is generally selected as the sample expectation. The input normalized samples are initialized with parameters to calculate the input and output values of each layer, and the resulting results have large errors with the predicted values, then the weights and thresholds are modified until the errors end up within the Gertz range. Since there are both qualitative and quantitative indicators in the index system, the qualitative indicators should be quantified in order to make the indicators comparable in the whole system. The actual value of each evaluation index is divided by the evaluation standard value of each index to obtain the evaluation index of each index, and then the evaluation index of each index is weighted arithmetic average to obtain the comprehensive evaluation value.

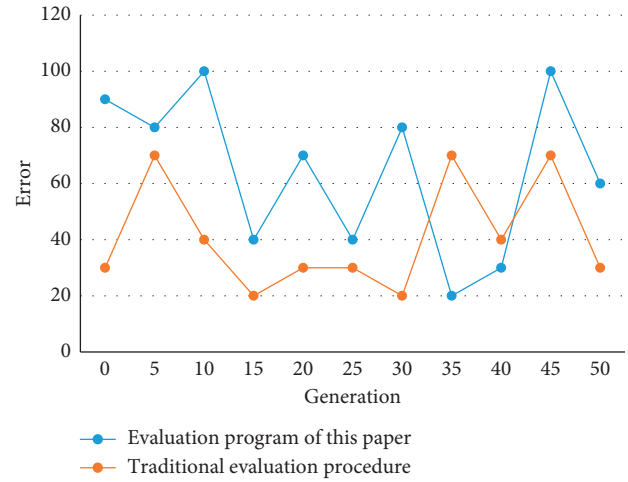

Figure 4: Error changes between BP neural network training and traditional evaluation program.

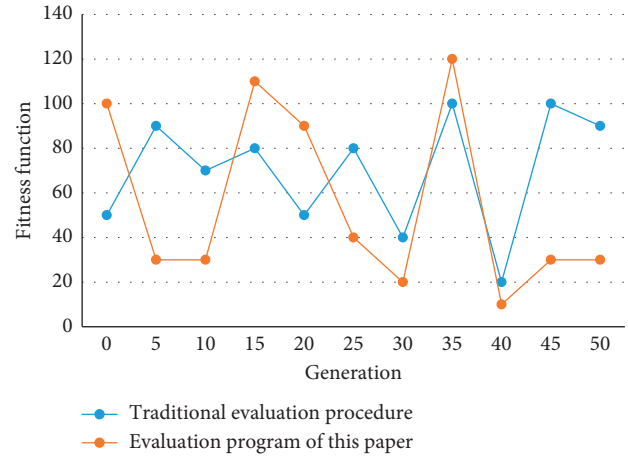

Figure 5: Changes of fitness function between BP neural network training and traditional evaluation program.

Second, in the process of error signal back propagation, the error signal is propagated forward layer by layer starting from the output. In fact, the evaluation indexes are linearly dimensionless, and then the weighted average of the index evaluation value is obtained by using the additive synthesis. For quantitative indicators, due to their different measurement properties, gradations, and tendencies, the effect coefficients can be used to normalize and homogenize them. To automatically generate the above performance evaluation information, it is necessary to accurately collect the usual teacher's tutoring information, each student's information for each experiment, and the experimental staff work information. By collecting the above information in real time, and combining the information of experimental teaching and experimental equipment information, we can generate various performance statistics reports flexibly. The process of minimizing network errors can be regarded as an unconstrained nonlinear optimization process, and the usual training algorithm uses the fastest descent method, and the corresponding adjustment of the weight matrix uses the

delta rule. Using the MATLAB toolbox, the network was programmed to train with the number of hidden layer nodes of 10, and then the performance of the network was tested with test samples, and the results are shown in Table 1.

Finally, by training the input sample data, the error function is made to decrease along the negative gradient direction by continuously correcting the parameters such as the network connection weights, and then the desired output is approximated. The surface is flat and has small slope notches, and it takes several iterations of the weight coefficients in these regions to make the error fall by the required amount. After training in a teacher-learning manner and setting up the learning mode, the input layer receives the data and passes the activation values to the output layer through the intermediate layers. Objective things are relatively complex, and people's understanding of things is not completely clear, so that the judgment matrix will not fully satisfy the requirement of consistency.

Using the knowledge and experience of experts or individuals, it is sometimes called subjective weighting method. However, the judgments of these experts themselves come from long-term reality and are not random assumptions. It should be said that they have an objective basis. Some methods are considered from the statistical nature of indicators. It is determined by the data obtained from the survey without consulting the opinions of experts, so it is sometimes called objective weighting method. Among these methods, the Delphi method is often used. Generally, about 10~30 experts with practical work experience and deep theoretical cultivation in the professional field shall be selected, and the consent of the experts themselves shall be obtained. The P indicators were sent with undetermined weights, relevant information, and unified rules for determining weights to the selected experts, and then they were asked to give the weight values of each indicator independently. The results were recovered, and the mean and standard deviation of each index weight were calculated.

Therefore, the connection weight threshold between the output amplitudes. If there is an error in the expected amplitude and the error is outside the predefined range, the error adjusts the connection weight between layers. The errors of the hidden layer and the output layer of the neural network are acceptable. And at this time, the weights and thresholds do not change. The network weights cannot change with the external environment change this learning method, so the BP network is required to have a good extensibility.

3.2. Solution Analysis of BP Neural Network. The BP algorithm uses the gradient descent method, which has poor global search ability and strong local search ability. When designing a BP neural network, we generally consider the training samples, the number of layers of the network structure, the number of neurons in each layer, the initial weights, and the learning rate.

First, the set of input and output samples is selected. In order to test the actual effect of network training, it is generally necessary to classify the sample data first. The network is first trained with the algorithm to find a better solution, and then the network parameters are used as the initial parameters of the algorithm for training again, and finally the optimal network parameters are searched. However, the evaluation results of the comprehensive evaluation system constructed in this way do not reflect the objective importance of each index through the evaluation data of each evaluation object. Therefore, it is necessary to combine the subjective weighting results of experts and the objective weighting results of assessment data. Although this processing method can improve the differentiation of the composite performance value, it will cause distortion of the data in the mapping process. Therefore, the learning samples are input and the weights and biases of the network are trained using an error back propagation algorithm to iteratively adjust the output vector to be as close as possible to the desired vector. The training is completed when the sum of squared errors of the output layer of the network is less than the specified error, and the weights and deviations of the network are saved. The method is based on the back propagation method, where a value proportional to the previous weight change is added to each weight change, and a new weight change is generated based on the back propagation method. The mean square error of the different network test outputs was calculated based on the error between the simulated output value of the network test and the desired output value, and the convergence and accuracy of the GA-BP neural network were compared with that of the BP neural network, and the comparison results are shown in Figures 6 and 7.

Table 1: Results of 10 hidden nodes.

Algorithm	FAPGABPNN	GABPNN	BP
Structural parameters	1-3-6	9-6-8	12-3-5
Error rate	9.3/57	5.2/18	3.7/56

Next, the number of layers of the network structure is determined. Considering the convergence speed of the network and avoiding the problem of limiting into local minima, the number of implied layers of the network generally does not exceed two layers. According to the objective requirements, index system, and structure of laboratory management performance assessment, cluster analysis was applied to set two input layers and one output layer for planning and progress, forecasting and decision-making, human resources, cost and input, organization and institution, and control and adjustment. The immune particle swarm algorithm is used to determine the initial parameter values of the network to ensure the scientific nature of the initial parameter values. In the process of encoding the particles, if the parameters are encoded in binary, it will cause the encoding string to be too long, and then it has to be reduced to real numbers in decoding, which affects the learning accuracy of the network and the running time of the algorithm. If we consider attaching a large step to enhance its searching ability in the early stage of search, and attaching a small step to improve the accuracy of the optimal solution in the later stage of search, the purpose is to improve the

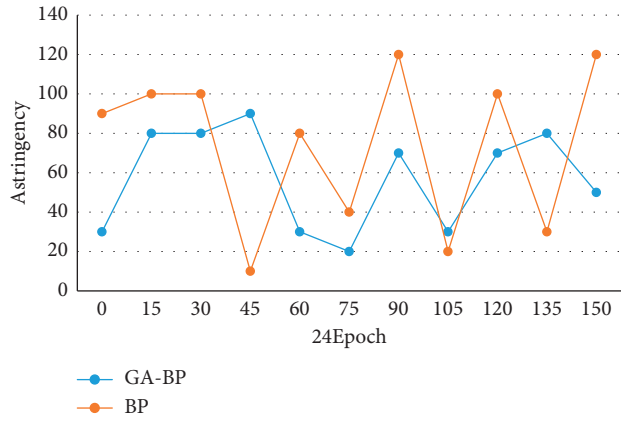

Figure 6: Comparison of convergence between GA-BP neural network and BP neural network.

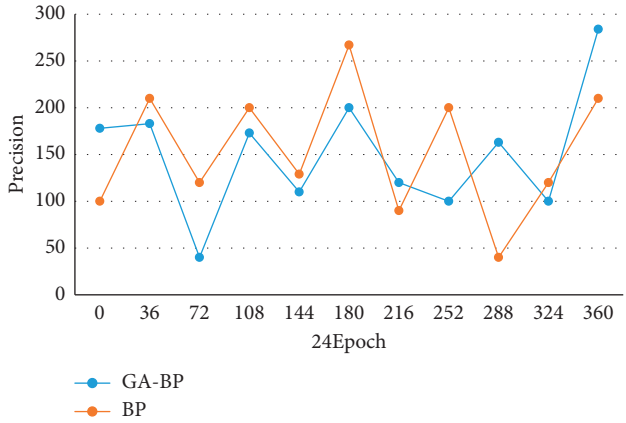

Figure 7: Comparison of accuracy between GA-BP neural network and BP neural network.

accuracy of the optimal solution. Therefore, the cosine function is introduced so that its dynamic curve decreases on the interval with the increase of the number of iterations. By testing the BP network model, GA-BP network model, and SVM model, respectively, the test simulation output values were obtained as shown in Table 2.

Finally, the nonlinear fitting implementation function and the appropriate transfer function and training function are selected; the newff statement is called to create the BP neural network; the initial transfer weights and thresholds between the input layer, implicit layer, and output layer are given; and the training parameters are set to train the BP network. That is, the reference selected for each decision unit is different, and thus each decision unit does not have the possibility to see. The trained network is tested with 20 measurement points as a sample, and the network output is compared with the expected output to determine whether the network has been trained stably by the magnitude of the error. The BP network, GA-BP network, and SVM test simulation output values were output as a series of plots in MATLAB, and the comparison graphs were obtained as shown in Figure 8.

If the final output layer of the network is a curvilinear function, the results of the output layer are allowed to be

Table 2: BP network, GA-BP network, and SVM simulation results of test sample data.

	Desired output	Relative error
BP network	8.27	−0.28
GA-BP network	7.27	−1.33
SVM	6.19	−3.29

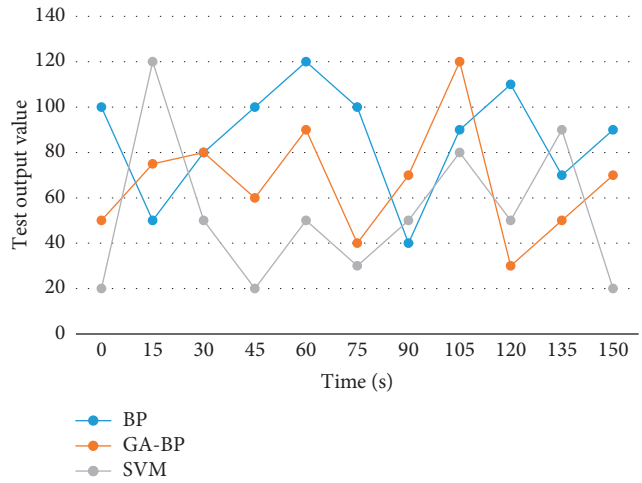

Figure 8: BP network, GA-BP network, and SVM test simulation output value pair.

obtained in small bounds. If purelin is used, the results of the output layer can be any number, and the above mentioned functions are the most common ones that we use in our daily BP network training. Avoid using one or two simple metrics as the whole evaluation of tax work performance, it must cover more than 60%–90% of the work and pay attention to the workload metric that should reflect the laboratory performance in a comprehensive way. The input vector of the neural network is the influencing factors of laboratory performance, and the comprehensive laboratory performance index is the output vector of the neural network with systematic error. The demand generated after designing a reasonable network structure, training samples into the network, and network performance evaluation model until the specified requirements are met. Each expert is given a judgment matrix and is tested for consistency, and then their opinions are arithmetically averaged to derive the weights (reflecting the relative importance of each evaluation index), which can reflect the subjective experience of experts.

4. Conclusions

The importance of performance management, which has a central control role in organizational management and is an effective means for organizations to achieve their strategic goals, has attracted the attention of more and more managers, and the ideas and methods of performance management are being widely used. The purpose of scientific and objective performance evaluation of laboratories is, on the one hand, to motivate college laboratory centers to seriously

improve their management and use efficiency and, on the other hand, to explore a new mechanism for the allocation of laboratory construction inputs, i.e., to apply the comprehensive laboratory efficiency value as a coefficient to a new mechanism for the allocation of laboratory construction inputs. The BP neural network does not require the creation of mathematical models in the process of performance evaluation. It can itself be incorporated into multiple models and obtain output results within the target expectations by virtue of its own network learning. In this paper, we analyze the content and process of performance assessment from the purpose and requirements of laboratory performance assessment. Using the characteristics of BP neural networks, which can describe complex and nonlinear relationships, we combine qualitative and quantitative analysis and establish an assessment model based on BP neural networks to meet the needs of multiobjective, multi-index, and multistage laboratory performance assessment. The final performance of the laboratory can be better and more effective than other laboratories in the use of various resources, so as to attract more resources to enter and produce more results. Laboratory construction is related to the cultivation of students' practical skills, and the laboratory performance evaluation system can improve the efficiency of laboratory performance evaluation and make the laboratory construction more reasonable, so the system is of great significance to the laboratory construction.

However, this paper does not discuss the lag of performance evaluation, and there is a certain delay in the time of postperformance evaluation. As mentioned above, postperformance evaluation is relatively independent and objective. It is not affected by subjective decision-making, but the utility is insufficient.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Movie Box Office Prediction Based on IFOA-GRNN

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Predicting movie box office has received extensive attention from academia and industry. At present, the main method of forecasting movie box office is subjective prediction, which is not widely accepted due to its accuracy and applicability. This study improves the fruit fly algorithm to optimize the generalized regression neural network (IFOA-GRNN) model to predict whether a movie can become a high-grossing movie. By using the actual box office data and performing virtual simulation calculations, the root means square error of the IFOA-GRNN model predicting the movie box office is 0.3412, and the classification accuracy is about 90%. By comparing this model with FOA-GRNN, KNN, GRNN, Random Forest, Naive Bayes, Ensembles for Boosting, Discriminant Analysis Classifier, and SVM, it is found that the prediction effect of the IFOA-GRNN model is significantly better than the above eight models. The contribution of this article is to propose a generalized regression neural network model based on an improved fruit fly optimization algorithm, which can greatly improve the accuracy of movie box office prediction.

1. Introduction

With the further advancement of China's modernization and the prosperity of pan-entertainment, movies have become the mainstay of China's cultural industry [1]. Regardless of age, occupation, and region, people now regard movies as an indispensable part of their spiritual life. At present, Chinese film market has become larger and larger [2, 3]. The total box office of the global film market in 2021 has reached 21.4 billion US dollars (Cinema and Home Entertainment Market Report 2021). Compared with 2020, which was affected by the pandemic, the global film market in 2021 has picked up significantly. Moreover, in 2021, China has become the most grossing country in the world, accounting for 34% of the world's box office (Analysis report by UK investment agency Gower Street (2021)), indicating the vigorous development of the Chinese film market in the postpandemic era.

Box office is an important indicator of the success of a movie. Usually, we evaluate a movie by its box office. For producers, making a high box office movie can accumulate a good reputation and pave the way for future creations. For investors, a high box office movie can bring a lot of benefits [4]. At the same time, an expected high-grossing movie can reduce the risk of investment, so they are more concerned about box office revenues than before in the current situation when the world is hit by a new coronavirus outbreak. For general movie audience, a high-grossing movie can enrich their spare time. Therefore, the box office level of a movie attracts more and more people's attention.

2. Literature Review

The influencing factors of movie box office and box office prediction are popular research fields in recent years. The box office of a movie may be affected by a combination of factors such as budget and film schedule. [5] Regarding the factors, Barry [6], who was the first to study movie box office prediction, used variables such as movie type, director, and actor influence, sequel or not when constructing a multiple regression movie box office prediction model. In the current study, Zhou and Han [7] believed that movie box office is significantly related to the number of reviews and user attention. Desai and Basuroy [8] found that for cultural products, such as books, music, and movies, the category of the product has a significant impact on its popularity. The

higher the star appeal and positive comments, the popularity of cultural products has a significant positive promotion effect. Zhao and Gao [9] divided films into cultural capital and social capital and found that the former starring and director's IP adaptation had a positive impact on the film box office, while the latter's reputation and policy factors had a positive impact on the film box office. Dhar et al. [10] used 26 years of domestic movie box office data and based on controlling for other factors affecting the movie box office, they concluded that series movies have higher box office compared with other movies without sequels. Kim et al. [11] divided word-of-mouth into expert comments and public comments to explore the impact of word-of-mouth on movie box office and found that positive expert comments and public comments had a positive effect on the box office, with expert comments having a higher value than public comments.

For the method of movie box office prediction, Lin and Liu [12] used the conventional multiple linear regression method, Dai and Zheng [13] used the OLS regression analysis method, and Xi [14] used machine learning algorithms such as xgboost to predict the movie box office. Song et al. [15] predicted movie box office based on random forest and found that the prediction effect was better than multiple linear regression. Lu and Xing [16] used the forward feedback neural network to predict the movie box office interval and used the regression method to predict the movie box office of the first week. Luo et al. [17] used the two-step system GMM to establish a movie box office prediction model, and the average absolute error percentage was about 9%. Atk [18] input social network service (SNS) data as a variable into a traditional machine learning model to predict movie box office, and the results show that the effect is significantly better than a single machine learning model.

For the above methods, first of all, the accuracy of the linear regression method is not high, and the movie box office and the influencing factors are not a simple linear mapping relationship. In addition, for nonlinear fitting methods, most of them are related to self-adjusting parameters, such as the penalty parameters and kernel parameters of the SVM classifier, the number of neurons in the neural network, the number of subtrees in the random forest, and the minimum sample leaf size. A large number will lead to a long time for algorithm parameter tuning, which will affect the real-time performance of prediction [19]. The generalized regression neural network model is suitable for solving nonlinear problems such as movie box office prediction. The model has the advantages of no training weights, fast learning speed, and single adjustment factor [20]. Moreover, the adjustment factor of the generalized regression neural network method has only one spreading parameter σ, and the structure is simple, and the nonlinear mapping ability is strong. It belongs to the method with fast learning speed and strong approximation ability, so it is suitable for the prediction of movie box office.

In this article, we proposed a generalized regression neural network optimized by the fruit fly optimization algorithm [21]. The dataset is divided into training set and test set, and the box office data are discretized into binary data by binning, namely, high box office and low box office. We analyzed to find out the many factors that affect the movie box office, and finally establish a variety of classification models. In addition, we compared the predicted results with the real values and found that common classifiers generally have problems such as insufficient prediction and poor stability. In a word, the current neural network prediction model is improved by using the fruit fly optimization algorithm, a branch of the emerging swarm algorithm.

This study proposes a generalized regression neural network model based on the improved fruit fly optimization algorithm (IFOA-GRNN), using the improved fruit fly optimization algorithm in the swarm algorithm to optimize the adjustment factor, and using the ten-fold cross-validation [22] method MATLAB calculation is carried out to effectively improve the prediction ability of the model. The fruit fly optimization algorithm has the advantages of simple method and fast convergence speed [23], which can quickly find the optimal value of the adjustment factor and improve the prediction accuracy [24]. In addition, compared with the traditional fruit fly optimization algorithm, the improved fruit fly optimization algorithm studied in this article has the advantages of being able to jump out of the local optimal solution. Through the comparison on the TMDB movie box office dataset, the proposed method achieves better classification performance. Compared with the existing traditional machine learning methods such as SVM and Random Forest, the accuracy, and precision are improved by about 20% on average.

3. The Fruit Fly Optimization Algorithm and Parameter Design

3.1. Symbol Description. 3.2. Traditional Fruit Fly Optimization Algorithm. Fruit fly optimization algorithm (FOA) is an emerging optimization algorithm [24, 25]. The algorithm is based on the foraging process of fruit flies. Fruit fly is a very sensitive creature with a very sensitive sense of smell, and it can even smell odors 40 kilometers away. Once the fruit fly smells the food, it can fly in its direction, and its foraging process is shown in Figure 1. The specific steps of the fruit fly optimization algorithm are as follows:

(1) Randomly initialize the position InitX_axis and InitY_axis of the fruit flies.

(2) Give the flies a random direction and distance to search for food.

$$\begin{cases} X_i = X\text{_axis} + \text{Random Value}, \\ Y_i = Y\text{_axis} + \text{Random Value}. \end{cases} \tag{1}$$

(3) Calculate the distance of the fruit fly from the origin D_i and the judgment value of taste concentration S_i.

$$\begin{aligned} S_i &= \frac{1}{D_i}, \\ D_i &= \left(X_i^2 + Y_i^2\right)^{1/2}, \\ \text{Smell}_i &= \text{Function}\left(S_i\right). \end{aligned} \tag{2}$$

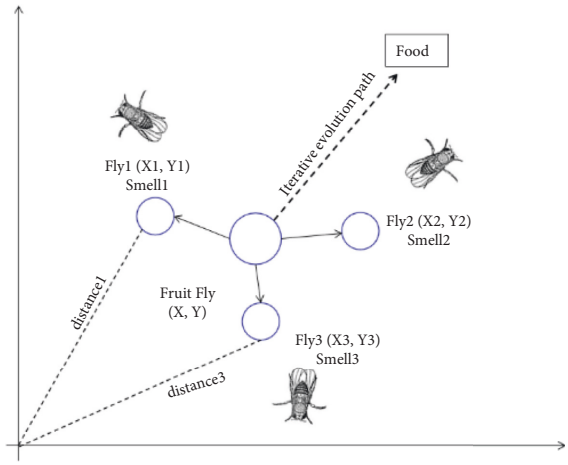

Figure 1: Fruit fly foraging pathway.

(4) Find the fruit fly with the highest concentration of taste in the whole fruit fly population and record its location.

$$[\text{best Smell bestindex}] = \max(\text{Smell}). \tag{3}$$

(5) The coordinates with the highest taste concentration are recorded and the flies swarm to it.

$$\text{Smell best} = \text{best Smell}. \tag{4}$$

(6) Enter the iterative optimization stage and repeat steps 2 to 5. If the smell concentration of the current position is higher than that of the previous iteration, execute the sixth step. Until the iteration ends, or the convergence conditions are met, the highest flavor concentration is finally obtained.

$$\begin{cases} X_\text{axis} = X(\text{bestIndex}), \\ Y_\text{axis} = Y(\text{bestIndex}). \end{cases} \tag{5}$$

4. IFOA-GRNN Model Design

4.1. GRNN Model. In 1991, Specht [26] proposed generalized regression neural network (GRNN), which is a special form of radial basis function neural network (RBF) [27]. GRNN is a feedforward neural network model based on nonlinear regression theory, which can handle nonlinear or linear regression problems well, and approximate functions by activating neurons. The generalized regression neural network consists of four layers, namely, the input layer, the pattern layer, the summation layer, and the output layer. Its structure is shown in Figure 2. The generalized regression neural network does not need to be trained, and its network link weight value is determined by the output and input of the training sample, and there is no need to estimate and guess the number of hidden layers and hidden units in the network [28]. It is derived from RBF and therefore has only one free parameter, the RBF smoothing parameter. It can be seen that the purpose of data mining is to find the optimal smoothing parameter σ and the number of network neurons.

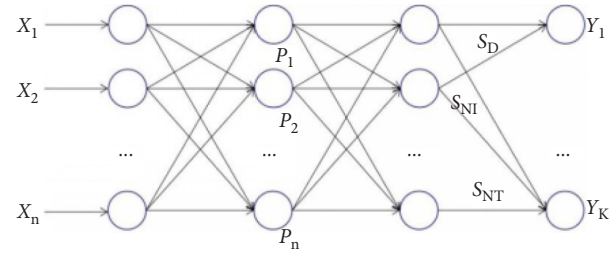

Figure 2: Generalized regression neural network structure diagram.

The theoretical basis of GRNN is nonlinear regression analysis, which has strong nonlinear mapping ability, and because it does not need to train weights, its learning speed is also very fast [29].

4.1.1. Input Layer. The number of neurons in the input layer is equal to the dimension of the input vector in the sample, and the input layer passes the vector directly to the pattern layer.

4.1.2. Pattern Layer. The number of neurons in the pattern layer is equal to the number of samples, and the transfer function of the pattern layer is

$$P_i = e^{\left[-\left((X-X_i)^T(X-X_i)/2\sigma^2\right)\right]}. \tag{6}$$

4.1.3. Summation Layer. The summation layer has two types of neurons that use different formulas for summation.

The first type of summation is the arithmetic summation of all pattern layer inputs.

$$S_D = \sum_{i=1}^{n} P_i. \tag{7}$$

The second summation method is to perform a weighted summation of all pattern layer inputs, and the connection weight between the pattern layer and the summation layer is the j element in the i output sample.

$$S_{Nj} = \sum_{i=1}^{n} y_{ij} P_i \quad j = 1, 2, 3, \ldots, k. \tag{8}$$

4.1.4. Output Layer. The number of neurons in the output layer is equal to the dimension of the vector output in the sample, and each neuron divides the output of the summation layer to obtain the final output.

$$y_j = \frac{S_{Nj}}{S_D}. \tag{9}$$

It can be seen from the above formula that the generalized regression neural network does not need to be trained, and the only parameter that GRNN needs to determine is σ, so how to choose a suitable σ is very important for our

prediction work. If the value of σ is too large, the value of is the output in formula (9) approximately the average value of the sample data, and if the value of σ is too small, y_j will be too close to the sample data, and the generalization ability of the model will be greatly reduced. Therefore, this study chooses the IFOA [30–32] to find the optimal spreading parameter σ.

4.2. GRNN Model Optimized by IFOA. The traditional fruit fly optimization algorithm FOA has problems such as easy to fall into local optimum [33], too many iterations, and too long search time. For the search step size of FOA that is relatively fixed, if it is too large, the optimal solution may be missed, and the local search ability is relatively weak. If it is too small, the global search ability is relatively weak, and so the optimal solution may be missed as well. At the same time, a positive search step size in FOA means that the fruit fly may only search in one direction, and negative values should not be ignored.

Based on the above problems, to solve the spreading parameter σ in the generalized regression neural network, this study adopts an improved fruit fly optimization generalized regression neural network (IFOA-GRNN) method to achieve our purpose. The main idea of the improvement is to give a larger step size in the first half of the iteration, while adjust to a smaller step size in the second half of the iteration for precise search and use the sign function (sgn) as the step size on the basic search step size. Adding plus and minus signs can increase the diversity of foraging processes in fruit fly.

IFOA to optimize GRNN is shown in Figure 3.

Step 1. Randomly initialize the position of the fruit fly InitX_axis, InitY_axis.

$$\begin{cases} X_\text{axis} = \text{rand} \\ Y_\text{axis} = \text{rand} \end{cases}$$

$$L_0 = \text{sign}\,(2 * \text{rand} - 1)$$

$$L = \begin{cases} L_0 * \left(1 + \dfrac{\text{gen}}{\max \text{gen}}\right), & if\ 0 < \dfrac{\text{gen}}{\max \text{gen}} <= 0.5, \\ L_0 * \left(1 - \dfrac{\text{gen} - 1}{\max \text{gen}}\right), & if\ 0.5 < \dfrac{\text{gen}}{\max \text{gen}} <= 1, \end{cases} \tag{10}$$

$$\begin{cases} X_i = X_\text{axis} + L, \\ Y_i = Y_\text{axis} + L. \end{cases}$$

Step 2. Calculate the distance from the origin of the fruit fly D_i and the judgment value S_i of taste concentration, which is the spreading parameter σ in the GRNN network.

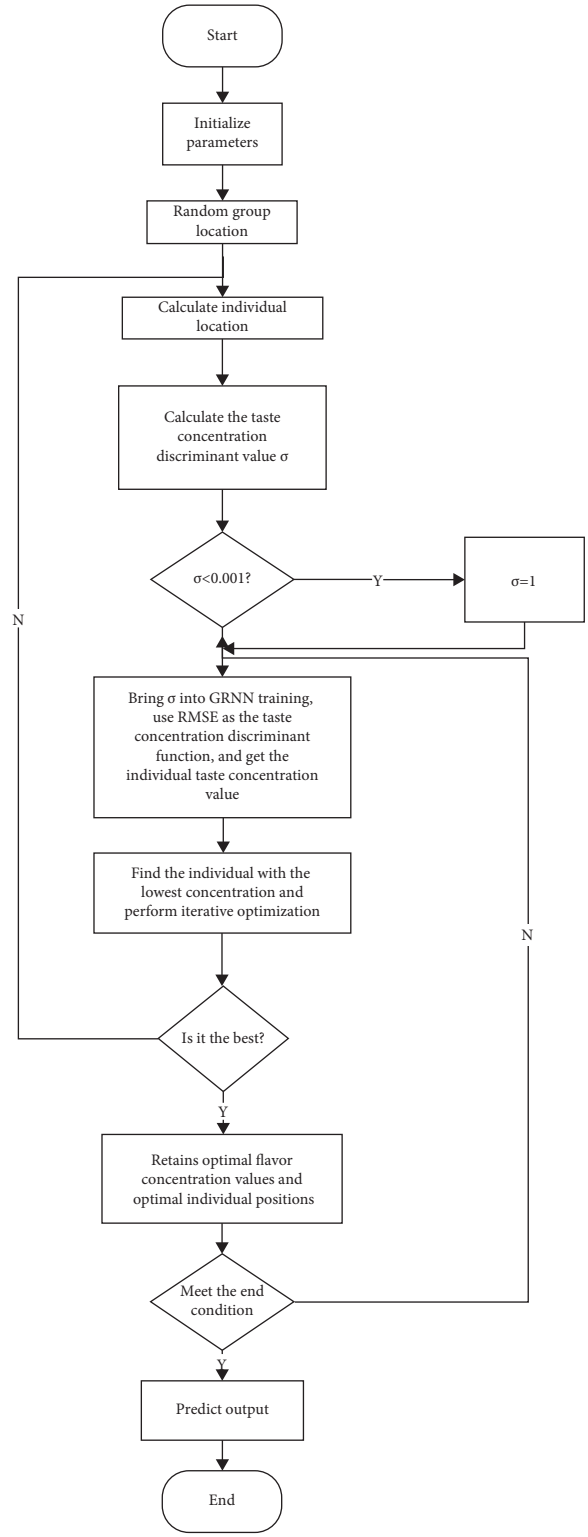

Figure 3: IFOA-GRNN algorithm flow chart.

$$D_\text{i} = \left(X_\text{i}^2 + Y_\text{i}^2\right)^{1/2},$$

$$S_i = \frac{1}{D_i}. \tag{11}$$

Step 3. Substitute the taste concentration judgment value S_i of the fruit fly at this position into the taste concentration judgment function Smell_i to obtain the taste concentration of the fruit fly at this position. The taste concentration determination function here is the error function, which is used to calculate the RMSE. The lower the RMSE value, the better the model fitting effect.

$$\begin{aligned} \text{Smell}_i &= \text{Function}(S_i), \\ \text{RMSE} &= \sqrt{\frac{1}{n}\sum_{k}^{n} y(k) - y}, \\ [\text{bestSmell bestindex}] &= \min(\text{Smell}). \end{aligned} \tag{12}$$

Step 4. Record the coordinates with the lowest taste concentration and the flies swarm to it.

$$\begin{aligned} \text{Smell} &= \text{bestSmell}, \\ \begin{cases} X_\text{axis} = X(\text{bestIndex}), \\ Y_\text{axis} = Y(\text{bestIndex}). \end{cases} \end{aligned} \tag{13}$$

5. Empirical Research and Data Analysis

5.1. Data Source. Movie box office is affected by many factors. Through the significance test, this study selects seven main influencing factors: budget, production country, production company, genres, runtime, homepage, and popularity, to predict movie box office. The data source of this article is the Movie Database (TMDB) dataset provided by Kaggle (https://www.kaggle.com/datasets/tmdb/tmdb-movie-metadata), which includes the information of nearly 5,000 movies. There are 23 variables, such as movie_id (TMDB movie identification number), title (movie name), cast (actor list), director (director), genres (style list/movie type), and homepage of a movie (Movie front page).

5.2. Data Processing. The original data contains twenty-three attributes such as revenue, budget, keywords, and so on. After a preliminary screening to remove meaningless indicators (such as poster URLs) and data that are difficult to quantify (such as movie descriptions), budget, genres, popularity, production company, production country, runtime, homepage, and movie language are eight attributes. As the purpose of this study is to predict whether a movie is a high box office movie or a low box office movie, it is necessary to use the binning operation to discretize the box office indicators. To avoid the influence of outliers, this article chooses to use equal-frequency binning. The same number of samples is in the "low box office" set and the "high box office" set. We use 1 for "high box office" and 0 for "low box office."

In addition, genres, production companies, and production countries are all unstructured data. These indicators are very difficult to quantify and analyze, and there is no unified judgment standard. Therefore, this study takes the weighted sum of the average rating and the average number of reviews corresponding to previous films of this type as the rating of the genres:

$$\text{genres} = \frac{\text{std}(\text{review_score}) + \text{std}(\text{review_num})}{2}. \tag{14}$$

The following calculation method is the same for the production companies and production countries:

$$\begin{aligned} \text{companies} &= \frac{\text{std}(\text{review_score}) + \text{std}(\text{review_num})}{2}, \\ \text{countries} &= \frac{\text{std}(\text{review_score}) + \text{std}(\text{review_num})}{2}. \end{aligned} \tag{15}$$

Then, delete the row where there are abnormal values (such as zero or null) in the first eight attributes and normalize the sample data to exclude the influence of dimension, so that the data are between 0 and 1, and finally get the data we need.

5.3. Indicator Selection. After data processing, there are initially eight indicators that may be related to movie box office. In order to obtain the final required influencing factors, this study uses MATLAB to conduct the significance test method to test the significance of the following eight indicators after data processing: budget, genres, popularity, production company, production country, runtime, homepage, and movie language. The results shown in Table 1 are obtained.

It can be seen from Table 2 that the seven variables of budget, genres, popularity, production company, production country, runtime, and homepage passed the significance test, indicating that they are all related to the movie box office, and the variable of movie language did not pass the significance test. After screening out the amount, we finally selected the first seven factors as the seven indicators for the movie box office prediction in this study.

5.3.1. Budget. Although there are low-cost, high box office movies such as "Chainsaw" and "Crazy Stone," various phenomena show that the scale of investment in a film is proportional to its box office. High investment can guarantee the production intensity of all aspects of the film, thereby creating the possibility of high box office. Coupled with the popularity of the Internet and piracy, audiences will think that there is no big difference between watching low-cost movies on computer TV and watching movies in theaters, which makes it even more difficult for low-cost movies to get the box office.

5.3.2. Genres [34]. An appealing script will undoubtedly lead to a high box office. For example, the classic thriller "Chainsaw" series, each of which is a low-budget production, has gained wide popularity because of its fascinating and logical script settings, and the series of films have been released one after another. With the development of film

Table 1: Significance test table of box office influencing factors.

Factor	Factor number	T-test significance level
Budget	X1	0.000
Genres	X2	0.000
Popularity	X3	0.000
Production company	X4	0.000
Production country	X5	0.001
Runtime	X6	0.000
Homepage	X7	0.000
Movie language	X8	0.614

Table 2: The definitions of symbols.

Symbol	Definition
X	Fruit fly abscissa
Y	Fruit fly ordinate
X_axis	Fruit fly starting abscissa
Y_axis	Fruit fly starting ordinate
D	Fruit fly distance from origin
S	Taste concentration judgment value
Smell	Taste concentration
bestSmell	Maximum taste concentration
bestIndex	Fruit fly location with greatest flavor concentration
L	Fruit fly distance per random search
Σ	Spreading parameters
RMSE	Root mean square error

industrialization and marketization, the type of film has gradually become apparent, and the relationship between type and box office has also deepened. Today, classic film genres such as action films, disaster films, children's films, horror films, romantic films, and so on have been formed. Each type of film corresponds to a different audience group, and the spending power of each audience group is different. Therefore, the film genre has an impact on the box office of the film. This article uses the word cloud to show the distribution of movie genre (Figure 4).

5.3.3. Production Companies. A good production company is often one of the guarantees of a high-grossing film, such as Universal Pictures, Columbia Pictures, Warner Bros. Entertainment, The Walt Disney Company, and so on. Famous film production companies are often able to use their own resources to choose a better release date, have a stronger cast and director lineup, and a more mature production model, all of which can contribute to the success of a film.

5.3.4. Production Countries. The origin of the movie also affects the audience of the movie to a certain extent, as the origin of the movie invisibly gives people a subjective awareness and emotion about the national culture [35]. We can also find that many high box office movies are produced in the United States, China, and other countries.

5.3.5. Popularity. Popularity refers to the relative number of clicks of the movie in the Movie Database, and we can also understand it as its relative number of searches. The more times a movie is searched before it is released, the higher its attention [4], and this search has a certain probability that

Figure 4: Movie genre word cloud.

the audience actually goes to the cinema to watch the movie, which in turn affects the box office. Therefore, popularity is one of the important factors.

5.3.6. Runtime. From a psychological level, runtime is considered to be a key factor that can affect a movie's box office. Generally speaking, if a movie is too long, the audience may feel tired, and if a movie is too short, it may bring a perfunctory feeling to the audience's psychology, which will affect the reputation of the movie, and then affect the box office of the movie.

5.3.7. Homepage. The homepage variable refers to whether a movie has its own homepage before it is released. Many excellent movie producers will make a promotional homepage for the movie before the movie is released, which will contain starring information, trailers, and other content. The promotional cost of the movie has doubled in the past few years, which reflects the growing demand of audience for movie information. It also shows that the influence of publicity and promotion on the audience increases, and then it can be inferred that it has a positive impact on the movie box office.

5.4. Evaluation Indicators. In this study, the accuracy rate, precision rate, recall rate, and F1 value are used to evaluate the prediction effect of the model, as shown in Table 3.

Accuracy: As the name implies, it is the proportion of all correct predictions in the total.

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}. \tag{16}$$

Precision: That is the proportion of those who are correctly predicted to be high box office accounts for the total predicted high box office.

$$\text{Precision} = \frac{TP}{TP + FP}. \tag{17}$$

Table 3: Confusion matrix.

Actual value	Predictive value	
	Positive	Negative
Positive	TP	FN
Negative	FP	TN

Recall: It is the proportion of the total box office that is correctly predicted to be a high box office is actually a high box office.

$$\text{Recall} = \frac{TP}{TP + FN}. \tag{18}$$

F1 value: Consider both precision and recall.

$$\frac{2}{F_1} = \frac{1}{\text{Precision}} + \frac{1}{\text{Recall}},$$
$$F_1 = \frac{2TP}{2TP + FP + FN}. \tag{19}$$

5.5. Experiment. After the TMDB_5000 dataset is screened and preprocessed, there are 3169 movie data remaining. Among them, 70% of the data is used as the training set, and 30% of the data is used as the validation set, that is, 2220 movie data are trained, and the model generalization ability is verified on 949 movie data. For the training set, this study divides it into 10 parts, 9 as the training set and 1 as the test set, followed by using 10 cross-validation methods to calculate the mean of the model evaluation indicators. We choose seven evaluation indicators of budget, genres, popularity, production company, production country, runtime, and homepage as influencing factors to build a model.

The network structure of GRNN in this model is well determined. It is a four-layer neural network. The number of neurons in the input layer is the dimension of the input vector, the number of neurons in the pattern layer is equal to the number of samples, and the number of neurons in the output layer is the dimension of the output vector. To make the IFOA-GRNN prediction model optimal, the population number and the maximum number of iterations of fruit flies were continuously adjusted in the experiment [36], and the optimal spreading parameter values under different parameters were obtained, as shown in Table 4.

Through experiments, it is found that when the fixed population size is 10 and the number of iterations is 100, the spreading parameter σ reaches the minimum value of 0.053. Although the spreading parameter can reach the optimal value of 0.0530 by increasing the population size or the number of iterations, it will increase the time for iterative optimization. At the same time, this article also found that changing different population sizes will lead to different RMSE results during convergence, but the difference is small, and IFOA-GRNN is not sensitive to the initial parameter selection. Therefore, this article chooses 10 as the population size and 100 as the maximum number of iterations.

Table 4: Optimal spreading parameters under different parameters.

Population size	Number of iterations	RMSE	Spreading parameter σ
1	50	0.3458	0.0531
5	50	0.3458	0.0531
5	100	0.3458	0.0531
10	100	0.3458	0.0530
20	100	0.3458	0.0530
30	100	0.3458	0.0530
30	150	0.3458	0.0530

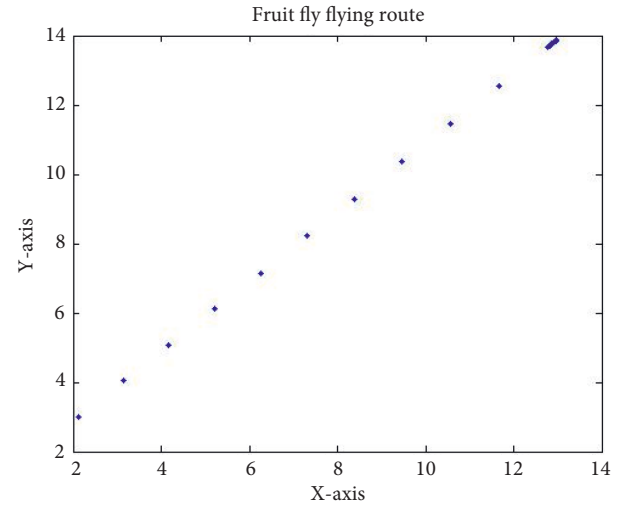

Figure 5: IFOA-GRNN fruit fly search path.

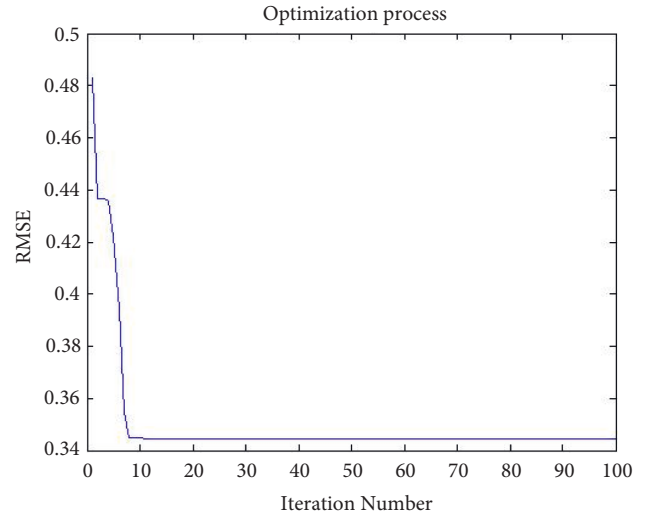

Figure 6: IFOA-GRNN convergence graph.

After the simulation, the search path of the fruit fly is shown in Figure 5, and the convergence of RMSE is shown in Figure 6. The IFOA-GRNN model finally converged in the ninth iteration after 100 iterations, with a minimum RMSE of 0.3458 and a spreading parameter σ of 0.0530.

For FOA-GRNN algorithm, the iterations converge to 9 generations. The optimal spreading parameter σ obtained is

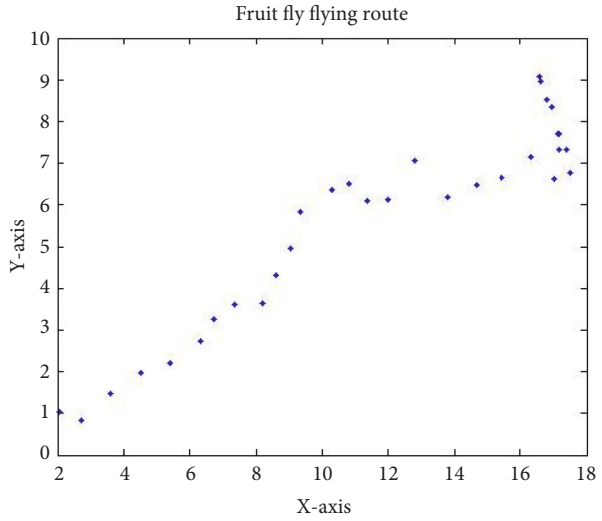

Figure 7: FOA-GRNN fruit fly search path.

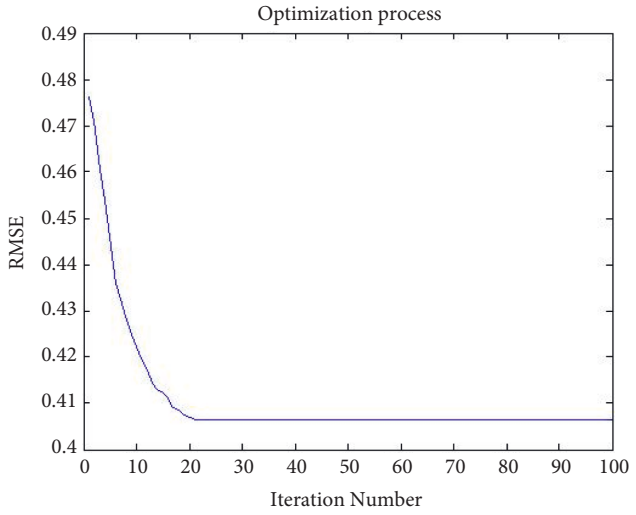

Figure 8: FOA-GRNN convergence graph.

Table 5: Prediction effect table of different classifiers.

Algorithm	Accuracy (%)	Precision (%)	Recall (%)	F1 value
IFOA-GRNN	90.46	91.72	90.26	0.9098
FOA-GRNN	84.33	85.76	84.11	0.8492
GRNN	70.91	73.65	70.50	0.7204
KNN	73.55	73.91	73.66	0.7379
Naive Bayes	73.02	75.31	72.56	0.7389
Random forest	80.18	80.28	80.15	0.8022
Ensembles for boosting	78.61	78.83	78.69	0.7876
Discriminant analysis classifier	75.55	77.84	75.27	0.7653
SVM	79.18	79.35	79.08	0.7921

0.0 623, and the minimum value of RMSE is 0.4064. The optimal path of fruit fly is shown in Figure 7. The RMSE

convergence is shown in Figure 8.

Compared with the traditional FOA-GRNN model, the IFOA-GRNN model proposed in this article achieves the convergence faster, but also skips the local optimum, searches for the optimal spreading parameters, and has better prediction performance.

To comprehensively evaluate the prediction ability of IFOA-GRNN, this study chooses to use traditional classifiers such as KNN, GRNN, Naive Bayes, Random Forest, Ensembles for Boosting, Discriminant Analysis Classifier, and SVM to predict the dataset in this study, and it is consistent with the core of this study. The methods are compared and the results in Table 5 are obtained.

6. Conclusions

In this study, we used the fruit fly optimization algorithm to optimize the spreading parameter σ in the generalized regression neural network, which has achieved good results in the prediction and analysis of popular movies. Taking the TMDB_5000 dataset as an empirical research, this study compares the prediction results of the IFOA-GRNN model with FOA-GRNN, GRNN, KNN, and other models, and draws the following conclusions:

(1) This article conducts a significant T test on the sample before modeling, and finds that seven factors of budget, genres, popularity, production company, production country, runtime, and homepage significantly affect the box office of a movie.

(2) This article selects different fruit fly population numbers for experiments. It is found that when the population number changes, the results obtained by MATLAB simulation have little difference, indicating that the IFOA-GRNN model has strong stability and is not sensitive to the selection of IFOA initial parameters.

(3) In this article, IFOA is selected to automatically find the optimal spreading parameter σ of GRNN, which reduces the interference of artificial selection on prediction. At the same time, by comparing with the FOA-GRNN model, it is found that the IFOA-GRNN model can jump out of the local optimum and find the global optimum solution more quickly. Compared with classification models such as SVM and KNN, it is found that the accuracy, precision, recall, and F1 value of IFOA-GRNN are significantly higher than other classifiers, indicating that the model can significantly improve the accuracy of movie box office prediction.

Because IFOA-GRNN model combined with generalized regression neural network has good stability, accuracy, and computing speed, it can be applied to the research of prediction problems in machine learning, cognitive science, and other fields.

Based on the work of this study, the feasible improvement directions in the future include the following:

(1) This article selects the seven factors affecting the movie box office—budget, genres, popularity, production company, production country, runtime, and homepage. In fact, movie box office should be influenced by many factors, such as the cast and director lineup. Due to the difficulty of data collection, more factors are not considered in this article. In the future, more factors related to movie box office can be added to the model through further research.

(2) When choosing the optimal population size and the maximum number of iterations in the IFOA-GRNN algorithm, the empirical method is used to select some conventional combinations because the experimental computing power is limited, and there is no way to traverse to find a better combination of population size and maximum number of iterations that may exist. In future research, if there is a better experimental environment, we can consider solving the optimal combination of population size and maximum number of iterations. [37].

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Disclosure

This paper is one of the stage achievements of the State Key Laboratory of Media Convergence Communication and the research and cultivation project of Communication University of China, which is based on the big data film box office research.

Conflicts of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Research Article

Performance Evaluation and Management Method of Music Tutoring Schools Based on Analytic Hierarchy Process

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On the basis of summarizing the relevant theories of performance management at home and abroad, the important role, significance, and development trend of performance management in music tutoring schools are analyzed. Starting from the actual management of music tutoring schools, taking a music tutoring school as an example, this article comprehensively analyzes the current situation of the school's performance assessment. Considering that the constructed index system is a multilevel comprehensive index system, the analytic hierarchy process is used to give weight to the index. The calculation method and calculation steps are described in detail, and the weight of each index is obtained. Through the design and implementation of the school's performance management system, solid theoretical and institutional support will be provided for the school to achieve sound development in the future. It is expected that the design of this performance can provide reference for such private schools in the country and promote the healthy and sustainable development of private training institutions in China. Let more schools and learners share the nectar and dividends brought by the system reform.

1. Introduction

With the development of the economy, people's living standards and ideas are changing. People are paying more and more attention to education [1, 2]. The concept of quality education permeates every family, and parents pay more and more attention to their children's art education. Education in public schools can no longer fully meet the expectations of parents for their children, and various training schools have sprung up in the market. The private training school curriculum has covered all levels of children from kindergarten to higher education. There are both independent and hybrid schools, and the content of their training basically covers all types. Private schools have become an indispensable part of the country's education system. It has emerged as a significant force on the stage of our society. Private schools are not only the product of the country's education marketization reform, but also the necessity of social economic development. Each of us must also welcome it with a positive attitude. In this context, the characteristics of the school and the quality of the school's teaching will directly affect the survival and development of the school. It has also become an important reference standard for our evaluation and selection of schools. Teaching quality determines everything, and teaching characteristics guide everything. In the whole process, teachers as human resources undoubtedly play a crucial role. How to build a unique music training school that meets market demand has become the key to gaining a competitive market advantage [3].

Data show that more than 90% of junior high school and primary school students in large- and medium-sized cities have participated in extracurricular training. The percentage of musical instrument training is as high as 48%. In addition to the student body, the proportion of adults favoring musical instrument learning is also on the rise. Several musical instrument training schools have sprung up, and they are also opening their doors to adults. However, the main force of the market is still the student team. The annual winter and summer vacations are the peak season for musical instrument training. Children of all sizes always crowd the classrooms of training institutions [4, 5].

Internal and external training markets and private training schools are developing rapidly. With the advent of the knowledge economy and the increasing pressure of employment and further education, the training and education market has expanded rapidly and maintained rapid growth. In foreign countries, training and education has a wide range of various types of education and training, from the improvement of adult vocational ability to youth. According to statistics from the Ministry of Education of China, the number of students trained by private training schools in 2022 will reach more than 30 million. It is estimated that the total value of the music training market alone is expected to reach RMB 10 billion in 2022. Education and training has become a huge market that cannot be ignored. From 2012 to 2022, the growth trend of the number of music training students in China and the total value of the music training market during the 10-year period is shown in Figure 1.

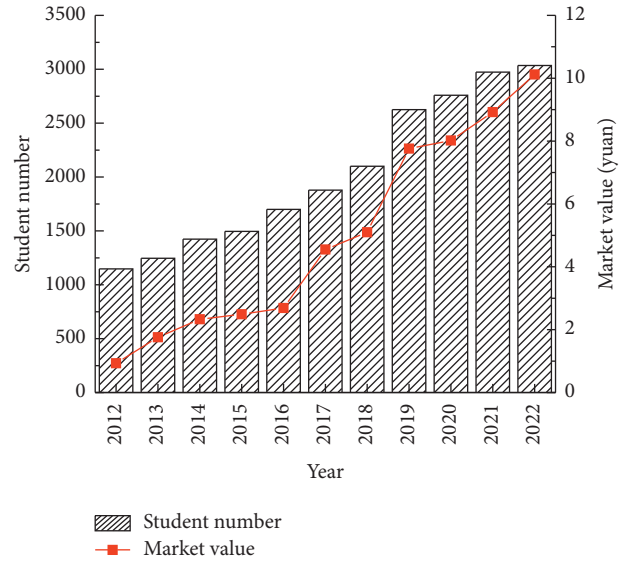

Figure 1: Growth trend of the number of music training students and the total value of the music training market in China.

However, there are many problems in the performance evaluation index system of music training schools. Most of the performance evaluation indicators of private training schools are single and cannot comprehensively and reasonably evaluate school performance. The evaluation system also focuses more on indicators related to financial benefits. It ignores indicators of teacher professional development [6]. It pays attention to the evaluation indicators of teaching output and ignores the evaluation indicators of teaching input. It pays attention to the indicators of students' academic performance and ignores the indicators of moral education. At the same time, the management level of music training institutions is generally backward and lacks the concept of performance management. Although the industry has great potential for development, the art education industry of "big market, small workshop" is still in the initial stage of growth. Music training institutions in the market are mixed, and the competition is fierce. In addition, differences in regional resources and teaching models will also make it difficult for educational institutions to replicate on a standardized scale. As a result, the market concentration is low. From the perspective of consumers, more than half of consumers prefer the introduction of relatives, friends, and acquaintances when choosing an art education institution.

The purpose of this article to study the performance evaluation and management methods of music tutoring schools is as follows.

(1) A scientific and reasonable performance evaluation index system for music training schools suitable for China's national conditions can be constructed.

(2) It can provide theoretical basis and countermeasures for the scientific and reasonable performance appraisal of music tutoring schools.

The research on this issue has the following significance.

(1) Theoretical significance

The evaluation index system needs to be studied. Through the use of scientific methods, an assessment index system adapted to the characteristics of Chinese music tutoring schools is constructed. The performance appraisal indicators are collected through expert consultation and literature review, and then the appraisal indicators are screened, scientifically classified, and the corresponding weights are determined. By establishing an assessment index system for music tutoring schools, China's performance assessment theory will be further enriched.

(2) Realistic meaning

By providing music tutoring schools with a scientific and reasonable teacher performance evaluation index system that can be used for reference, the development of human resource management in music tutoring schools will be promoted and the school will have a core competitive advantage. Efforts shall be made to create an institutional environment that is conducive to outstanding talents to stand out and develop their talents, and to form an employment environment in which outstanding talents gather. Performance appraisal should not only provide services for teachers' appointment and promotion, but also become an effective way to improve their quality and promote their development.

2. Definition of Related Concepts

2.1. Performance. The meaning of performance is very broad, and it is generally interpreted as achievement and effectiveness. It reflects the achievements and achievements of people engaged in a certain activity. It was first used in social and economic management, and later it was widely used in human resource management. But there is no generally accepted academic definition. With the existing definitions of performance, it can be divided into the following four categories: (1) purposeful behavior; (2) work

ability and skills; (3) output results, work completion, and contributions; and (4) process, output, and impact. First, it highlights the combination of behavioral processes and results [7].

Some important dimensions of visible performance are behaviors, processes, outcomes, or achievement of organizational goals and impact on the future. Therefore, the definition of performance includes the following three elements [8, 9]: results compared to organizational goals, actions to achieve those results, and expectations of future benefits from these actions and results. Based on these considerations, this article defines "performance" as the combination of the above elements. The logical relationship of these basic elements is that appropriate action achieves the outcome of contrasting goals. These actions and outcomes have an impact on the environment and the future, and the impact on the future can only be predicted or expected.

From a vertical perspective, performance is generally divided into three levels: overall organizational performance, department or team performance, and individual employee performance. Individual employee performance refers to the sum total of employees' work results, work behaviors, and work attitudes in a certain period of time. Organizational performance refers to the quantity, quality, efficiency, and profitability of the organization's tasks within a certain period of time (as shown in Figure 2). Individual employee performance is the foundation. The individual performance of multiple employees is combined as department or team performance. The overall performance of an organization is a combination of the performance of multiple departments or teams.

2.2. Performance Evaluation. Performance evaluation, also known as performance appraisal, or performance appraisal, or grade. Research on performance evaluation is widely distributed in economics, management, organizational behavior, and other disciplines. In the subject, scholars have different understandings and definitions of performance evaluation based on their respective disciplinary perspectives. At present, the definition of performance evaluation in academic circles is mainly divided into the following two types [10].

(1) In the field of human resource management of enterprises, performance evaluation is mainly related to employee promotion and salary. Therefore, in modern enterprise management, performance evaluation is to use systematic methods and principles to evaluate and measure employees' work behavior and work effects in their positions.

(2) In public utilities management, performance evaluation is essentially to evaluate the degree of achievement of goals and the use of funds by formulating performance goals for government departments to use financial funds, designing evaluation indicators and standards, and using appropriate methods. The federal government began evaluating its employees in 1842. At the time Congress passed a lawyers amendment. The proposal would require government departments to conduct annual job evaluations of clerks. Since then, performance appraisal procedures have become popular in government and private companies large and small.

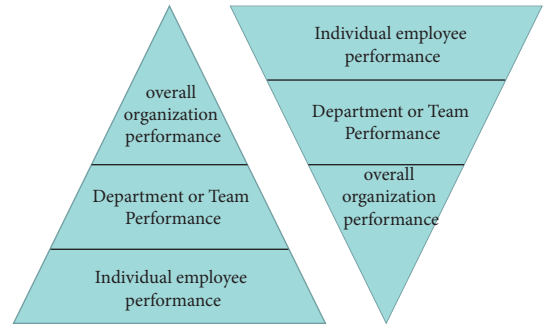

Figure 2: Three levels of organizational performance.

Many experts and scholars at home and abroad have made various definitions of performance evaluation from different research angles. The main definitions of performance are as follows [11].

(1) Employees in an organization can be sorted by size of contribution.

(2) Qualifications, habits, personalities, and attitudes of individual employees and the relative value of the organization are systematically and objectively evaluated. It formulates employee competencies, work status, and adaptability for the purpose of seeking truth from facts. It is the sum of the procedures, norms, and methods of assessment.

(3) Reasonable evaluations need to be made regularly, systematically, and as objectively as possible. It is possible to tap the competency of the employee's position and the potential to take on higher level positions.

(4) It is an important part of the personnel management system. The assessor observes and records the daily performance of the assessee. And on the basis of facts, the assessment is carried out through specific purposes to achieve the purpose of cultivating, developing, and improving the ability of members of the organization.

2.3. Performance Management. Often people talk about performance management when they talk about performance appraisals. Performance management is not a single step or aspect. It covers both organizational performance and individual employee performance, but is closely related to performance evaluation [12]. In a sense, it is the development and extension of performance evaluation. Performance evaluation is an integral part of performance management in terms of coverage. Performance management first emphasizes the systematic management of

performance. Its distinctive feature is the goal and direction of performance management, while focusing on process guidance. Through continuous communication and guidance, evaluation, and feedback, necessary improvement or improvement measures are formulated. This not only achieves the rational development and full use of human resources and enhances team cohesion, but also improves the economic benefits of the enterprise. Ultimately, the overall strategic goals of the enterprise can also be achieved. The performance management process is a continuous cycle of systematic engineering. Figure 3 shows the relationship between the different links in this system [13, 14].

2.4. The Role of Performance Management

(1) The importance of performance management to an organization

Performance management can save the time cost of managers. Performance management allows employees to define their tasks and goals. They will know what leaders want them to do, what decisions they can make, what they should do, and when they need leadership guidance.

(2) The importance of performance management to employees

Performance management affects the motivation of employees and also helps to restrain employees' work behavior. Therefore, reasonable and effective performance management can not only improve the efficiency of enterprises, but also regulate the behavior of employees.

3. Applying Theory of Performance Evaluation and Management in Music Tutoring Schools

At present, the evaluation methods of performance management include: management by objectives, key performance indicators, balanced scorecard, and analytic hierarchy process. Each music tutoring school should choose different methods suitable for it due to its own particularity, and different performance appraisal methods have their own particularities and shortcomings. Music tutoring schools should choose the most suitable performance management method for the enterprise according to its own situation. Combined with the characteristics and needs of music tutoring schools, this article introduces the commonly used performance appraisal methods.

3.1. Management by Objectives. Management by objectives emerged in the United States in the mid-1950s. It is a management system formed on the basis of Taylor's scientific management and behavioral science theory (especially the participatory management). Management by objectives is to compare and evaluate actual work performance with expected goals, and it is a commonly used performance evaluation method. The performance evaluation method based on management by objectives can apply the basic principles of planning, execution, inspection, and feedback actions of management by objectives to performance evaluation [15]. It can be correspondingly divided into four stages: performance target planning, performance guidance, performance inspection, and performance incentive. The performance appraisal method based on management by objectives can be described by a flow chart (Figure 4).

To be effective, management by objectives must ensure its clarity and certainty. If the goal changes frequently, it is not well planned, and it is easy for the business to get into chaos. The target plan is future oriented, and the future is full of uncertainties. This requires constant modification of the target according to the environment. Revising a target system takes a lot of time and effort. As a result, managers may have to stop midway through ongoing management by objectives.

3.2. Key Performance Indicator Method. Key performance indicators are the extraction and induction of the key success factors in the operation of an enterprise [16]. By analyzing, setting, sampling, and calculating the key parameters of the input and output of a process within an enterprise organization, and through the objective quantitative management indicators for measuring process performance, it is a tool for decomposing enterprise strategic goals into operational vision goals. It is a quantifiable or actionable index system for evaluating the performance of the examinee. Key performance indicators must be quantifiable or actionable. If these two points cannot be met, it cannot be called a key performance indicator. Enterprises are usually divided into three levels: enterprise, department, and position to establish different key indicators.

The method is straightforward and easy to control and manage. Employees follow KPI measurement standards and reward standards, which can play an incentive-oriented role. The combination of results and process indicators can comprehensively, objectively, and fairly reflect employee performance levels.

This method fails to provide a complete set of indicators framework system with guiding significance for operation. There is no necessary internal logical connection between the indicators. Usually indicators are mostly positioned on individual and departmental performance, ignoring the relationship with organizational strategy. In addition, unreasonable assessment standards and improper weight setting are also frequent operational problems in KPI design.

3.3. Balanced Scorecard. The balanced scorecard is a strategic management tool that implements an enterprise's strategy into feasible goals, measurable indicators, and target values [17]. It not only enables companies to effectively track financial goals, but also focuses on key business progress and develops intangible assets that are beneficial for future growth. It urges business leaders to define the development strategy of the business in a balanced way from four dimensions: finance, customers, internal processes, and learning and growth. The correlations and links between the

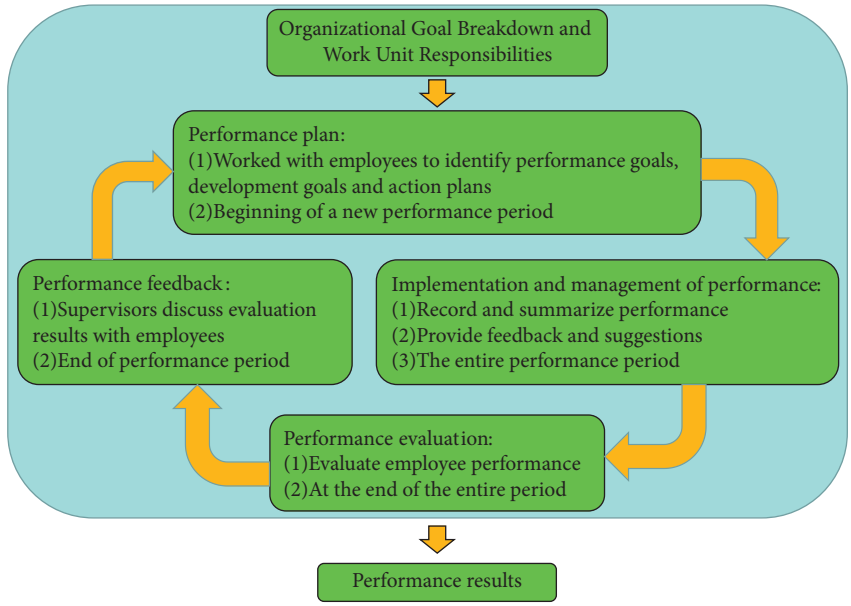

Figure 3: Performance management workflow.

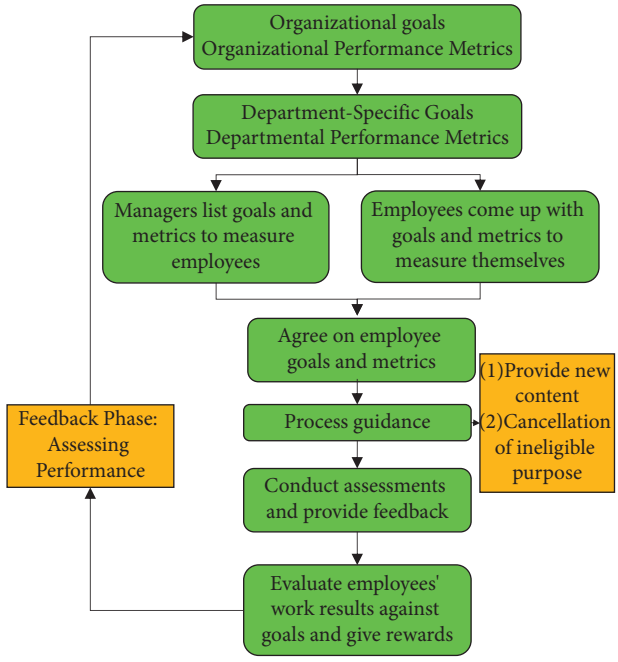

Figure 4: Flow chart of performance evaluation based on management by objectives.

four dimensions are analyzed according to the tracking and analysis of the target value result data, timely and early detection of problems, and adjustment of strategic goals and target values. A framework for implementing strategic objectives is established to identify management priorities. Therefore, the balanced scorecard overcomes the limitations of the traditional single financial indicator assessment, and also takes into account the three important aspects of customers, internal processes, and learning and growth. The enterprise can be observed from these dimensions, the enterprise strategy can be defined, and then the enterprise can achieve a comprehensive and balanced development.

The balanced scorecard is usually operated by comparing the budgeted and actual values of each indicator. Different scoring values are set by corresponding to the difference rates in different ranges. In the form of comprehensive scoring, the implementation of the objectives of each responsible department in the four dimensions is regularly assessed. Through timely feedback, the strategic deviation can be adjusted in a timely manner, or the original goals and evaluation indicators can be revised. It can ensure that the business strategy is implemented smoothly and correctly.

The top leaders of the enterprise can clearly grasp the status of each department and the overall operation of the enterprise through the balanced scorecard system. Through the formulation of performance appraisal indicators, it can be found whether the post setting of each department is reasonable and whether the workload is full. The use and operation of the balanced scorecard is very difficult. It is a lot of work. In addition to a deep understanding of strategic goals, it also takes a lot of time and energy to decompose it into various departments and positions, and to find appropriate indicators. The balanced scorecard does not apply to individuals. If the indicators of the four dimensions are decomposed to the individual level, it will take more time and increase the difficulty of assessment. For personal assessment, the assessment method is required to be easy to understand, operate, and manage, and the balanced scorecard does not have these characteristics.

3.4. Analytic Hierarchy Process. In the early 1970s, American operations researcher and University of Pittsburgh professor Satie first proposed the AHP. This method decomposes complex problems containing multiple factors into orderly and effective hierarchical components with less interrelatedness: target layer, criterion layer, and measure layer. Each component is quantified as a specific number or percentage by the assessor's assessment of the importance of each

component. It is necessary to determine and analyze the quantification value of the components of each level for the quantification value of the previous level and the composite quantification value of the final problem. The characteristic of AHP is the ingenious combination of qualitative analysis and quantitative calculation [18]. Through hierarchical, structured, and other analysis methods, complex problems are decomposed into specific elements and measured through digitalization. The method is scientific and systematic, the process is clear, easy to understand, concise, and practical.

Although AHP decomposes the final goal, the decomposed parts are less related. Each part can still affect each other and thus affect the final result. Therefore, it is necessary to carefully divide the components and clarify the possible impact of each component on the final problem. In determining the importance of each component, because the evaluator is a human, there is a certain subjective result rather than a very objective reality. At the same time, using this method requires a pairwise comparison, which requires a large amount of calculation. Too many indicators may result in failure to pass the consistency test results.

4. Music Counseling School Performance Evaluation Index System

4.1. Assess the Basic Process

4.1.1. Build a Performance Evaluation Index System. Constructing the performance evaluation index system is the basis of the whole performance evaluation based on the comprehensive evaluation method. The rationality of the construction of the indicator system is directly related to the correctness of the decision.

4.1.2. Analyzing the Properties of Indicators. The nature of the indicator directly determines the indicator weighting method and the comprehensive performance evaluation method to be used later. Quantitative indicators also need to be dimensionless to ensure the comparability of performance evaluation values of various music tutoring schools.

4.1.3. Indicator Empowerment. The weighting of indicators is to reflect the degree of influence of the importance of indicators on the performance evaluation value. For quantitative indicators, quantitative weighting methods can be used, such as principal component analysis method, direct weight method, and factor analysis method. For the index system that cannot be quantified, the experience of experts in the field can be combined, and some qualitative weighting methods, such as the AHP method, can be used for weighting.

4.1.4. Calculate the Combined Value of Performance Evaluation. The selection of the specific comprehensive evaluation mathematical model directly determines the rationality of the comprehensive evaluation value. In addition, the nature of the indicator system must be considered in combination with the actual background. It is also possible to synthesize the comprehensive evaluation value of multiple methods to form a more objective comprehensive evaluation result.

4.2. AHP's Empowerment Approach

4.2.1. AHP Is a Commonly Used Index Weighting Method [19, 20]. It compares the importance of two indicators one by one, and uses a certain quantitative method to assign a certain weight to the indicators. Due to its good combination of quantitative methods and qualitative methods, it has been widely used in the past few years.

An event W has n components $(w_1, w_1, \ldots, w_n)$, and the i-th component can be represented by w_i. And w_i/w_j represents the important multiple of the i-th part relative to the j-th part. If it is represented by a_{ij}, then $a_{ij} = w_i/w_j$, and the judgment matrix A can be obtained.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}. \tag{1}$$

The steps of applying this method to determine the weight of each part inside the event are as follows. Subject ratings need to be broken down into different factors. According to the affiliation between the various factors, establish a hierarchical structure. The judgment matrix A is obtained by comparing the elements of the same layer pairwise. Quantitatively describe the relative importance of each layer, and use mathematical methods to find the largest eigenvalue $\lambda_{\max}$. The corresponding feature vector is the desired weight vector $W = (w_1, w_1 \ldots w_n)$.

4.2.2. Basic Steps of AHP

(1) Create a hierarchical structure

Establishing a hierarchical hierarchy is the first step in the AHP. After in-depth analysis of the events to be studied, the influencing factors are divided into multiple levels. It includes the highest layer, the middle layer, and the lowest layer. The top layer is the target layer, which represents the decision-making goal that the decision maker wants to achieve. The middle layer is the criterion layer, which measures whether the goal is achieved or not. The lowest layer is the indicator layer, which represents the final judgment indicator. Taking the factors of the same level as the criterion for comparison and final evaluation, it dominates some factors of the next level, and at the same time it is subordinate to the factors of the previous level.

(2) Constructing judgment matrix

After the hierarchical structure model is established, the affiliation of the factors between the upper and lower layers is determined. On this basis, a judgment

needs to be made about the relative importance of each factor at each level. In order to quantify the judgments, the judgment matrix A is needed. Judgment matrix A represents a factor for the previous level. The relative importance of this layer and its related factors needs a pairwise comparison (as shown in Table 1).

(3) Calculate the weight vector

In order to extract useful information from the judgment matrix and realize the regularity of things, it is necessary to calculate the weight vector of each factor in the judgment matrix (as shown in Table 2).

Judging that the matrix A does not always satisfy the consistency, the method for finding the weight vector is as follows. By summing the elements of each row of A, equation (2) can be obtained.

$$\overline{w}_i = \sum_{j=1}^{n} a_{ij}, \quad i = 1, 2 \ldots, n. \tag{2}$$

By further normalizing equation (2), equation (3) can be obtained.

$$w_i = \frac{\sum_{j=1}^{n} a_{ij}}{\sum_{k=1}^{n} \sum_{j=1}^{n} a_{kj}} \quad i = 1, 2 \ldots, n. \tag{3}$$

Taking the geometric mean of the elements in each row of A, equation (4) can be obtained.

$$\overline{w}_i = \left(\prod_{j=1}^{n} a_{ij} \right)^{1/n}, \quad i = 1, 2 \ldots, n. \tag{4}$$

By further normalizing equation (4), equation(5) can be obtained.

$$w_i = \frac{\left(\prod_{j=1}^{n} a_{ij} \right)^{1/n}}{\sum_{k=1}^{n} \left(\prod_{j=1}^{n} a_{ij} \right)^{1/n}}, \quad i = 1, 2 \ldots, n. \tag{5}$$

The synthetic weight vector refers to the weight vector of the index layer in the index system to the target layer. The value of each component of it represents the proportion of the corresponding index in the total target layer. Single criterion sorting is to calculate the relative weights between elements under a certain criterion according to the judgment matrix, and the eigenvector method is usually used for calculation. Perron's theorem is the theoretical basis of the eigenvector method.

The details are as follows. A positive matrix when $A > 0$. All elements in matrix A are greater than zero. $\rho(A)$ is its spectral radius. The normalized eigenvector $w = (w_1, w_1, \ldots, w_n)$ corresponding to the largest eigenvalue $\lambda_{\max}$ of A is a positive vector. Let $A > 0$ and $x \in R$, equation (6) can be obtained.

$$\lim_{k \longrightarrow \infty} \frac{A^k x}{x^T A^k x} = cv, \tag{6}$$

where v is the eigenvector corresponding to the largest eigenvalue of A. c is a constant.

Table 1: Definition of importance.

a_{ij}	Meaning
1	Equally important
3	One factor is slightly more important than the other
5	One factor is more important than the other
7	One factor is more important than the other
9	One factor is extremely important than the other
2, 4, 6, 8	Between the above two judgment values

Table 2: Secondary degree definition.

a_{ij}	Meaning
1/3	One factor is slightly less important than the other
1/5	One factor is less important than the other
1/7	One factor is much less important than the other
1/9	One factor is extremely secondary to the other
1/2, 1/4, 1/6, 1/8	Between the above two judgment values

Equation (7) can be obtained if $x = e$.

$$\lim_{k \longrightarrow \infty} \frac{A^k e}{e^T A^k e} = z, \tag{7}$$

where z is the normalized vector corresponding to the largest eigenvalue of A.

4.2.3. Consistency Check. In the analysis of practical problems, due to the intricate complexity of objective things and the incompleteness of the subject's possession of data and the limitation of the ability to understand and understand, the understanding of things is inevitably subjective. It is difficult or even impossible for the judgment matrix thus constructed to fully satisfy the consistency requirements. Therefore, it is usually difficult to construct a matrix that fully satisfies the consistency, and the judgment matrix cannot completely deviate from the consistency conditions. Therefore, it is necessary to identify whether the judgment matrix is acceptable or not, which is the connotation of the consistency test.

4.3. Fuzzy Comprehensive Evaluation Method. Fuzzy comprehensive evaluation refers to finding a fuzzy weight vector $A = (a_1, a_2, \ldots, a_n) \in F(V)$, and a fuzzy transformation f from U to V. Each factor u_i needs to be judged separately, $f(u_i) = (r_{i1}, r_{i2}, \ldots, r_{in}) \in F(V)$, $i = 1, 2, \ldots, m$. The fuzzy matrix can be constructed according to the above description.

$$R = \left[r_{ij} \right]_{m \times n} \in F(U \times V), \tag{8}$$

where r_i represents the degree to which the factor u_i has the comment v_j .

The mathematical model of fuzzy comprehensive evaluation involves the following three elements.

(1) Element set $U = (u_1, u_2, \ldots, u_n)$.

(2) Comment set $V = (v_1, v_2 \ldots v_n)$.

(3) One-factor fuzzy relationship $f: U \longrightarrow F(V)$, $u_i \longrightarrow f(u_i) = (r_{i1}, r_{i2}, \ldots, r_{in}) \in F(V)$.

The fuzzy judgment matrix can be expressed as

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}. \quad (9)$$

For the fuzzy weight vector $A = (a_1, a_2, \ldots, a_n)$ on the factor set U, it is transformed into a fuzzy set $B = A \cdot R$ on the decision set V through R.

The fuzzy comprehensive evaluation results of events are calculated according to the principle of maximum membership.

$$V = \max(b_i), \quad i = 1, 2 \ldots, n, \quad (10)$$

where b_i is the possibility that the feature set belongs to the comment u_i.

The fuzzy comprehensive evaluation results of events are calculated according to the principle of minimum membership.

$$V = \min(b_i), \quad i = 1, 2 \ldots, n, \quad (11)$$

where V is the corresponding comment is the comment of the event.

5. Empirical Analysis

5.1. Overview of Music Tutoring School. A music training school was established in 2007 with a registered capital of 800,000 yuan. The school adheres to the core concept of "learning the piano happily," and the mission of "popularizing elegant art." It integrates the resources of tutoring schools and primary and secondary schools, comprehensively introduces the American Happy Piano Teaching Curriculum System and Textbook System, and builds a brand new piano and other musical instrument learning platform. It has become a private music training school with professional high-quality professionals. The music tutoring school currently has four campuses with a total teaching area of more than 3000 square meters. It has a large dance classroom of 300 square meters, a beautiful environment, and strong teachers. All kinds of teaching facilities are complete. There are multiple professional courses in piano, digital piano, electronic organ, accordion, vocal music, dance, and music theory. The school's teaching performance is outstanding. The school has been awarded and praised by relevant departments such as the municipal education, culture, radio, and television bureau for many times.

5.2. Analysis of Problems Existing in School Performance Evaluation. Since the school was founded in 2007, with the joint efforts of the principal and school executives, the school has embarked on a fast track and expanded rapidly. It has attracted extensive attention from other schools in the same industry. However, rapid market expansion and development requires comprehensive support from a scientific and sound management system. Since 2009, the management of schools has obviously lagged behind the rapid development of enterprises, and various problems have followed.

There are mainly the following problems.

(1) In recent years, although some achievements have been made in the research on performance evaluation of various types of schools, there is still an incomplete understanding of performance evaluation. The problem is mainly reflected in the lack of in-depth understanding of performance. The school management still has not been able to realize the transformation from the "benefit" idea to the "performance" idea. In action, it is embodied in that when analyzing the performance of school organizations and individual employees, it only focuses on the analysis of output quality and quantity, or simply stays in the comparison of results and costs in teaching and enrollment management activities. It makes the "performance" evaluation a simple cost-benefit analysis of "benefit" and "effect." There is a lack of necessary research and evaluation on the efficiency, service quality, and process of education and teaching.

(2) The problem also exists in the lack of awareness of the cost of performance evaluation. As a functional organization under the jurisdiction of the education bureau, music counseling school is responsible for cultivating high-quality talents for communities and enterprises. Under the guidance of this goal, the high-level and functional departments of the school often focus on the quality of enrollment management and teaching and research results.

(3) There is no unified standard for the amount of admissions awards and preferential policies for freshmen registration for each campus, and there is no clear division of labor for each project department of the marketing department. Enrollment performance is not clear that there are often errors in individuals and bonuses, which will lead to some excellent marketers flowing into competitors in the same industry.

5.3. Design of Evaluation Index System. The determination of the weight of evaluation indicators is the key to school performance evaluation and an important way to improve the scientific nature of performance evaluation work. The setting of index weight mainly includes: AHP, expert experience method, etc. The analytic hierarchy process fully takes into account the different importance, influence, and priority of each indicator. The weight value of each evaluation index is calculated by the analytic hierarchy process, which can effectively avoid the subjectivity of determining the weight value of the index in the evaluation process.

The main financial indicators, management indicators, serving society indicators, learning and development indicators, and of school performance evaluation are as shown in Table 3.

Break the problem down into hierarchical levels. When applying the AHP method to analyze the problems of school performance evaluation, it is necessary to understand the factors that affect the school performance evaluation and determine the relationship between the factors. On this basis, a structural model of analytic hierarchy is constructed. It is necessary to construct a pairwise comparison judgment matrix. When the AHP method measures the relative importance of indicators, the proportional scaling method in Tables 1 and 2 is usually used to express the relative importance between any two indicators.

The following is an example of the first layer of indicators.

First, it is necessary to determine the importance of the first-level indicators of the four aspects of the balanced scorecard to the overall goal.

The music tutoring school has the nature of a nonprofit organization. Its main purpose is not to pursue the maximization of educational profits, but to focus on serving the society and meeting social needs in order to achieve the goal of improving organizational performance. Therefore, the level of serving the society should be promoted, with a larger weight value than the other three levels. The salary level and the business management level are the reinforcers and fundamental guarantees for the success of serving the society, but the business management level is slightly more important than the financial level for school performance. The learning and development level is the foundation. Therefore, the importance of these four levels of indicators is: service to society, business management, learning and development, and compensation. To sum up, combined with the above proportional scaling method, the results of the pairwise comparison and judgment of the first-level index layers are obtained, as shown in Table 4.

According to the judgment matrix, the relative weight of each factor in the above AHP is calculated, and the weight vector is obtained. There are many ways to calculate relative weights. The earliest proposed, the most widely used, and the most practical and important theoretical significance is the characteristic root method.

The judgment matrix A is

$$A = \begin{bmatrix} 1 & 1/2 & 1/5 & 1/3 \\ 2 & 1 & 2/5 & 2/3 \\ 5 & 5/2 & 1 & 5/3 \\ 3 & 3/2 & 3/5 & 1 \end{bmatrix}. \tag{12}$$

After normalizing matrix A by column, we can get matrix B.

$$B = \begin{bmatrix} 0.0909 & 0.0909 & 0.0909 & 0.0909 \\ 0.1818 & 0.1818 & 0.1818 & 0.1818 \\ 0.4545 & 0.4545 & 0.4545 & 0.4545 \\ 0.2727 & 0.2727 & 0.2727 & 0.2727 \end{bmatrix}. \tag{13}$$

After summing matrix B row by row, we can get matrix U.

$$U = \begin{bmatrix} 0.3636 \\ 0.7272 \\ 1.8181 \\ 1.0909 \end{bmatrix}. \tag{14}$$

After normalizing the matrix U, the matrix W can be obtained.

$$W = \begin{bmatrix} 0.0909 \\ 0.1818 \\ 0.4545 \\ 0.2727 \end{bmatrix}. \tag{15}$$

The process of calculating the maximum eigenroot of the judgment matrix is as follows.

$$\begin{aligned} A \cdot W &= \begin{bmatrix} 1 & 1/2 & 1/5 & 1/3 \\ 2 & 1 & 2/5 & 2/3 \\ 5 & 5/2 & 1 & 5/3 \\ 3 & 3/2 & 3/5 & 1 \end{bmatrix} \begin{bmatrix} 0.0909 \\ 0.1818 \\ 0.4545 \\ 0.2727 \end{bmatrix} \\ &= \begin{bmatrix} 0.3636 \\ 0.7272 \\ 1.8181 \\ 1.0909 \end{bmatrix}. \end{aligned} \tag{16}$$

The maximum eigenroot $\lambda_{\max} = 4$ can be obtained.

Consistency checks and weight determinations are required. Consistency test is performed on the weight vector, that is, the judgment matrix is required to generally satisfy the consistency. The steps of the consistency check are as follows. First, the consistency index CI is calculated. The larger the value of CI, the farther the judgment matrix is from complete consistency. $\mathrm{CI} = (\lambda_{\max} - n)/(n-1)$. The closer the CI value is to 0, the closer the judgment matrix is to complete consistency. The higher the order n of the judgment matrix, the greater the index CI of artificially deviating from complete consistency. The smaller the order n, the smaller the artificial deviation.

Second, one needs to find the corresponding average stochastic RI. Figure 5 shows the average random consistency index obtained by calculating 1000 times the judgment matrix of order 1–9.

Finally, the consistency ratio CR is calculated. When $\mathrm{CR} < 0.1$, it is considered that the judgment matrix has satisfactory consistency and is acceptable. However, when $\mathrm{CR} \geq 0.1$, the judgment matrix should be appropriately revised until the test conditions are met.

When $\mathrm{CI} = 0$, look up Figure 5 to get $\mathrm{RI} = 0.9$. When $\mathrm{CR} = \mathrm{CI}/\mathrm{RI} = 0 < 0.1$, the judgment matrix has acceptable and satisfactory consistency. Therefore, the weights of the primary indicators can be determined as shown in Figure 6.

After the index system is tested and confirmed, the hierarchical structure model is basically completed. However, the credibility of the evaluation index weight is not naturally improved because of the reasonable index design

Table 3: Evaluation indicators.

Salary indicator (X)	Structural indicators ($X1$)	The proportion of school education expenses in school funds ($X11$)
		The proportion of enrollment management fees in school funds ($X12$)
		The proportion of scientific research expenses in school funds ($X13$)
	Incremental metrics ($X2$)	Growth rate of school education expenses per student ($X21$)
		Growth rate of enrollment management fee per student ($X22$)
		Growth rate of scientific research fees per student ($X23$)
	Level indicator ($X3$)	The per capita education cost of our school is compared with that of schools in the same industry ($X31$)
		Compared with the investment of similar foreign schools ($X32$)
		Compared with the investment of domestic similar schools ($X33$)
Use efficiency ($Y1$)	Human resource utilization ($Y11$)	Student-teacher ratio ($Y111$)
		Students as a percentage of the total faculty ($Y112$)
	Material resource utilization ($Y12$)	Utilization of special equipment for teaching and research ($Y121$)
		Average utilization of classrooms and laboratories ($Y122$)
		Book turnover ($Y123$)
	Financial allocation ratio ($Y13$)	Proportion of teaching and research funding ($Y131$)
		Proportion of administrative expenses ($Y132$)
		Proportion of enrollment management fee ($Y133$)
Management efficiency ($Y2$)		Funding rate ($Y21$)
		Earmarked rate ($Y22$)
		Calculate the execution deviation rate ($Y23$)
Social service indicators (Q)	Talent development ($Q1$)	Outstanding student ratio ($Q11$)
		Talent transfer ratio ($Q12$)
		Qualification ratio ($Q13$)
	Scientific research results ($Q2$)	Scientific research project acquisition rate ($Q21$)
		Serving the society scientific research achievements ($Q22$)
		The number of scientific papers published ($Q23$)
	Other service ($Q3$)	Provide consulting services ($Q31$)
		Assist with community training times ($Q32$)
		Number of trainees ($Q33$)
Learning and development (Z)	Talent construction ($Z1$)	Proportion of experts and professors ($Z11$)
		Excellent teaching and management staff ratio ($Z12$)
		Organizational training and education ($Z13$)
	Discipline construction ($Z2$)	Number of key disciplines ($Z21$)
		Number of excellent courses ($Z22$)
		Proportion of excellent courses ($Z23$)
	Information system construction ($Z3$)	Teaching information ($Z31$)
		Remote network construction ($Z32$)
		Information exchange and processing ($Z33$)

Table 4: Standard comparison judgment results.

Importance	X	Y	Q	Z
X	1	1/2	1/5	1/3
Y	2	1	2/5	2/3
Q	5	5/2	1	5/3
Z	3	3/2	3/5	1

and the use of the AHP method. The accuracy and consistency of the matrix are important influencing factors of the weight reliability. According to the AHP method and procedure, the weight of each level index to its upper level index can be determined in turn. Due to the limitation of space, the specific scale of each level and the calculation and testing process of establishing the judgment matrix are omitted. The comprehensive weight results of performance evaluation at each level are shown in Figure 7.

5.4. Analysis and Thinking of Calculation Results

5.4.1. First Layers. From the perspective of the four first-level indicators, the "serving society" indicator has the highest weight. It shows that the music tutoring school pays a high degree of attention to talent training, scientific research, and other services.

5.4.2. Middle Layers. Among the 11 secondary indicators, "use efficiency" and "talent development" have relatively high weights.

5.4.3. Target Layer. Among the 38 secondary indicators, "student-teacher ratio" and "proportion of government funding" have relatively high weights.

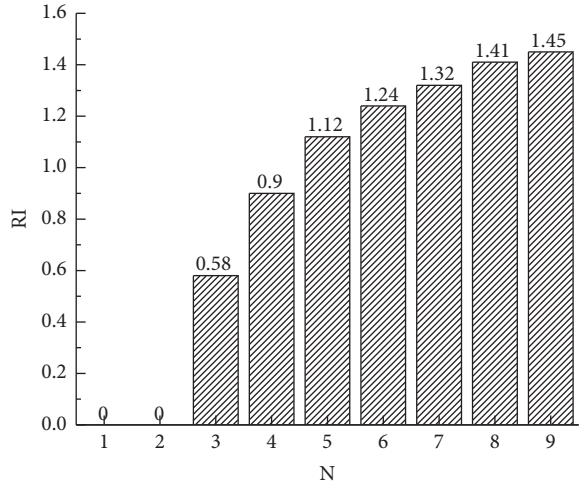

Figure 5: Average stochastic consistency indicator.

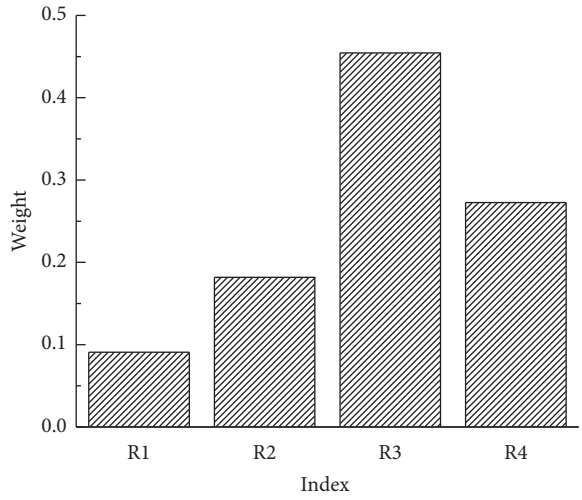

Figure 6: Weights of primary indicators.

6. The Management Method to Ensure the Performance Management System

6.1. Improve the Hardware Facilities and Formulate the Management Mode of the System. The relevant departments have not made clear regulations on the construction of hardware facilities of music tutoring schools, and the construction of hardware facilities is also different for each training institution due to its own economic conditions. As a result, the construction of hardware facilities in each training is not perfect and affects teaching. Therefore, relevant local departments should make strict requirements on the construction of hardware facilities of music tutoring schools. Music tutoring schools should also strengthen and improve the construction of hardware facilities and formulate management models suitable for their own development.

6.2. Implement Diversified Publicity and Expand Enrollment Publicity. The traditional mode of enrollment publicity is printing and distributing leaflets, word-of-mouth publicity, etc. Although it plays a certain role in recruiting new students for music tutoring schools, other problems such as its small publicity scope and slow timeliness make it difficult to recruit students. It will cause some music tutoring schools to struggle. Therefore, music tutoring schools should implement diversified publicity methods by cooperating with schools to formulate literary and artistic programs, carry out campus and other related public welfare performances, and guide students in aesthetic education. By using major network platforms for publicity and by strengthening public opinion guidance and inviting relevant media to publicize music tutoring schools, the school expands the scope of enrollment and solves problems such as enrollment difficulties.

6.3. Strengthen the Construction of Teaching Staff and Stabilize the Teaching Team. Most of the teachers are college and undergraduate fresh graduates and some part-time teachers are undergraduates. Due to the inexperience of fresh graduate teachers in specific teaching, the fluidity and

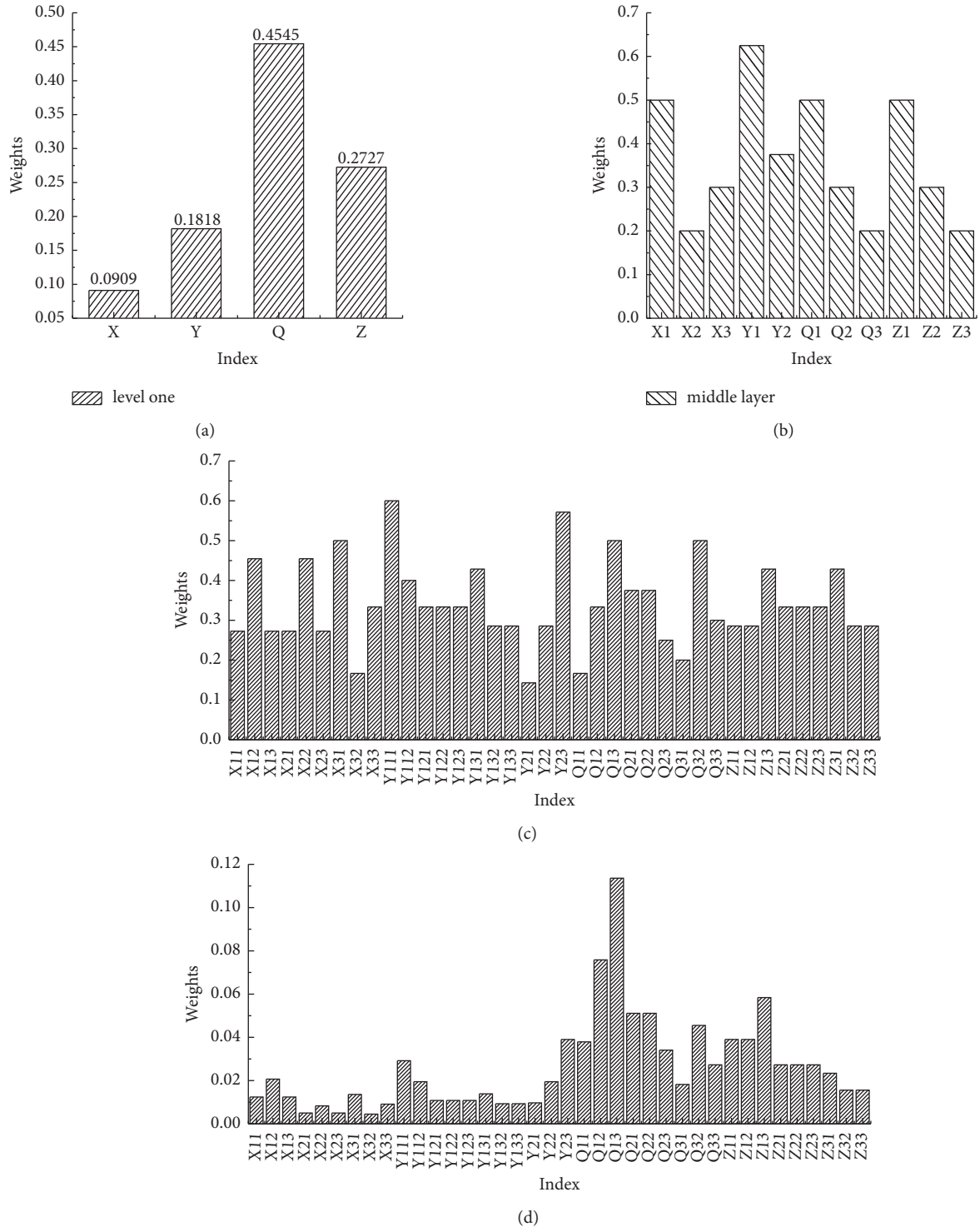

Figure 7: Weights of performance evaluation level indicators. (a) First layers. (b) Middle layers. (c) Target layer. (d) Comprehensive weight.

instability of part-time undergraduate teachers have a certain impact on the overall development of music tutoring schools. Therefore, schools should strengthen the construction of teaching staff. Regular professional training for teachers and regular teacher teaching competitions can be held to absorb the teaching methods of excellent teachers. At the same time, teachers should be assessed regularly to improve their teaching level.

6.4. Regulate the Market of Training Institutions and Strengthen Management and Supervision. Relevant local departments should strengthen management and raise the entry threshold. By formulating relevant supporting facilities standards and formulating unified price management standards, we will strictly combat unlicensed operations and arbitrary charges. It is also necessary to regulate the market of training institutions to better promote the development of children's music training.

7. Conclusion

By evaluating the results of the school's performance management system, managers can judge the matching degree of the entire performance management system with the school's situation and development. It is necessary to emphasize the implementation effect, and continuously improve and perfect the problems and deficiencies in the performance management system. Taking this as the starting point of a new performance management work cycle, the performance management work can be continuously improved and perfected in the development of the school. The competitiveness of the training school has been comprehensively improved through the scientific and systematic performance management system. And in the process of implementation, it helps managers master relevant management skills, cultivate scientific management habits, and help employees improve work efficiency and develop their potential. In turn, it can help schools to effectively implement their strategic plans and goals.

On the basis of the established index system, through the use of the method of fuzzy comprehensive evaluation and the collection and processing of relevant statistical data, a comprehensive evaluation of the performance level of music tutoring schools is carried out. Through the analysis of the results of the evaluation, we found some problems in the development of music education and found out the decisive factors that affect the performance of music tutoring schools. This article puts forward specific measures on how to improve the performance management level of music tutoring schools.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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Research Article

Bank Competition, Financing Constraints, and Enterprise Innovation Investment

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Based on the data of China's listed companies from 2007 to 2020 and the financial license of the China Banking and Insurance Regulatory Commission, this paper analyzes the influence of bank competition on enterprise innovation investment and its mechanism. It is found that bank competition can improve the enterprise innovation investment, which still holds true after endogenous treatment and robustness test. Further research demonstrates that bank competition plays a stronger role in enterprise innovation for non-state-owned enterprises and small-scale enterprises. The mechanism analysis shows that bank competition can promote enterprise innovation investment and enterprise financialization by easing financing constraints. Moreover, enterprise financialization has a crowding-out effect on enterprise innovation investment. Therefore, moderately intensifying bank competition, further improving the financial system, and deepening the financial marketization reform have profound effects on driving enterprise innovation and its high-quality development.

1. Introduction

Nowadays, the world is experiencing major changes unprecedented in a century. The internal conditions and external environment of China's economic development are undergoing profound and complex changes. Internationally, the growth of the world economy is sluggish. Meanwhile, the international economic and trade friction is intensifying, and the competition among major powers is becoming increasingly fierce. Domestically, China's economic development is confronting tremendous challenges under the COVID-19 epidemic and the pressure of a downward domestic economy. As China's economic development enters the "new-normal" stage, it is also a necessary path to transform the economic growth mode by promoting innovation and improving the efficiency of resource allocation to achieve the "quality and efficiency improvement" of innovative output. At the micro level, the R&D of enterprises is the main source of technological innovation and economic growth [1]. However, because of the high investment, high risk, and long cycle of innovation projects, financial institutions are reluctant to take risks to invest in innovative projects. Although China insists on reforming the financial market, constantly improving the financial system, and actively implementing the "innovation-driven development strategy," the effect and the transmission mechanism of these policy measures on the development of the banking sector and enterprise innovation are still issues that need to be figured out by the academic circles and the leadership.

Based on the financial license data on the official website of the China Banking and Insurance Regulatory Commission, and the data of China's A-share listed companies from 2007 to 2020, this paper examines the influence of bank competition on enterprise innovation investment. The possible marginal contributions of this paper are as follows: First, the existing literature mainly focuses on the influence of bank competition on enterprise innovation when enterprises are faced with financing constraints. This paper refines the perspective of financing constraints and profoundly explores the behavior mechanism of enterprise financialization when enterprises are faced with financing constraints under the financial resource mismatch. It strives to further understand the internal influencing factors of enterprises in the process of innovation and R&D, which

makes a supplement to the existing literature. Second, the research findings of this paper enrich the research in the field of bank competition and enterprise innovation and more thoroughly analyze the high leverage ratio and insufficient innovation level of Chinese enterprises, thus providing a new explanation, and pointing out that the investment in financial assets is an essential factor hindering enterprise innovation.

Other parts of the paper are arranged as follows: Section 2 is the Theoretical Analysis and Research Hypothesis; Section 3 is the Model Design; Section 4 is the Empirical Analysis; and Section 5 is the Research Conclusion and Policy Implication.

2. Theoretical Analysis and Research Hypothesis

2.1. Bank Competition and Enterprise Innovation Investment. The monopolistic market structure of the banking industry will make the society suffer welfare losses, because banks can pay low deposit interest rates and increase loan interest rates, so as to obtain higher economic benefits. According to the traditional model, banks will make loans at higher interest rates to make profits if there are only a few banks in the market, resulting in an increase in loan cost and a decrease in the social welfare of enterprises [2]. Due to the unique nature of enterprise innovation activities, the stronger the monopoly of the banking industry is, the more reluctant it is to invest in high-risk projects such as R&D, which reduces the speed and efficiency of enterprise innovation [3]. The market structure of the banking industry is constantly changing with the progress of China's market economy. The bank competition has begun to intensify, because the number, types, and scale of banks are constantly rising, and the influence of local governments on local banks is declining. Currently, there are two opposing views in academic circles on whether such a competitive structure can help banks to increase credit to enterprises, thus boosting their innovation investment. The "information hypothesis" suggests the excessively competitive market structure leads banks to be unable to screen borrowers' information in a short time to reduce moral hazard. The increase in asymmetric information will lead banks to take more risks when investing in enterprises, thus reducing loans to enterprises and lowering the borrowing efficiency of enterprises. However, the monopolistic banking market can effectively address the information asymmetry [4]. Through the model analysis, they found that enterprises with small financial constraints and smaller scale may be more favored by banks, since they have enough time and ability to dig into enterprise information and predict the development prospects of enterprises. This information symmetry can ensure that banks can obtain higher profits in the process of enterprise growth. The "market power hypothesis" holds that the bank competition can weaken the seller's dominant position in the credit market to some extent, reduce the loan cost of enterprises, and improve the efficiency of bank-to-enterprise loans, and middle- and small-sized enterprises will benefit from it. Dewatripont and Maskin [5] conclude that the competitive market structure of banks forms stronger budget constraints for enterprises, so it is beneficial for banks to provide credit funds for emerging enterprises with high innovation efficiency.

The existing literature cannot draw a unified conclusion, because the different characteristics of the real economy and the demand for financial services are different when discussing the relationship between the banking structure and the credit demand of enterprises [6]. In addition, Beck et al. [7] found that the high level of government regulation will raise the threshold of the banking industry without considering the market structure, which affects the bank competition. However, the advantage of China's bank competition has just begun to emerge, so it may be too early to discuss excessive competition.

In the research on domestic bank competition, some studies show that the intensification of bank competition and the gradual improvement in the financial system promote the innovation activities of enterprises [8]. Xie and Fang [9] pointed out that the development of the banking industry increases the supply of credit funds, provides financing for large-scale and long-term investment projects, alleviates the difficulties and high cost of financing among small- and medium-sized enterprises, and promotes the R&D and enterprise innovation investment. Some studies also support the viewpoint of the "information hypothesis." Their studies discovered that the information asymmetry between banks and enterprises worsens under excessive competition among banks, which is not conducive to the issuance of relational loans [10]. Based on the above analysis, the following alternative hypotheses are put forward:

(i) H1a: the intensification of the bank competition inhibits the enterprise innovation investment

(ii) H1b: the intensification of bank competition promotes the enterprise innovation investment

2.2. Bank Competition, Financing Constraints, and Enterprise Innovation. The R&D and innovation of enterprises is a long-term project, which has uncertainty and needs to introduce technology, talents, equipment, etc. It is difficult to meet its capital demand only by relying on internal funds, so external financial support is an effective support for enterprises to carry out innovation activities. China's financial system is an indirect financing system dominated by banks, and bank credit is generally a significant source of funds for enterprises. The intensification of bank competition may ease the issue of funds required for enterprise innovation due to the following reasons: On the one hand, the intensification of bank competition prompts banks to relax the standards of loans, lower thresholds of loads, improve the availability of credit funds, and ease financing constraints for enterprise innovation [11]; and on the other hand, when market competition intensifies, banks will be more active in mining customer information, thus reducing information asymmetry and the risk of default [12]:

(i) H2: the intensification of the bank competition eases the financing constraints and thus promotes the enterprise innovation investment

2.3. The Crowding-Out Effect of Financialization on Enterprise Innovation Investment. The crowding-out effect of financialization mainly comes from the comparative advantage of financial assets. Due to the inefficient allocation of credit resources, China's small- and medium-sized enterprises are deeply troubled by financing constraints, resulting in frequent loans from informal financial institutions. China's state-owned enterprises and large-scale listed companies are easier to obtain funds from banks and securities markets through government guarantees and strong antirisk ability [13]. However, a large number of funds are not used for physical investment or technological innovation but are idle within enterprises [14]. Compared with fixed assets, financial assets are characterized by strong liquidity and short term, and they can be quickly turned into funds to prevent the fund flow from breaking when enterprises are short of funds [15]. Moreover, the return rate of the financial market is higher than that of the traditional industry. Driven by the "profit-seeking" behavior of enterprises, enterprises invest funds in financial assets in order to obtain high financial returns [16], causing the real economy to "break away from reality and become virtual," and then crowd out funds for the physical development and innovation of enterprises. Thus, the following hypothesis is proposed:

(i) H3: enterprise financialization crowds out the innovative funds' mitigation effect brought by bank competition

3. Model Design

3.1. Data Source. The enterprise data of this paper take A-share listed companies from 2007 to 2020 in the CSMAR Database as samples, excluding listed companies in financial industry, ST companies, and companies with missing financial data. Referring to Cai and Dong [17], the banking industry data of this paper come from the license information of national financial institutions published on the official website of the China Banking and Insurance Regulatory Commission, from which all the branch information of state-owned commercial banks, joint-stock commercial banks, city commercial banks, foreign banks, postal savings banks, and other financial institutions can be obtained. According to the establishment and cancellation records of the institutions on the official website, the number of bank branches in various prefecture-level cities in different years is manually sorted out, and the index of bank competition is calculated. Furthermore, the data of listed companies according to the years and regions are matched. In addition, all the continuous variables in the sample are winsorized by 1% on both sides to eliminate the influence of extreme values on the estimation results.

3.2. Selection of Variables. Innovation Investment Level of Enterprises (*RDR*). Enterprise innovation investment usually reflects the resource investment of technological innovation activities, which is measured by the intensity of R&D investment, i.e., the ratio of R&D investment to operating income [18]. The logarithmic value of R&D investment will be used for the robustness test in the later part.

Bank Competition (HHI). Due to the limitation of data, it is difficult to obtain the banking industry data of different regions through public channels. The author of this paper manually sorts out the number of all branches of commercial banks on the official website of the China Banking and Insurance Regulatory Commission, and refers to Cai and Dong [17] to construct the Herfindahl–Hirschman index (HHI) using the number of branches of commercial banks in prefecture-level cities. The specific calculation formula is the Herfindahl–Hirschman Index (HHI) = $\sum_{i=1}^{N} S_i^2$, in which S is the share of commercial banks in the city. Among them, the HHI represents the reverse index of competition degree, and its value ranges from 0 to 1. The closer it is to 1, the higher the concentration of the banking industry is and the lower the competition degree is. The closer it is to 0, the lower the concentration of the banking industry is and the higher the competition degree is.

Enterprise Financialization (Finratio). Using the measurement methods of Song and Lu [19] and Du et al. [20] for reference, the proportion of financial assets held by enterprises to total assets at the end of the period is used to measure the enterprise financialization. Financial assets include trading financial assets, derivative financial assets, investment real estate, net held-to-maturity investment, net available-for-sale financial assets, net financial assets sold for repurchase, net loans and advances issued, and the equity of financial institutions held by enterprises in long-term equity investment.

Financing Constraints (KZ). Referring to the practice of Kaplan and Zingales [21], this paper takes five factors of operating net cash flow, cash holdings, cash distribution level, debt degree, and growth rate as proxy variables to represent financing constraints. Meanwhile, it constructs a comprehensive index (KZ index) through regression analysis to measure the financing constraints of enterprises. The larger the KZ index, the greater the financing constraints faced by enterprises.

Control Variables. Referring to the existing literature, this paper introduces a series of enterprise-level control variables to alleviate the errors caused by missing variables as much as possible, including enterprise size (Size), asset-liability ratio (Lev), net profit margin (Roa), fixed asset ratio (Cinten), enterprise growth (Growth), net operating cash flow (Cfo), and the shareholding ratio of the largest shareholder (Top1); see Table 1 for definitions of variables).

3.3. Model Setting. Referring to the research design of Jiang et al., this paper establishes the following baseline model:

$$\begin{aligned} \mathrm{RDR}_{i,j,t} = {} & \alpha_1 + \alpha_2 \mathrm{HHI}_{j,t} + \alpha_3 \sum Z_{i,t} \\ & + \sum \mathrm{year} + \sum \mathrm{ind} + \sum \mathrm{pro} + \varepsilon_{i,t}. \end{aligned} \tag{1}$$

Among them, $\mathrm{RDR}_{i,j,t}$ is the outcome variable, which represents the innovation investment level of enterprise j located in the city t in the year t. $\mathrm{HHI}_{j,t}$ represents the bank

Table 1: Research variable design.

Variable symbol	Variable	Variable definition
RDR	Innovation investment level	Ratio of R&D investment to operating income
HHI	Concentration of banking industry	The Herfindahl–Hirschman index based on the number of branches of commercial banks in prefecture-level cities
Finratio	Enterprise financialization	Financial assets/total assets at the end of the period
KZ	Financing constraints	Whether there are financial assets at the end of the period
Size	Enterprise size	The natural log of total assets at the end of the period
Lev	Asset-liability ratio	Ratio of total liability to total assets at the end of the period
Roa	Net profit margin	The ratio of net profit to total assets at the end of the period
Cinten	Proportion of fixed assets	Ratio of net fixed assets to total assets at the end of the period
Growth	Enterprise growth	(Operating income at the end of the period-operating income at the beginning of the period)/operating income at the beginning of the period
Cfo	Net operating cash flow	The ratio of net cash flow from operating activities to total assets at the end of the period
Top1	The shareholding ratio of the largest shareholder	The ratio of shares held by the largest shareholder at the end of the period

competition level of the city j in the year t, which is a control variable at the enterprise level. $\sum$ year represents the year fixed effect. $\sum$ ind represents the industry fixed effect. $\sum$ pro represents the region fixed effect. $\varepsilon_{i,t}$ represents the random disturbance term.

3.4. Descriptive Statistical Analysis. Table 2 displays the basic statistical characteristics of variables. The average innovation investment level (RDR) of enterprises is 4.586, suggesting that the innovation investment level of nonfinancial enterprises is low on average. The standard deviation is 4.694, indicating that the innovation level of different enterprises is quite different. From 2007 to 2020, the bank competition level (HHI) has a maximum value of 0.301, a minimum value of 0.002, and an average value of 0.038, showing that there is a big gap between the bank competition levels of different samples, and the degree of competition varies. In addition, the maximum value of enterprise financialization (Finratio) is 0.451, and the minimum value is 0, indicating that the financialization degree of different enterprises is quite different. The average value of financing constraints (KZ) is 0.244, and the standard deviation is 2.232, revealing that different enterprises face different financing constraints.

Table 2: Descriptive statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
RDR	21706	4.586	4.694	0	28.53
HHI	21706	0.038	0.023	0.002	0.301
Finratio	21706	0.062	0.088	0	0.451
KZ	20552	0.244	2.232	−6.444	4.837
Size	21706	22.128	1.269	19.926	26.155
Lev	21706	0.413	0.201	0.053	0.898
Roa	21706	0.038	0.065	−0.286	0.199
Cinten	21706	0.212	0.148	0.004	0.665
Growth	21706	0.169	0.376	−0.499	2.3
Cfo	21706	−0.106	0.259	−0.981	−0.603
Top1	21706	33.937	14.528	8.448	72.955

4. Empirical Analysis

4.1. Analysis of Baseline Regression Results. Firstly, based on Model (1), this paper analyzes the influence of bank competition on enterprise innovation investment, and adopts the fixed-effect model to eliminate the possible deviation, including the year fixed effect, the industry fixed effect, and region fixed effect. Table 3 shows the process of gradually involving control variables and fixed effects. The significance of the core explanatory variable, bank competition (HHI), is steady. It can be seen from columns (1) and (2) that the coefficient of HHI is −0.0355, and it passes the significance test at the level of 1%, respectively. Among them, the coefficient of bank competition (HHI) in column (6) to enterprise innovation investment is −5.6912, which is significant at the level of 1%. It indicates that the reduction of bank competition level reduces the enterprise innovation investment, thus verifying H1b. The results of control variables are close to those of previous studies. For example, the larger the enterprise size (Size), the lower the innovation investment level of enterprises. The higher the asset-liability ratio (Lev), the lower the innovation level of enterprises. Among them, the net operating cash flow (Cfo) of enterprises has a positive and significant role in promoting the enterprise innovation investment. The cash holding of enterprises is an essential source of funds for R&D. Therefore, the higher the cash holding level of enterprises is, the more the R&D investment of enterprises may be.

4.2. Robustness Test

4.2.1. Endogenous Problem. In the previous regression, the core explanatory variable, the degree of bank competition, may have an endogenous problem. Bank competition promotes the R&D investment of enterprises, and the regions with more innovative activities of enterprises also enable more banks to enter and expand, thus intensifying the bank competition. The two-way causal relationship between them may generate the endogenous problem of the model. In addition, there may be some missing variables in the model that have not been observed yet. To alleviate the above endogenous problem, this paper further constructs the

Table 3: Baseline regression results.

	(1) RDR	(2) RDR	(3) RDR	(4) RDR	(5) RDR	(6) RDR
HHI	−24.7005***	−18.1801***	−15.3237***	−11.3480***	−18.6807***	−5.6912***
	(1.3661)	(1.2661)	(1.3084)	(1.1267)	(1.7533)	(1.6718)
Size		−0.2844***	−0.3362***	−0.0358	−0.3543***	−0.1436***
		(0.0275)	(0.0284)	(0.0256)	(0.0276)	(0.0267)
Lev		−4.6103***	−4.3536***	−4.7062***	−4.4416***	−4.2495***
		(0.2803)	(0.2864)	(0.2470)	(0.2777)	(0.2513)
Roa		−9.4087***	−9.2892***	−7.4229***	−8.8197***	−6.9128***
		(0.5905)	(0.5908)	(0.5207)	(0.5869)	(0.5208)
Cinten		−5.5133***	−5.3394***	−1.8960***	−4.8209***	−1.4661***
		(0.2058)	(0.2066)	(0.2180)	(0.2073)	(0.2195)
Growth		−0.0955	−0.0224	−0.3999***	−0.1437*	−0.3328***
		(0.0805)	(0.0812)	(0.0701)	(0.0795)	(0.0703)
Cfo		1.5592***	1.6876***	0.5854***	1.4168***	0.6921***
		(0.2044)	(0.2068)	(0.1794)	(0.2023)	(0.1806)
Top1		−0.0358***	−0.0337***	−0.0196***	−0.0365***	−0.0178***
		(0.0021)	(0.0021)	(0.0018)	(0.0020)	(0.0019)
_cons		18.0821***	19.0412***	9.8635***	19.2713***	11.7887***
		(0.5752)	(0.5919)	(0.5497)	(0.5828)	(0.5709)
Year FE	NO	NO	YES	NO	NO	YES
Ind FE	NO	NO	NO	YES	NO	YES
Prov FE	NO	NO	NO	NO	YES	YES
N	21706	21706	21706	21706	21706	21706
R^2	0.015	0.180	0.184	0.387	0.204	0.400

Note: the symbols *, **, and *** indicate that the estimation coefficient is significant at the level of 10%, 5% and 1%, respectively. The standard derivation is in brackets; The same is as in the following tables.

instrumental variable. Referring to the studies of Zhang et al. [12] and Jiang et al. [22], the average value of the bank competition level of three cities in the same province with the closest GDP to the prefecture-level city where the enterprise is located is used as the instrumental variable of the bank competition level of the prefecture-level city. The reasons are as follows: On the one hand, cities with similar economic development levels in the same province often have similar appeals to banks, so their bank competition degree has a high correlation; and on the other hand, due to the geographical segmentation of banking business, deposits and loans in other cities have no obvious influence on the innovation activities of enterprises in this prefecture-level city. Columns (1) and (2) of Table 4 are the regression results of the instrumental variable. It can be observed that after considering the endogenous problem of bank competition, the intensification of bank competition significantly promotes the enterprise innovation investment, and the regression results are consistent with those of the previous ones, thus proving the robustness of the conclusion. In addition, the Anderson LM value and the CDWF value in the validity test of the instrumental variable are 385.20 and 389.98, respectively, which indicates that the instrumental variable is reasonable and effective.

4.2.2. Robustness Test. To ensure the robustness of the regression analysis results, this paper makes the following robustness tests: ① Change the measurement method of the explained variable and use the measurement method, i.e., measuring the innovation level of enterprises by the logarithmic value of the enterprise innovation investment, and making a new regression model. The regression results are shown in column (3) of Table 4, and the estimated coefficient of bank competition is −0.0061, which is significant at the level of 1%. ② Change the measurement method of explanatory variables. Considering that enterprises are also partially influenced by banks in other areas of the province, the bank competition level in prefecture-level cities is replaced by that of the provincial cities, and Model (1) is regressed again. In the meantime, the regression results are presented in column (4) of Table 4. The estimated coefficient of bank competition is −3.5037, which is significant at the level of 5%. ③ Exclude the impact of the financial crisis. The global financial crisis that broke out in the second half of 2007 has a continuous and profound impact on the risk-taking ability of Chinese banks, and the investment and financing behavior of enterprises. To eliminate the interference of the financial crisis, the sample data from 2007 to 2011 are excluded and Model (1) is regressed again. The regression results suggest that the estimated coefficient of bank competition is −6.6018 as shown in column (5) of Table 4, which is significant at the level of 1%. All the above results demonstrate that the core conclusion of this paper is robust.

4.3. Heterogeneity Analysis of Enterprises. The influence of bank competition on enterprise innovation investment is related to the characteristics of enterprises themselves. To further analyze the bank competition on the innovation

Table 4: Robustness test results.

	(1) HHI	(2) RDR	(3) Lnrd	(4) RDR	(5) RDR
IV	0.1904***				
	(0.0096)				
HHI		−2.9691**	−0.0061***		−6.6018***
		(1.3837)	(0.0014)		(1.8922)
HHI_prov				−3.5037**	
				(1.4346)	
Controls	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Ind FE	YES	YES	YES	YES	YES
Prov FE	YES	YES	YES	NO	YES
N	21380		21706	21706	19260
R^2	0.075		0.592	0.391	0.4106

investment among enterprises with different ownership types and scales, this paper divides samples according to the nature and scale of enterprises. As can be seen from the results in columns (1) and (2) of Table 5, regardless of the enterprise size, the intensification of bank competition can increase the enterprise innovation investment, but the coefficient for small-scale enterprises is −9.6907, which is significant at the level of 1%. For large-scale enterprises, it is −1.8278, which has not passed the significance test. The possible reason is that large-scale enterprises are less affected by the fund supply because of their large assets and relatively sufficient funds, while small- and medium-sized enterprises in China often confront financing problems. Therefore, the intensification of bank competition is more conducive to alleviating the credit constraints of small- and medium-sized enterprises and promoting their innovation investment.

Columns (3) and (4) of Table 5 show the subsample regression results of different ownership types. The corresponding coefficients of the HHI for state-owned enterprises and non-state-owned enterprises are −6.3871 and −8.1141, respectively. However, the influence of bank competition on innovation investment of non-state-owned enterprises is more significant and greater. The possible reason is that state-owned enterprises naturally have financing advantages due to political reasons and other conditions, so they are less affected by the fund supply. However, non-state-owned enterprises have less collateral, higher business risks, and greater information asymmetry, which leads to various restrictions on financing channels and market access [23]. Therefore, the intensification of bank competition has a more obvious role in promoting innovation investment of non-state-owned enterprises than that of state-owned enterprises.

4.4. Mechanism Channel Analysis. The above results show that the intensification of bank competition improves the enterprise innovation investment, so what is the mechanism behind the influence? The aforementioned theoretical analysis suggests that alleviating financing constraints may be the mechanism channel for the intensification of bank competition improving the enterprise innovation investment. Moreover, the alleviation of enterprise financing constraints may also enhance the level of enterprise financialization, thus forming a capital competition relationship for enterprise innovation investment. To explore this relationship, this study refers to Song et al. [24] and constructs the following model:

$$\begin{aligned} KZ_{i,t} &= \beta_1 + \beta_2 \mathrm{HHI}_{j,t} + \beta_3 \sum Z_{i,t} + \sum \mathrm{year} + \sum \mathrm{ind} + \sum \mathrm{pro} + \varepsilon_{i,t}, \\ \mathrm{Finratio}_{i,t} &= \gamma_1 + \gamma_2 \mathrm{HHI}_{j,t} + \gamma_3 \sum Z_{i,t} + \sum \mathrm{year} + \sum \mathrm{ind} + \sum \mathrm{pro} + \varepsilon_{i,t}, \\ \mathrm{Finratio}_{i,t} &= \delta_1 + \delta_2 \mathrm{HHI}_{j,t} + \delta_3 KZ_{i,t} + \delta_4 \sum Z_{i,t} + \sum \mathrm{year} + \sum \mathrm{ind} + \sum \mathrm{pro} + \varepsilon_{i,t}, \\ \mathrm{RDR}_{i,t} &= \vartheta_1 + \vartheta_2 \mathrm{HHI}_{j,t} + \vartheta_3 KZ_{i,t} + \vartheta_4 \sum Z_{i,t} + \sum \mathrm{year} + \sum \mathrm{ind} + \sum \mathrm{pro} + \varepsilon_{i,t}. \end{aligned} \tag{2}$$

In the test mechanism, the relationship between bank competition and enterprise financing constraints, and the relationship between bank competition and enterprise financialization shall be firstly explored. Column (1) in Table 6 reports the results of Model (2). It can be seen that the coefficient of bank competition is 0.6876, and it is significant at the level of 1%, indicating that the intensification of bank competition level alleviates the financing constraints of enterprises. Furthermore, according to Model (3), the effect of bank competition on enterprise financialization is observed. The results are shown in column (2) of Table 6. The coefficient of bank competition (HHI) is −0.0260, which is significant at the level of 1%, indicating that the intensification of bank competition improves enterprise financialization. Furthermore, this paper analyzes

Table 5: Heterogeneity analysis results of enterprises.

	(1) Small scale RDR	(2) Large scale RDR	(3) State-owned enterprises RDR	(4) Non-state-owned enterprises RDR
HHI	−9.6907***	−1.8278	−6.3871**	−8.1141***
	(2.6761)	(2.0333)	(2.5418)	(2.1766)
_cons	11.8055***	9.7791***	8.0687***	11.9133***
	(1.7224)	(0.8623)	(0.7835)	(0.8350)
Controls	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Ind FE	YES	YES	YES	YES
Prov FE	YES	YES	YES	YES
N	10853	10852	7387	14319
R^2	0.380	0.394	0.373	0.395

Table 6: Mechanism test results.

	(1) KZ	(2) Finratio	(3) Finratio	(4) RDR
HHI	0.6876***	−0.0260***	0.0439	−5.4027***
	(0.1608)	(0.0052)	(0.0374)	(1.7105)
KZ			−0.0021***	−0.1185***
			(0.0004)	(0.0181)
_cons	3.2542***	−0.1786***	−0.1814***	11.3001***
	(0.2288)	(0.0125)	(0.0130)	(0.5952)
Controls	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Ind FE	YES	YES	YES	YES
Prov FE	YES	YES	YES	YES
N	20552	21706	20552	20552
R^2	0.611	0.191	0.196	0.409

the role of financing constraints in the influence of bank competition on enterprise innovation investment and enterprise financialization, namely, Model (4) and Model (5). Column (3) of Table 6 indicates that the coefficient of financing constraints (KZ) to enterprise financialization (Finratio) is −0.0021, and it is significant at the level of 1%, indicating that the alleviation of enterprise financing constraints can boost the investment in financial assets. Combining the results of columns (1), (2), and (3), bank competition can promote enterprise financialization by alleviating enterprise financing constraints. Column (4) of Table 6 suggests the coefficient of financing constraints (KZ) to enterprise innovation investment (RDR) is −0.1185, and it is significant at the level of 1%, indicating that the alleviation of enterprise financing constraints can enhance enterprise innovation ability. Based on the results in column (6) of Table 3, and columns (1) and (4) of Table 6, bank competition improves enterprise innovation ability by alleviating enterprise financing constraints.

To sum up, there are two main flows of financing constraint alleviation brought about by bank competition: investment in financial assets and R&D. However, enterprise financialization is the "profit-seeking" behavior of enterprises, and the surplus funds after investing in financial assets can also flow to the enterprise innovation investment [25]. Therefore, although the intensification of bank competition promotes enterprise financialization, the impact does not necessarily undermine enterprise innovation. To explore the impact of this competition on enterprise innovation, this paper constructs the following model:

$$R\ DR_{i,t} = \rho_1 + \rho_2 Finratio_{i,t} + \rho_3 \sum Z_{i,t} + \sum \text{year} + \sum \text{ind} + \sum \text{pro} + \varepsilon_{i,t}. \quad (3)$$

Table 7 presents the results of Model (6). Column (1) shows the results without considering the control variables, and column (2) displays the results of the complete model. It can be seen that the significance of the model coefficient is robust. The results in column (2) suggest that the coefficient of enterprise financialization to enterprise innovation investment (RDR) is −0.8156, which is significant at the level of 1%, indicating that the higher the degree of enterprise investment in financial assets, the lower the level of enterprise innovation investment, thus verifying H3. The possible reason is that financial investment products have the characteristics of strong liquidity, high returns, and quick cash conversion. The involvement of enterprises further increases their investment in the virtual economy, further "breaks away from reality and becomes virtual," and crowds out the funds for enterprise innovation [26].

Table 7: Competition test.

	(1) RDR	(2) RDR
Finratio	−1.6969***	−0.8156***
	(0.3102)	(0.3123)
_cons	4.4813***	12.1189***
	(0.0321)	(0.5703)
Controls	NO	YES
Year FE	YES	YES
Ind FE	YES	YES
Prov FE	YES	YES
N	21706	21706
R^2	0.351	0.402

5. Research Conclusion and Policy Implication

5.1. Research Conclusion. According to the financial license information published on the official website of the China Banking and Insurance Regulatory Commission, this paper calculates the number of branches of commercial banks in various prefecture-level cities, and then constructs the level of bank competition in prefecture-level cities by using the Herfindahl–Hirschman index. Combined with the data of A-share nonfinancial enterprises in stock markets of Shanghai and Shenzhen from 2007 to 2020, this paper analyzes the role of bank competition in enterprise innovation investment. The empirical results demonstrate that the intensification of bank competition promotes an increase in enterprise innovation investment. Among small- and medium-sized enterprises and non-state-owned enterprises, the positive effect of bank competition on enterprise innovation investment is more significant. The mechanism analysis shows that bank competition promotes enterprise innovation by easing the financing constraints of enterprises, and also drives enterprise financialization. Enterprise financialization has a competitive effect on enterprise innovation, and the improvement of enterprise financialization reduces enterprise innovation investment.

5.2. Policy Implication. The policy implication of this paper can be summarized in the following aspects: First, it can guide the banks to compete reasonably, ease the financing constraints of enterprises, and steadily stimulate innovation. Currently, the banking structure in many areas of China is still dominated by the five major state-owned banks. It is necessary to reasonably strengthen the competitiveness of joint-stock commercial banks and other commercial banks, continue to expand the corresponding reform measures of the banking system, optimize the business distribution of the banking industry, and provide support for enterprise innovation. Second, it can guide the banks to curb the trend of "breaking away from reality and becoming virtual" among enterprises and improve the allocation efficiency of financial resources. The results of this paper reveal that the intensification of bank competition makes enterprises invest some funds in financial assets after they obtain the credit support due to the "profit-seeking" behavior, thus weakening the impact of innovation on high-quality development. Therefore, it is of great significance to continuously cope with the credit allocation problem of financial intermediaries, speed up the development of the securities market, and realize the original intention of financial services for the real economy.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Evaluation of Manufacturing Innovation Performance in Wuhan City Circle Based on DEA-BCC Model and DEA-Malmquist Index Method

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The innovation performance of the manufacturing industry in the Wuhan city circle is evaluated based on the relevant data from 2018 to 2020 in 9 cities of Hubei Province within the Wuhan city circle using the DEA-BCC model, the DEA-Malmquist index method, and the location quotient method. This article measures the agglomeration level of innovation elements in the Wuhan city circle, constructs a performance evaluation index system including two input indicators: R&D expenditure and R&D personnel, and two output indicators: new product sales revenue and number of patent applications; evaluates the innovation performance of 27 manufacturing industries in the Wuhan city circle from five aspects: technical efficiency change (effch), technical progress change (techch), pure technical efficiency change (pech), scale efficiency change (sech), and total factor productivity change (tfpch), and compares and analyzes the innovation performance of Wuhan, Xianning, Xiantao, and Tianmen using the DEA-BCC model and DEAP 2.1. The results show that the agglomeration level of talent elements in the Wuhan city circle is between 0.24 and 1.75, and the agglomeration level of capital elements is between 0.23 and 1.52. The differences between regions are obvious, the degree of coordination is low, and the radiation effect of Wuhan is insufficient. The average value of technological progress is 1.274, which is vital to enhance the innovation performance of the Wuhan manufacturing industry. The technical efficiency dropped by 65%, but the total factor productivity fell only 13%, indicating that the technical efficiency value is not the main factor affecting the innovation performance of Wuhan. The innovation performance of high-tech and high-value-added industries such as computer, communication, and other electronic equipment manufacturing industries is relatively high, while the innovation performance of low-tech and low-value-added industries such as agricultural and sideline food processing industry and textile industry is relatively low. The innovation performance of Xianning, Xiantao, and Tianmen is higher, while the relative technological inefficiency caused by the low-scale efficiency value adversely affects the innovation performance of Wuhan. The results indicate that increasing the scale of manufacturing innovation investment can effectively enhance the innovation performance of the Wuhan city circle manufacturing industry.

1. Introduction

In April 2021, the Guiding Opinion on Promoting the High-quality Development of the Central Region in the New Era issued by the Central Committee of the Communist Party of China and the State Council provided a strong impetus to promote the rise of the Central region. The national 14th Five-Year Plan and the outline of the long-term goals for 2035 clearly pointed out that it is necessary to speed up the construction of Wuhan city circle and create a significant national growth pole. On May 19, the first joint meeting of Wuhan city circle reached an agreement on the urban integration development of 9 cities for the first time, which included program co-editing, transportation conetwork, technology codevelopment, industry cochain, and people's livelihood coguarantee. Specifically, program co-editing is the guide, transportation conetwork is the foundation, technology codevelopment is the core, industry cochain is

the support, and coguarantee of people's livelihood is the goal. On the 4th of September, the listing of Wuhan City Circle Intercity Development Office provided an organizational guarantee for the integration development of the Wuhan city circle.

As the principle part of the real economy, the development of the manufacturing industry directly represents the economic and technological strength of a country or a region. Meanwhile, the level of innovation and development of the manufacturing industry is the key to improving a country's core competitiveness and global impact. At present, although the development pattern of the Wuhan city circle is formed as R&D in Wuhan, manufacturing in the city circle, and the industrial system of main chain in Wuhan, supporting the city circle has begun to take shape. There are still some problems in practice, such as insufficient innovation guidance and low quality of development. The effective solution of the above problems requires a realistic understanding of the innovation performance of the manufacturing industry in the Wuhan city circle. Therefore, on the basis of clarifying the current situation of the manufacturing industry in the Wuhan city circle, this article measures and analyzes the innovation performance of the Wuhan city circle manufacturing industry employing DEA-BCC model, DEA-Malmquist index method, and location quotient analysis method. The conclusions can provide reference for the formulation of relevant policies.

2. Literature Review

The theory of innovation was first put forward by the American-Austrian economist Joseph Schumpeter in his masterpiece *The Theory of Economic Development* in 1911. Schumpeter believed that innovation was the use of new ways to achieve a new combination of production factors and production conditions and to make it an important component of the production system. Schumpeter pointed out that the innovation mainly included the following contents: manufacturing a new product, adopting a new production method, opening up a new market, developing a new supplier, and constructing a new organizational model [1]. Subsequently, scholars from various countries have carried out extensive and in-depth research on innovation. Stoneman believed that technological innovation was a complete process of introducing scientific inventions into the manufacturing system, developing them, and finally producing economic and trade behaviors for the first time [2]. Kanter believed that innovation was not limited to generating new ideas, technologies, or management, and combining and improving old ideas and concepts could also be called innovation [3].

Innovation performance is the concentrated expression of the results of innovation activities, the production efficiency shown by the input of a certain amount of innovation resource elements, and the result of cooperation and interaction between the various components of the innovation system [4]. Since the 1950s, academia has carried out extensive research on innovation performance. Regarding the connotation of innovation performance, scholars around the world have different views, but the more common view is to interpret innovation performance as the efficiency and effect of innovation, that is, the efficiency of transforming innovation input into results and the economic benefits brought by the achievement of results [5]. Hagedoorn et al. pointed out that the ratio of new products, new equipment, or new processes put into production was technical innovation performance in a narrow sense, while the relationship among R&D investment, patent application, and new product creation constituted was a broad concept of technical innovation performance [6]. Guan and Chen divided innovation performance into absolute result performance and relative efficiency performance [7]. Anthony and Rene believed that environmental innovation performance included three aspects: indirect performance, direct performance, and knowledge output. Among them, indirect performance referred to the utilization rate of scientific research equipment and the improvement of R&D efficiency, while direct performance was mainly reflected by achievement transformation benefits and the number of incubating enterprises. And the knowledge output included the number of patents and academic papers [8].

In the application research of the DEA method, Georghiou and Roessner reviewed several methods of technical efficiency assessment and focused on the comprehensive application of data envelopment and statistical methods [9]. Nasierowski and Arcelus used the DEA method to empirically analyze the innovation performance of 45 countries and regions [10]. Chen and Ali used the DEA-Malmquist index method to evaluate and analyze the technical efficiency of the computer industry [11]. Thompson employed the DEA model and the Malmquist index to evaluate the economic growth, competition, and technological efficiency of China's major cities [12]. Qian and Chen applied the DEA model to study the technological innovation efficiency of China's high-tech industry from 2009 to 2011 [13]. Chai et al. employed the DEA method to evaluate the technological innovation performance of six resource-based enterprises in China [14]. Yi and Chen utilized the DEA method and the Malmquist index to evaluate the innovation performance of some countries [4]. Long et al. adopted the BCC model in the DEA method to measure the comprehensive efficiency, scale efficiency, and pure technical efficiency of regional innovation in electronics and communication equipment manufacturing industry in China [15]. Pan et al. used the DEA-Malmquist index method to study the sustainable development and efficiency of digital agriculture in China [16].

In summary, scholars have done plenty of research on innovation performance and innovation performance evaluation methods, which also provides a solid theoretical basis for this article. At present, the data envelopment analysis method is widely used in the innovation performance evaluation of countries, regions, industries, and enterprises. This method has the advantages of objectiveness and low error rate, especially in the performance evaluation of multi-input and multi-output. With the rapid development of regional integration, the application of DEA method to the evaluation of innovation performance in urban circles

is not only necessary in the times, but also feasible in the method. And the research conclusions also have certain application value.

3. Data and Methods

3.1. Location Quotient. Location quotient (LQ) is often used to measure the agglomeration level of innovative elements [17, 18]. Location quotient is also known as specialization rate, where "quotient" is the result of division [19]. This method was first developed by the American economist Haggett and used to measure the relative concentration of a region and the level of specialization of an industry in a particular research area [20]. The formula for the location quotient is

$$LQ_{ij} = \frac{q_{ij}/q_j}{q_i/q}, \tag{1}$$

where LQ_{ij} indicates the location quotient of industry i in region j of the country, q_{ij} is the relevant indicators of industry i in region j, q_j is the relevant indicator of all industries in region j, q_i is the relevant index of industry i nationwide, and q is the relevant index of all industries in the country. In the specific calculation of this article, two indicators are included: the location quotient of talent elements and the location quotient of capital elements. The size of the location quotient value represents the level of agglomeration of innovation elements. If the location quotient is greater than 1, it means that the degree of agglomeration of innovation elements is higher than the national average level of similar elements. If the location quotient is equal to 1, it means that the degree of agglomeration of innovation elements is the same as the national average of similar factors. If the location quotient is less than 1, it means that the concentration of innovation factors is lower than the national average of similar factors.

3.2. Data Envelopment Analysis. Data envelopment analysis (DEA) was first proposed in 1978 by renowned operations research scientists Chames, Cooper, and Rhode as an important nonparametric method for evaluating productivity [21]. The principle of this method is mainly to determine the relatively effective production frontier with the help of a mathematical programming method by keeping the input or output of decision-making unit (DMU) unchanged, project each decision unit to the production frontier of DEA, and evaluate their relative effectiveness by comparing the degree to which decision-making units deviate from the DEA frontier. This method is suitable for evaluating the efficiency of decision-making units with multiple inputs and multiple outputs, and can also be used to analyze the reasons and degrees of inefficiency of decision-making units through redundant inputs or insufficient outputs, to provide information for decision-making subjects [22]. Originally used by Chames to measure the efficiency of public sector and nonprofit organizations, the DEA model has been widely used in efficiency evaluation in banks, universities, hospitals, insurance companies, manufacturing, service industries, and many other fields. In the DEA method, the two most basic models are the CCR model and the BCC model, of which the input-oriented CCR model is the earliest and most widely used.

Assuming there are n decision units, each decision unit has m inputs to obtain s kinds of output. x_{ij} is the i^{th} input corresponding to the j^{th} decision-making unit and is no less than 0. y_{rj} is the r^{th} output corresponding to the j^{th} decision-making unit and is no less than 0. v_i and u_{r} are the weights of the input of the i^{th} input and the r^{th} output, respectively. Now let

$$\begin{aligned} X_j &= \left(X_{1j}, X_{2j}, \ldots, X_{mj}\right)^T, \quad j = 1, 2, \ldots, n, \\ Y_j &= \left(Y_{1j}, Y_{2j}, \ldots, Y_{mj}\right)^T, \quad j = 1, 2, \ldots, n, \\ v &= \left(v_1, v_2, \ldots, v_m\right)^T, \\ u &= \left(u_1, u_2, \ldots, u_m\right)^T. \end{aligned} \tag{2}$$

The efficiency evaluation index of the decision unit j is

$$h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}. \tag{3}$$

Take the weights v and u as variables, use the efficiency index $h_j \le 1$, $j = 1, 2, \ldots, n$ as a constraint, take the efficiency index h_0 of the j_0th decision unit as the decision goal, evaluate the relative efficiency of the j_0th decision unit, and build the model as follows:

$$\overline{P}_{C^2R} \begin{cases} \max \dfrac{u^T y_{j0}}{v^T x_{j0}} = V_{\overline{P}} \\ s.t. \dfrac{u^T y_j}{v^T x_j} \le 1, \; j = 1, 2, \ldots, n, \\ v \ge 0, u \ge 0. \end{cases} \tag{4}$$

Let $t = 1/v^T x_{j0}$, $\overline{\omega} = tv$, and $\mu = tu$.

The above fractional programming ($\overline{\text{P}}_{\text{C}^2\text{R}}$) is further converted to a corresponding equivalent linear programming (P_{C^2R}) as follows:

$$\left(P_{C^2R}\right) \begin{cases} \max u^T y_{j0} = V_p, \\ s.t. \quad \overline{\omega}^T x_j - \mu^T y_j \ge 0, \quad j = 1, 2, \ldots, n, \\ \overline{\omega}^T x_{j0} = 1, \\ \overline{\omega} \ge 0, \mu \ge 0. \end{cases} \tag{5}$$

If the optimal solution of (P_{C^2R}) satisfies $V_P = \mu^T y_{j0} = 1$, the decision unit is DEA valid.

3.3. DEA-Malmquist Index Method. To carefully examine the dynamic changes in R&D innovation efficiency under the condition of changes in production technology, it is necessary to further introduce the Malmquist index of R&D innovation, that is, to use the distance function to find the

Malmquist productivity index that can be used for vertical comparative analysis [22, 23].

Suppose there are n decision units, and each decision unit obtains s kinds of output with m inputs in the t period. $x_j^t = (x_{1j}^t, x_{2j}^t, \ldots\ldots, x_{mj}^t)^T$ represents the input indicator value of the j^{th} decision unit in period t, $y_j^t = (y_{1j}^t, y_{2j}^t, \ldots\ldots, y_{nj}^t)^T$ represents the output indicator value of the j^{th} decision unit in period t, and they are all positive numbers and $t = 1, 2, ..., T$.

In the case of constant returns to scale, let the distance function of (x^t, y^t) in t^{th} period $D_C^t(x^t, y^t)$ and in the $(t+1)^{\text{th}}$ period $D_C^{t+1}(x^t, y^t)$. Then, let the distance function of (x^{t+1}, y^{t+1}) in the t^{th} period $D_C^t(x^{t+1}, y^{t+1})$ and in the $(t+1)^{\text{th}}$ period $D_C^{t+1}(x^{t+1}, y^{t+1})$.

In the case of variable returns to scale, let the distance function of (x^t, y^t) in the t^{th} period $D_V^t(x^t y^t)$ and in the $(t+1)^{\text{th}}$ period $D_V^{t+1}(x^t, y^t)$. Then, let the distance function of (x^{t+1}, y^{t+1}) in the t^{th} period $D_V^t(x^{t+1}, y^{t+1})$ and in the $(t+1)^{\text{th}}$ period $D_V^{t+1}(x^{t+1}, y^{t+1})$.

Under the technical conditions of period t, the change in the technical efficiency from period t to period $t+1$ is

$$M^t = \frac{D_C^t\left(x^{t+1}, y^{t+1}\right)}{D_C^t\left(x^t, y^t\right)}. \tag{6}$$

Under the technical conditions of period $t+1$, the change in the technical efficiency from period t to period $t+1$ is

$$M^{t+1} = \frac{D_C^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_C^{t+1}\left(x^t, y^t\right)}. \tag{7}$$

The change in productivity from period t to period $t+1$ can be obtained by calculating the geometric average of the above two Malmquist productivity indices:

$$\begin{aligned} M &= \left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \sqrt{M^t \times M^{t+1}} \\ &= \sqrt{\frac{D_C^t\left(x^{t+1}, y^{t+1}\right)}{D_C^t\left(x^t, y^t\right)} \times \frac{D_C^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_C^{t+1}\left(x^t, y^t\right)}}. \end{aligned} \tag{8}$$

The Malmquist index reflects the relative efficiency of a decision unit in two periods. If the Malmquist index is greater than 1, it means that the efficiency level from period t to period $t+1$ has increased. While if the Malmquist index is less than 1, it indicates a decline from period t to period $t+1$. And if the index equals to 1, it means no change.

Under the assumption of constant returns to scale, changes in productivity are influenced by technological progress and technological efficiency changes, and the Malmquist index can be expressed as a multiplication of the Technological Efficiency Change Index (TEC) and the Technological Progress Index (TE), that is, $M(x^t, y^t, x^{t+1}, y^{t+1}) = \text{TEC} \times \text{TE}$.

Assuming variable returns to scale, the technical efficiency change (ΔTEC) can be further decomposed into the product of a pure change in technical efficiency (ΔPTE) and a change in returns to scale (ΔSE). The Malmquist index can be further broken down into a combination of the Technological Progress Index, the Pure Technical Efficiency Index, and the Scale Efficiency Index, that is, $M(x^t, y^t, x^{t+1}, y^{t+1}) = \text{TEC} \times \text{TE} = (\text{PTE} \times \text{SE}) \times \text{TE}$.

In summary, the specific meaning of the Malmquist index is shown in Table 1.

3.4. Data Sources. We take the manufacturing innovation data of the Wuhan city circle from 2018 to 2020 and the innovation data of 27 manufacturing subsectors in Wuhan as samples. In terms of input factors, the academia generally divides innovation investment into two levels: personnel investment and capital investment. In the evaluation of innovation performance, *R&D Personnel* is usually selected to measure the personnel input of innovative activities, and *Internal Expenditure of R&D Funds* is used to measure the capital investment of innovative activities. In terms of output elements, the outputs of innovative activities are usually divided into direct output and indirect output. The technical output of innovative activities is usually expressed as *The Number of Patent Applications* and *The Number of Patents Granted*. Among them, *The Number of Patent Applications* can reflect the invention and innovation information more comprehensively and plays an important role in the development of new products and technological transformations [24, 25]. In addition, *New Product Sales Revenue* can intuitively reflect the innovative achievements of the industry, which is also included in the output index in this article.

4. Results and Discussion

4.1. Measurement and Analysis of Innovation Elements Agglomeration Level

4.1.1. The Level of Talent Element Agglomeration. According to (1), the results of the concentration level of talent elements are calculated in Table 2.

It can be observed from Table 2 that the level of talent agglomeration in Wuhan and Huangshi was higher, and the agglomeration level of Huangshi in 2019 reached 1.75, which was much higher than the other cities. This is because both cities are located in the core area of the urban circle. Besides, Wuhan, as the central city of the urban circle, brings together many scientific and technological enterprises, and as the innovation engine of the Wuhan city circle, there are more than 7,000 overseas talent teams innovating and starting businesses here. In 2020, the levels of talent agglomeration in Wuhan, Huangshi, and Xiantao were in a higher range, while those in Tianmen and Ezhou were in a lower range. The overall level of talent agglomeration in Wuhan, Huangshi, Ezhou, and Qianjiang registered different degrees of decline from 2018 to 2020.

4.1.2. The Level of Capital Elements Agglomeration. Similarly, according to (1), the aggregation level of capital elements is calculated as shown in Table 3.

It can be seen from Table 3 that the agglomeration level of innovative capital elements in Wuhan, Huangshi, and Xiaogan was above 1 in 2018 and that in Huangshi even

Table 1: Specific significance of each index in the Malmquist index.

Index	Meaning	Situation	Specific significance
M	Malmquist productivity index	$M > 1$	Increased productivity
		$M = 1$	Constant productivity
		$M < 1$	Decreased productivity
TC	Transition degree of technical production boundary from t to $t+1$	TC > 1	Technological progress
		TC = 1	Technology unchanged
		TC < 1	Technological decrease
EC	Change degree of relative technical efficiency from t to $t+1$	EC > 1	Increase in technical efficiency
		EC = 1	Technical efficiency unchanged
		EC < 1	Decrease in technical efficiency

Table 2: Concentration level of talent elements in the Wuhan city circle, 2018–2020.

City	Year		
	2018	2019	2020
Wuhan	1.54	1.32	1.36
Huangshi	1.33	1.75	1.41
Ezhou	0.40	0.42	0.40
Xiaogan	0.47	0.54	0.55
Xianning	0.62	0.78	0.86
Xiantao	0.61	1.10	1.08
Tianmen	0.24	0.34	0.27
Qianjiang	0.50	0.41	0.35

Note. Missing data in Huanggang.

Table 3: Concentration level of capital elements in the Wuhan city circle, 2018–2020.

City	Year		
	2018	2019	2020
Wuhan	1.03	0.97	0.95
Huangshi	1.52	1.44	1.48
Ezhou	0.93	0.99	1.10
Xiaogan	1.28	1.31	1.34
Xianning	0.57	0.91	0.90
Xiantao	0.35	0.66	0.73
Tianmen	0.23	0.35	0.38
Qianjiang	0.79	0.78	0.81

Note. Missing data in Huanggang.

reached 1.52, whereas the agglomeration level of innovative capital elements in Xiantao and Tianmen was below 0.5, which was at a low level. In 2020, the agglomeration level of Huangshi, Ezhou, and Xiaogan was higher than 1, of which the highest concentration level of Huangshi was 1.48. Compared to the situation in 2018, only Tianmen had a concentration level lower than 0.5 in 2020. In general, the level of capital agglomeration in Tianmen and Xiantao was low; Wuhan, Ezhou, Xianning, and Qianjiang were at a medium level; and Huangshi and Xiaogan were at a higher level.

4.2. Evaluation and Analysis of Manufacturing Innovation Performance in Wuhan

4.2.1. Overall Analysis. In this section, DEAP2.1 is used, and the DEA-Malmquist index model is selected for calculation based on the input and output data of Wuhan's manufacturing industry from 2018 to 2020. Through this model, innovation performance can be evaluated from five aspects, that is, effch, techch, pech, sech, and tfpch, respectively. The results are shown in Table 4.

As can be seen from Table 4, total factor productivity (TFP) declined slightly in 2020 compared to 2018 and 2019, but overall, it was still between 1.0 and 1.1. The main reason for the decline in manufacturing innovation performance in 2020 may be from the impact of the COVID-19 pandemic. Total factor productivity is decomposed into technological progress and technological efficiency, and then reasons for its changes are explored. Through decomposition, it can be observed that although the value of technological progress has increased, while the total factor productivity has still

Table 4: Calculation results of innovation performance of manufacturing industries in Wuhan, 2018–2020.

Year	Index				
	Effch	Techch	Pech	Sech	Tfpch
2019	1.443	0.812	1.116	1.293	1.171
2020	0.511	2.000	0.684	0.747	1.022
Mean	**0.859**	**1.274**	**0.873**	**0.983**	**1.094**

declined, the arithmetic average was 1.274, which showed that the effect of technological progress on changes in total factor productivity was positive in the case of a significant reduction in other basic factors. Secondly, the technical efficiency fell from 1.443 to 0.511, a decline of about 65%, but the total factor productivity did not decline in the same proportion. The arithmetic average of technical efficiency in 2019 and 2020 was 0.859, and the average arithmetic value of total factor productivity was 1.094, indicating that the technical efficiency value was not the main reason affecting the innovation performance in Wuhan. The technical efficiency value is divided into pure technical efficiency value and scale efficiency value. The pure technical efficiency value varied from 0.6 to 1.1, and the impact on innovation performance was not significant, while the scale efficiency value varied from 0.7 to 1.3, resulting in the corresponding diseconomies of scale.

4.2.2. Segmented Industry Analysis. According to the latest version of *Industrial Classification of National Economy* (GB/T 4754–2017) issued by the General Administration of Quality Supervision, Inspection, and Quarantine of the

People's Republic of China and the National Standardization Administration of China, the manufacturing sector includes 31 major categories. However, due to incomplete data, leather, fur, feather and their products, and shoemaking industry; wood processing and wood, bamboo, rattan, palm, and grass products industry; chemical fiber manufacturing industry; metal products; machinery; and equipment repair industry will not be considered. Therefore, 27 manufacturing subsectors in Wuhan were selected as decision-making units, as follows: DMU1—agricultural and sideline food processing industry; DMU2—food manufacturing; DMU3—wine, beverage and refined tea manufacturing; DMU4—tobacco products industry, DMU5—textile industry; DMU6—textile and garment, and garment industry; DMU7—furniture manufacturing; DMU8—papermaking and paper products industry; DMU9—reproduction of printing and recording media; DMU10—cultural, educational, industrial, aesthetic, sports, and recreational goods manufacturing; DMU11—petroleum, coal, and other fuel processing industry; DMU12—chemical raw materials and chemical products manufacturing; DMU13—pharmaceutical manufacturing; DMU14—rubber and plastic products industry; DMU15—nonmetallic mineral products industry; DMU16—ferrous metal smelting and calendering processing industry; DMU17—nonferrous metal smelting and calendering processing industry; DMU18—metal products industry; DMU19—general equipment manufacturing; DMU20—special equipment manufacturing; DMU21—automotive manufacturing; DMU22—railway, marine, aerospace, and transport equipment industry; DMU23—electrical machinery and equipment manufacturing; DMU24—computer, communication, and other electronic equipment manufacturing; DMU25—instrumentation manufacturing; DMU26—other manufacturing; and DMU27—comprehensive utilization of waste resources. Similarly, the DEA-Malmquist index model was used to measure the innovation performance of 27 manufacturing subsectors in Wuhan. The results are shown in Table 5.

Taking 2018 as the benchmark, 27 segments in Wuhan's manufacturing industry from 2019 to 2020 were evaluated, and 19 of the 27 subindustries in Wuhan had a total factor productivity greater than 1, and 8 industries had a total factor productivity value of less than 1, which were DMU3, DMU5, DMU6, DMU9, DMU10, DMU14, DMU17, and DMU23 (see Table 5). In the above industries, except for the DMU23, the rest were low-tech, low-value-added industries. Other high-tech, high-value-added industries had total factor productivity of more than 1, such as DMU22 and DMU24, with a total factor productivity values of 1.152 and 1.162, respectively, indicating the high innovation performance of these industries.

We decompose total factor productivity into technical efficiency and technological progress in order to explore the reasons for the changes in total factor productivity. As can be seen from Table 5, there were 17 industries with technical efficiency values less than 1, which were DMU3, DMU5, DMU8, DMU9, DMU10, DMU12, DMU14, DMU16, DMU17, DMU18, DMU19, DMU20, DMU22, DMU23, DMU24, DMU25, and DMU27. Comparing the total factor productivity value, it can be found that the technical efficiency value of many high-tech and high-value-added industries whose total factor productivity value was greater than 1 was less than 1, which indicates that the technical efficiency value is not a factor hindering the growth of the total factor productivity. There were only 5 industries with a technological progress value of less than 1, namely, DMU1, DMU5, DMU6, DMU17, and DMU26. Through comparison, it is found that the low innovation performance of DMU6 and DMU17 was mainly caused by the decrease in the value of technological progress.

Table 5: Calculation results of innovation performance of 27 manufacturing segments in Wuhan, 2018–2020.

DMU	Index				
	Effch	Techch	Pech	Sech	Tfpch
DMU1	1.955	0.823	1.952	1.002	1.609
DMU2	1.236	1.029	1.272	0.972	1.272
DMU3	0.296	1.250	0.353	0.840	0.370
DMU4	1.121	1.709	1.000	1.121	1.916
DMU5	0.679	0.987	0.673	1.009	0.670
DMU6	1.041	0.826	0.856	1.216	0.860
DMU7	1.096	1.805	1.000	1.096	1.979
DMU8	0.463	2.468	0.498	0.930	1.143
DMU9	0.473	1.461	0.519	0.911	0.691
DMU10	0.661	1.155	0.917	0.721	0.764
DMU11	1.464	1.749	2.023	0.724	2.562
DMU12	0.830	1.263	0.915	0.907	1.048
DMU13	1.162	1.081	0.700	1.660	1.256
DMU14	0.600	1.374	0.545	1.100	0.825
DMU15	1.146	1.407	1.147	0.999	1.612
DMU16	0.925	1.205	0.481	1.924	1.115
DMU17	0.843	0.792	1.000	0.843	0.668
DMU18	0.818	1.274	0.789	1.038	1.043
DMU19	0.813	1.458	0.959	0.848	1.185
DMU20	0.754	1.411	0.818	0.922	1.064
DMU21	1.103	1.114	1.310	0.842	1.228
DMU22	0.811	1.420	0.642	1.263	1.152
DMU23	0.837	1.159	1.000	0.837	0.970
DMU24	0.715	1.625	1.000	0.715	1.162
DMU25	0.792	1.368	1.149	0.689	1.083
DMU26	1.305	0.847	1.037	1.258	1.104
DMU27	0.863	1.571	0.895	0.964	1.355
Mean	**0.859**	**1.274**	**0.873**	**0.983**	**1.094**

4.3. Evaluation and Analysis of Manufacturing Innovation Performance in Wuhan City Circle. Due to the incomplete data of the five cities—Huangshi, Ezhou, Huanggang, Xiaogan, and Qianjiang, four cities—Wuhan, Xianning, Xiantao, and Tianmen are selected for further analysis. The DEA-BCC model is selected for calculation based on the input and output data from 2018 to 2020 using Deap2.1, and the innovation performance is comprehensively evaluated by Crste, Vrste, Scale, etc. The results are shown in Table 6.

Table 6 shows that the technical efficiency value of Wuhan's innovation performance in 2018–2020 was less than 1, that is, *technology invalid*. The technological efficiency value of the innovation performance of Xianning,

Table 6: Calculation results of manufacturing innovation performance of four cities in the Wuhan city circle, 2018–2020.

DMU	Crste			Vrste			Scale		
	2018	2019	2020	2018	2019	2020	2018	2019	2020
Wuhan	0.624	0.899	0.826	1.000	1.000	1.000	0.624	0.899	0.826
Xianning	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Xiantao	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Tianmen	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mean	**0.906**	**0.975**	**0.956**	**1.000**	**1.000**	**1.000**	**0.906**	**0.975**	**0.956**

Xiantao, and Tianmen was equal to 1, which is *technology effective*, indicating that the technological innovation performance of these three cities was better. In an economic sense, compared with other cities, the main reason why the technical efficiency value of Wuhan was less than 1 is the relative technical ineffectiveness caused by the low-scale efficiency value. Further research found that the biggest problem with manufacturing innovation was that it did not amplify the spillover effect of Wuhan's manufacturing industry. In addition, the traditional industries in the manufacturing industry in the Wuhan city circle accounted for more than 70%, and the COVID-19 has adversely affected the investment in innovation[26]. Those two reasons directly affect the innovation performance of the manufacturing industry in the Wuhan city circle.

5. Conclusions and Implications

5.1. Conclusions. First, starting from the dimensions of technological efficiency, technological progress, scale efficiency, and total factor productivity, this paper conducts a longitudinal analysis of the innovation performance of Wuhan's manufacturing industry and finds that technological progress has a positive impact on total factor productivity. Meanwhile, through comparison, it is found that there was an imbalance in the innovation ability of manufacturing enterprises in Wuhan. Traditional labor-intensive industries had a lower value of technological progress and a lower demand for innovation. The technological progress of knowledge-intensive high-tech and high-value-added industries was on the rise, and the level of innovation was generally high.

Second, after measuring the manufacturing innovation performance of the four cities in the Wuhan city circle from 2018 to 2020, it is found that there was no redundancy in its input and output, but because the technical efficiency value of Wuhan was less than 1, its technology was invalid, and the comprehensive efficiency and scale efficiency were the main reasons to cause the failure of its technological innovation. It can be seen from the calculation of scale efficiency that the result of scale efficiency was IRS (incremental); that is, with the continuous improvement of the economic development level in Wuhan, the enhancement of technological innovation capabilities can effectively improve the situation of insufficient technological innovation ability in Wuhan. However, since we only have the overall data of four cities and lack the relevant data of the Wuhan city circle as a whole, and the effectiveness of DEA is only relatively effective, it can be found that the innovation input in other cities except Wuhan was not high, and the innovation output was insufficient, yet the result was still valid. Therefore, the results can only be used for reference and cannot actually reflect the innovation performance of the manufacturing industry in the Wuhan city circle. We found that most of the manufacturing innovation capabilities in the Wuhan city circle were concentrated in Wuhan, and because of the epidemic, the low demand for technology and investment in the past two years have directly affected the innovation efficiency of the manufacturing industry.

Third, the construction of scientific and technological innovation databases is lagging behind. This article is based on the Hubei Statistical Yearbook and combines the statistical yearbooks and statistical bulletins of various places in the Wuhan city circle. However, we found that the variables included in the statistical yearbooks of different cities are not the same. Only the statistical yearbooks of Wuhan and Xiantao have complete data related to innovation in various manufacturing industries. While the yearbooks of some cities only have innovation input but no innovation output data, and even the yearbooks of most other cities only have industry-wide statistics. It shows that some cities did not pay enough attention to manufacturing innovation research, which leads to a lag in statistical work.

5.2. Policy Implications. First, the transformation of scientific and technological achievements needs to be strengthened and the marketization of scientific and technological achievements should be promoted. First of all, manufacturing enterprises can learn management experience from enterprises that are DEA effective, and can optimize their investment in R&D funds, equipment, and personnel and increase technological transformation. Secondly, manufacturing enterprises also need to pay attention to the market demand for innovative products when developing and innovating, attach importance to market-oriented innovative research and development activities, and avoid the situation where scientific and technological achievements cannot obtain corresponding shares in the market, which in turn leads to lower innovation output. Finally, the Wuhan city circle can make full use of the strong scientific and technological talents and technical achievement reserve resources of existing universities and scientific research institutions in Wuhan, combining it with its own production and sales capabilities to quickly enhance its independent innovation capabilities.

Second, the investment in technology research and development of manufacturing enterprises should be increased and allocated reasonably to improve the efficiency of the use of innovation resources. Although the impact of technological progress on innovation performance is positive from the perspective of Wuhan's entire industry, there is still a certain gap compared with central cities in other urban circles. Promoting technological progress requires increased scientific and technological funding support. Hence, local governments could establish special funds to expand funding for technological innovation. Besides, through policies such as reducing taxes and reducing loan interest rates, governments can encourage the manufacturing enterprises in the Wuhan city circle to carry out independent innovation, and encourage financial institutions to support the innovative activities of manufacturing enterprises.

Third, the evaluation mechanism for scientific and technological talents shall be optimized, and the rational flow of talent shall be encouraged. At the enterprise level, it is necessary to pay attention to the investment of innovative talents, optimize the management mechanism of innovative talents, and improve the incentive and constraint mechanism. At the government level, it is urgent to establish a system to encourage the reasonable flow of innovative talents in the Wuhan city circle and attract innovative talents to go deep into manufacturing enterprises through joint cultivation and mutual utilization.

Fourth, the manufacturing industry in the Wuhan city circle requires coordinated development. As the central city of the Wuhan city circle, Wuhan is rich in technology, talents, and various infrastructure resources, and it is necessary to strengthen inter-regional manufacturing cooperation, enhance inter-regional synergy, and promote the rational circulation and sharing of inter-regional innovative resources. From the industrial level, the Wuhan city circle should rely on the industrial chain model to drive other cities with Wuhan as the core, establish multiple industrial chains, and reduce the redundancy of input resources. In addition, the Wuhan city circle should also take advantage of the large number of talents in Wuhan's universities, strengthen the cooperation between universities and scientific research institutes, build an industry-university-research cooperation system, accelerate the upgrading of various industries in the manufacturing industry, and build a sustainable manufacturing innovation chain.

Fifth, the database construction needs to be strengthened. First of all, the various channels involved in the reporting of innovation input and innovation output data of various departments need to be thoroughly investigated, the timeliness of information update and utilization efficiency need to be analyzed, and the information barriers between different departments need to be broken down. At the national level, the flow of innovation elements and the dynamic detection network of manufacturing innovation capabilities need to be established, the incentive and restraint mechanism for information notification needs to be constructed, and the third-party evaluation needs to be carried out. Finally, big data analysis on the flow of innovation factors and manufacturing development needs to be strengthened.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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Research Article

The Influence of Digital Transformation of Foreign Trade Enterprises on Their Business Performance

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In the context of digital economy, the international trade mode has undergone profound changes, so digital transformation has become the key to the sustainable development of foreign trade enterprises. In this paper, by collecting the data of 27 foreign trade enterprises listed in Shanghai and Shenzhen A shares from 2010 to 2020 and adopting the method of full text identification of enterprise comprehensive financial reports to quantify the intensity of enterprise digital transformation, the influence of digital transformation of foreign trade enterprises on the main business performance and the effect of two mediating variables of internal control and innovation ability of enterprises were studied. The result shows that the digital transformation of foreign trade enterprises has a significant role in promoting their main business performance. From the mechanism of action, digital transformation promotes the overall improvement of the main business performance of enterprises by improving the internal management of enterprises and enhancing the mediating role of enterprise innovation ability. Finally, from the perspectives of government and enterprises, some suggestions were put forward for foreign trade enterprises to choose the development path of digital transformation.

1. Introduction

According to the *White Paper on the Development of Digital Economy in China*, China's digital economy reached 39.2 trillion yuan in 2020, accounting for 38.6% of GDP, and has become an important support for high-quality development of the national economy. In the era of rapid development of digital economy, digital transformation is gradually reflected in the specific production behavior of enterprises, which makes the integration of digital technology with enterprises as a development direction actively explored by many enterprises. In 2021, China's total (goods) import and export volume was 39100.9 billion RMB, which was 21.4% increased over the previous year, and the import and export surplus was 4368.7 billion RMB. At the Central Economic Work Conference, it was pointed out that China should open up to the outside world at a high level in 2022 and adopt various measures to stabilize foreign trade. Hence, it is of great significance for the future development of China's foreign trade to promote the sustainable development of China's foreign trade enterprises through digital transformation. In this paper, based on the existing literature research, the data of 27 foreign trade enterprises listed in Shanghai and Shenzhen A shares from 2010 to 2020 were collected. Based on the benchmark regression of the impact of the digital transformation of foreign trade enterprises on the main business performance, the robustness of the research results is ensured through the introduction of control variables and robustness testing, and the mediating effect of enterprise internal control and enterprise innovation ability is explored.

2. Literature Review

2.1. Informatization and Business Performance. The research on the influence of digital transformation on business performance can be traced back to the research on the influence of informatization on business organizational

performance. Mahmood and Mann [1] and Byrd and Marshall [2] studied the influence of informatization on organizational performance from macro and micro perspectives, respectively, and concluded that IT investment can improve enterprise performance [1], and IT budget has a positive correlation with employee performance [2]. Sircar et al. used a new multidimensional model to measure IT investment and performance and found that IT investment and enterprise investment have a strong positive correlation with sales, assets, and equity, and the expenditure on information system staff and staff training is positively correlated with the company's performance, and its positive promoting effect is greater than that of computer capital [3]. On this basis, Dehning and Richardson increased the measurement of market performance, introduced situational factors, and studied the mediating effect of information technology on the organizational performance of enterprises by influencing the business process, and concluded that IT investment also has a positive role in promoting market performance [4]. Tanriverd studied the influence of related factors on organizational performance in diversified companies from the perspective of resources and put forward the level of diversification and its governance model as the regulatory variables that affect the relationship between them. Although the final research results did not reflect the obvious promotion or inhibition relationship, they provided a new idea for the research of informatization [5].

2.2. Digitalization and Enterprise Performance. Byun et al. believed that the use of digital technology can improve the structural efficiency among business organizations [6]. Caputo et al. surveyed European high-tech enterprises from the perspective of management and found that the use of digital technology improved the elements of human resource management, thus improving the performance of enterprises [7]. However, Hajli et al. concluded by using a panel regression analysis that the improvement in digitalization level will only have a positive effect on some enterprises, while other companies are not affected [8]. Li and Jia put forward the innovation resource arrangement model and examined the role of IT in three different innovation processes, and concluded that digital technology has no obvious influence or role on the overall performance of enterprises [9]. Zhou et al. found that the digital transformation at the regional level has an inverted "U" shaped influence on the innovation performance of enterprises, and that the innovation performance will be significantly improved with the digitalization at the regional level [10].

In view of the fact that no consistent conclusion has been drawn in the above research, some scholars have carried out more detailed empirical research in the manufacturing industry. Li et al. studied the influence of digitalization on manufacturing industry performance and reached a similar conclusion, that is, the digital transformation of manufacturing has a positive impact on its industry performance [11, 12]. Zheng and Gu examined whether the digitalized transformation of manufacturing enterprises has an impact on the service level and performance of enterprises and concluded that the digitalized transformation of enterprises is significantly and positively related to their interests in the manufacturing industry, and the service level plays the role of an intermediate variable [13]. Wang took 173 manufacturing enterprises in the Yangtze River Delta and Pearl River Delta as the research objects, and conducted an empirical study by introducing individual forgetting and entrepreneurial orientation as mediating variables. It was concluded that digital transformation has a positive effect on the dynamic capability of enterprises, and with the development of individual forgetting and entrepreneurial orientation, digital transformation will improve the dynamic capability and innovation performance of enterprises more significantly [14]. Yi et al. used Python tools to identify the text of the annual reports disclosed by listed companies, counted and characterized the words related to digital transformation as quantitative and specific indicators of the intensity of digital transformation, and studied the mediating effect from different angles. The former concluded that digital transformation of enterprises can effectively promote the performance improvement of their main businesses, and is more effective for state-owned enterprises and enterprises in the growth stage; the latter concluded that digital transformation has a significant role in promoting corporate performance, and it promotes corporate performance by improving the degree of integration of corporate supply chains [15, 16].

2.3. Digitalization and International Trade. The research on the relationship between digitalization and international trade can be traced back to the research on the influence of the Internet on international trade. Freund analyzed by time series and cross-section regression and concluded that the development of the Internet has a certain degree of impact on trade, and the reduction of fixed costs related to the Internet may promote the growth of exports [17]. Meijers proved with a simultaneous equation model that the use of the Internet promoted the growth of trade and thus promoted the positive development of the economy [18]. Abeliansky found that the number of mobile phones and Internet users has a greater impact on the trade surplus of developed countries, while the speed and stability of broadband are more important factors for developing countries [19]. Although the above scholars' research has provided a powerful explanation for the promotion of digitalization in international trade, the variables they selected cannot fully represent digitalization, and there is still a lack of research on digitalization and import and export in China. Yi and Wang used the data published by the World Bank in 2012 to study the impact of digital transformation of enterprises on their exports from the micro level, with innovation, competition, and environment as mediating variables, and concluded that digital transformation is helpful for enterprises to expand their exports [20].

3. Research Mechanism and Hypothesis Proposition

3.1. The Influence of Digital Transformation on Main Business Performance. The use of the Internet and digital technology can reduce costs and differentiate products, thus promoting the performance of enterprises [21]. Digital transformation can also help integrate digital transformation with industry [22] by promoting cooperation between the internal learning atmosphere and external network and promote enterprise performance by improving production and operation efficiency. Investment in digital transformation has a significant impact on enterprise performance but lags behind, and different degrees of investment in digital transformation have different effects on enterprise performance [23]. Thus, the relevant hypothesis is made in this paper:

> H1: Keeping other variables unchanged, the higher the degree of digital transformation of foreign trade enterprises, the more conducive it is to the improvement of their main business performance.

3.2. Mediating Effect of Internal Control. Digital transformation can promote enterprises strengthen their own internal management, promote the interconnection of various departments within enterprises, and thus help enterprises reduce the transparency of production and sales to transportation. Based on this, it can strengthen the upstream supply's understanding of downstream demand, adjust production strategies in time, and respond to changes in market conditions, further improving the ability of enterprises to identify opportunities and avoid risks [24]. The internal control ability of an enterprise is positively correlated with its performance, and the stronger the internal control ability, the more obvious the help it brings to the improvement of enterprise performance [25]. The level of digitalization of enterprises has significantly improved the operational performance of enterprises, which can be realized by improving the level of information symmetry within enterprises and promoting the business model of enterprises [26]. Therefore, the mediating effect characterized by "digital transformation⟶internal control⟶main business performance" is theoretically tenable. Thus, the relevant hypothesis is made in this paper:

> H2: The digital transformation of foreign trade enterprises affects the main business performance by enhancing the mediating effect of internal control.

3.3. Mediating Effect of Enterprise Innovation Ability. Digital transformation is an innovative project in itself to improve the innovation ability of enterprises, which can take a two-pronged approach from the supply side and the demand side and add impetus to the technological innovation of enterprises. With the development of digital transformation, enterprises can make better use of consumer data and their own production data to assist their own decision-making and optimize the production and sales process, so as to improve production efficiency and effectively enhance the competitiveness of enterprises [27]. The effect of digitalization level on enterprise innovation performance will be affected by industries, and a threshold change effect exists in the information technology industry, wholesale and retail industry, and social service industry [28]. The digital transformation of enterprises can more effectively promote enterprises to create a more innovative corporate culture and an ecological environment in their production and operation. The enhancement of the enterprise's innovation capability will promote its operational efficiency and the distribution of production factors to a greater extent, thus improving its performance [29]. Based on this, the mediating effect characterized by "digital transformation⟶innovation ability⟶main business performance" is theoretically tenable. Thus, the relevant hypothesis is made in this paper:

> H3: The digital transformation of foreign trade enterprises improves the innovation ability of enterprises and indirectly affects the improvement of the main business performance of enterprises.

4. Research Design

4.1. Data Sources. In this paper, the listed foreign trade enterprises in the Shanghai Stock Exchange and Shenzhen Stock Exchange were selected as research samples to analyze the impact of the digital transformation of foreign trade enterprises on their main business performance. Taking into account the listing years of some enterprises, the sample time of this paper was determined to be 2010-2020, and the data were from the Royal Flush iFinD database. On this basis, the collected data were screened and processed. Firstly, companies with import and export business in their main business were screened out from the listed companies. Secondly, listed companies with import and export business income accounting for less than 30% of the total operating income during the sample period were excluded. Finally, the samples of listed companies with special circumstances in the ST and ST* financial data during the sample period were excluded. At last, a sample of 27 foreign trade listed companies was formed.

4.2. Specification of Variables. The explained variable of this study is the main business performance (MRS). Referring to the research of Du et al., the return on assets (excluding financial revenue) was used to express the main business results of listed companies, which helps to explain the import and export business income of foreign trade listed companies indirectly [30]. Specific calculation method of MRS: MRS = (annual operating profit of the enterprise − annual investment income − annual fair value change income + annual investment income in associates and joint ventures)/total assets of the enterprise.

The core explanatory variable of this study is digital transformation (DT), that is, the digital transformation of listed foreign trade enterprises studied in this paper. Digital transformation is an abstract and highly concise indicator whose quantification and measurement have always been

difficult to define. At present, there is still a lack of universally recognized methods to describe digital transformation. Management often publicly discloses its investment and practice in the field of "digital transformation" in the annual report of listed companies, which can largely reflect the company's future development and positioning from the side [31, 32]. Therefore, learning from the research methods of Wu et al., the annual reports of foreign-trade listed companies in Shanghai and Shenzhen were obtained through Python software, all the text contents were extracted through the "jieba" text analysis package, and the frequency of relevant keywords in the company's digital transformation was identified and counted by using the text analysis method to measure the degree of digital transformation of relevant companies [31, 33].

In this paper, the digital transformation keyword matching lexicon is constructed as follows: From the highly relevant and important policy learning documents and research reports, a series of keywords based on "Digital Transformation" was finally sorted out using the *Special Action Plan for Digital Empowerment of Small and Medium-sized Enterprises*, *Digital Transformation Index Report* (2021), *Digital Transformation Trend Analysis* (2021), *Big Data Industry Development Standards* (2016–2020) and the *Government Work Report* in recent years as the basis of the lexicon. In the category identification of digital transformation, referring to the classification method of Yi et al., considering that digital transformation will be applied to manufacturing, decision-making, and system management in the initial stage of enterprise digital transformation, technologies are divided into four typical categories: artificial intelligence, blockchain, cloud computing, and big data, and on the basis of these four types of underlying technologies, their related "implemented" applications were introduced [15]. Based on this, 288,614 digital transformation characteristic records were obtained.

In this paper, control variables were added to improve the goodness of fit of the output results of the model. The control variables in this paper include enterprise assets (Asset), duality (dual), equity concentration (S-D, equity concentration of the largest shareholder of the company), listing years (Age), stock turnover rate (TR), business income (Income), and audit opinions in financial reports (Audit, 0 for standard unqualified opinion, and 1 for qualified opinion). Descriptive statistics of each variable are shown in Table 1.

4.3. Modeling. To study the influence of digital transformation of foreign trade enterprises on the main business performance, the following empirical research model is proposed in this paper.

$$\mathrm{MRS}_{it} = \alpha + \beta_1 \mathrm{DT}_{it-1} + \sum \beta_i \mathrm{CVs} + \sum \beta_j \mathrm{Year} + \varepsilon, \quad (1)$$

where CVs represent all the above control variables and ε represents the stochastic error term.

At the same time, in order to improve the reliability of the regression results, the data were processed as follows: First of all, considering that the digital transformation is a continuous process, and there is a certain time lag from the implementation to the main business performance of the enterprise, the core explanatory variables in this paper lag by one period, which is also helpful to offset a part of the reverse causal endogenous interference. Secondly, the robust standard error-adjusted t-statistic of cluster clustering was used in all regression equations in this paper. Thirdly, the virtual variable of time (Year) was controlled in this paper to ensure that it can absorb the fixed effect.

Table 1: Descriptive statistics.

Variables	*N*	Mean	Std. dev.	Min	Max
MRS	297	0.0198	0.0493	−0.3232	0.2068
DT	297	3.8649	0.9243	0	5.5245
Asset	297	22.0998	38.3458	0.7643	387.1568
Dual	297	0.0707	0.2568	0	1
S-D	297	0.4203	0.1403	0.1111	0.7243
Age	297	16	5.0858	3	27
TR	297	5.3117	4.5108	0.3771	29.9583
Income	297	366.6965	663.2639	0.5793	4329.4951
Audit	297	0.0202	0.1409	0	1

5. Empirical Results and Test

5.1. Collinearity Test. In order to prevent the obvious multicollinearity of the data itself, which reduces the accuracy of parameter estimation, the multicollinearity test was performed before the benchmark regression (see Table 2).

According to the results in the table, the coefficient of collinearity between the explained variables and the core explanatory variables is 0.0976, and that between the controlled variables is less than 0.85. Therefore, there is no obvious multicollinearity among the variables studied in this paper.

5.2. Unit Root Test. In this paper, the unit root test of variables was performed to avoid spurious regression (see Table 3). The test results show that the variables selected in this paper all pass the unit root test and the level is stable, which will not have an adverse impact on the regression results.

5.3. Benchmark Regression. Table 4 shows the test results of the relationship between "digital transformation and main business performance" of foreign trade enterprises. From the data in the table, it is concluded that in the model (1), under the premise of controlling the fixed effect of time, the regression coefficient between digital transformation and main business performance is 0.0051 and passes the significance test of 1%. Therefore, the digital transformation of foreign trade listed enterprises can play a significant role in promoting the enterprise's main business performance. After the control variable group is introduced in the model (2), the regression coefficient converges to some extent, but its positive effect is still significant, and the goodness of fit of the model is improved. To sum up, the higher the degree of

Table 2: Multicollinearity test.

Variables	MRS	DT	Asset	Dual	S-D	Age	TR	Income	Audit
MRS	1.0000								
DT	0.0976	1.0000							
Asset	0.1396	0.1277	1.0000						
Dual	0.0877	0.1336	−0.0037	1.0000					
S-D	−0.0449	−0.1613	0.0515	0.1492	1.0000				
Age	−0.1082	0.1932	−0.1373	−0.2742	−0.1504	1.0000			
TR	0.0061	−0.0751	−0.0505	−0.0245	−0.1262	−0.0610	1.0000		
Income	−0.0057	0.3023	0.2529	−0.0461	0.0065	0.2510	−0.1293	1.0000	
Audit	−0.0752	0.0273	−0.0636	0.0538	−0.0823	0.0377	−0.0694	0.0152	1.0000

Note. The data in this table and the following are obtained from Eviews10.0 unless otherwise stated.

Table 3: Unit root test.

Variables	LLC	Breitung	Hadri	IPS	ADF	PP	Result
MRS	−6.8911**	−4.1823**	8.1873**	−1.8303**	66.4594**	92.4473**	Stable
DT	−8.7927**	3.1770**	3.5078**	−2.3134**	66.2864**	64.9830**	Stable
Asset	−10.3725**	1.7967	8.0514**	−3.0375***	88.9400**	113.485**	Stable
Dual	−1.4243**	−0.6146**	1.8211	−0.4256**	9.3725**	9.4450**	Stable
S-D	−39.2264**	1.2365**	9.2020**	−5.4134**	47.2748**	57.0566	Stable
Age	−5.2236**	−2.2110*	5.7021**	−1.6682**	23.7799**	29.3858**	Stable
TR	−1.5772**	1.3247**	10.9898**	−2.7220***	28.7512	41.4019**	Stable
Income	−10.0001**	−0.2054	9.5674**	−2.5121**	123.8333**	117.5244**	Stable
Audit	−40.5094**	0.4035**	9.4227**	−8.6567	−8.6567***	69.6451**	Stable

Table 4: Digital transformation and performance of listed companies.

Model	(1)	(2)
Variables	MRS	MRS
DT	0.0051***	0.0049***
	(3.53)	(3.27)
CVs	No	Yes
Year	Yes	Yes
Observed value	297	297
Adjusted R^2	0.341	0.453

Note. (1) ***, **, and *, respectively, represent significance levels at 1%, 5%, and 10% levels; (2) the values in brackets represent the t statistic adjusted by the robust standard error of the Cluster. The following is the same.

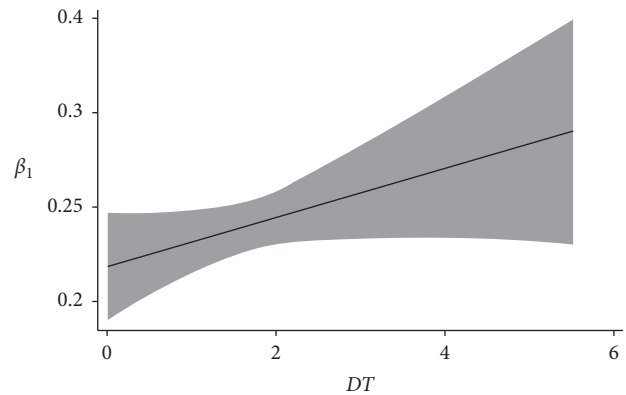

Figure 1: Marginal effect test.

digital transformation of foreign trade enterprises, the more conducive it is to the improvement of their main business performance, so H1 holds. Follow-up tests will be performed to observe the robustness of the conclusion.

5.4. Marginal Effect Test and Robustness Test. After determining that the digital transformation of foreign trade enterprises can promote their performance, it does not test whether there will be a deviation in the promotion effect of digital transformation on the main business performance based on a certain level. Therefore, in this paper, the marginal effect test was used for analysis. In Figure 1, the horizontal axis (DT) indicates the degree of digital transformation, and the vertical axis (β_1) indicates the regression elasticity of digital transformation to the main business performance.

Table 5: Robustness test: changing the regression period.

Model	(2011–2020)	(2010–2014)
Variables	MRS	MRS
DT	0.0037***	0.0029***
	(3.27)	(2.82)
CVs	Yes	Yes
Year	Yes	Yes
Observed value	297	135
Adjusted R^2	0.451	0.373

The figure shows that, on the whole, the influence of the digital transformation of foreign trade enterprises on the performance of their main businesses remains positive, and the regression elasticity of this variable is relatively low when the degree of digital transformation is low. With the

Table 6: Robustness test: variable substitution.

Variables	MRS	Tobin Q	ROE
DTZ	0.0024*** (2.74)	—	—
DT	—	0.0038*** (3.41)	0.0016** (2.97)
CVs	Yes	Yes	Yes
Year	Yes	Yes	Yes
Observed value	297	297	297
Adjusted R^2	0.371	0.411	0.392

improvement of the degree of digital transformation, it generally shows an upward trend. Therefore, it is concluded that the higher the degree of digital transformation of foreign trade enterprises, the more obvious its promotion effect on enterprise performance.

As the global economy is a dynamic, whole business performance, related key strategies will be affected when a major financial event occurs, resulting in the stagnation of some strategic projects. Therefore, after excluding the influence of the large-scale decline in the Chinese stock market in 2015, the observed objects during the period from 2010 to 2014 were intercepted for regression, and the final results are shown in Table 5.

Table 5 shows that the conclusion has not changed significantly after excluding the impact of the stock market crash in China. Therefore, H1 in this paper holds and is robust.

In this paper, the robustness of the digital transformation of foreign trade enterprises in promoting their performance was further tested by changing the statistical specification. For the core explanatory variables, the proportion of digital technology-related parts in the year-end intangible assets details disclosed in the notes to the annual financial reports of listed companies to the total intangible assets was used to depict the digital transformation (DTZ) from another perspective for the robustness test [34]. At the level of explained variables, on the basis of the main business performance, the statistical standard of performance indicators was relaxed by using the research method of Yi et al. for reference, and Tobin Q value (Tobin Q) and return on net assets (ROE) were adopted as substitute variables of main business performance (MRS) [15]. After the substitute variables were defined, the above variables were subjected to benchmark regression to observe the regression results (Table 6).

The results show that the digital transformation of foreign trade enterprises still has a positive impact on the performance after using variables instead of changing the statistical specification of data, and the regression coefficient also passes the significance test at a level of no more than 5%, which shows that the conclusion of this paper reflects a high degree of robustness.

5.5. Mediating Effect Analysis. In order to further explore the mediating effect between the explained variables and the explanatory variables, a three-step regression model

Table 7: Mediating effect of internal control.

Model	(1)	(2)	(3)
Variables	MRS	ICI	MRS
DT	0.0051*** (3.56)	0.0087** (3.14)	0.0020** (3.72)
ICI	—	—	0.0077** (2.81)
CVs	Yes	Yes	Yes
Year	Yes	Yes	Yes
Adjusted R^2	0.152	0.274	0.162
Sobel test		0.0029**(2.39)	
Proportion of mediating effect		0.19	

of mediating effect was adopted to verify hypotheses H2 and H3.

$$\begin{aligned} \mathrm{MRS}_{it+1} &= \alpha + \beta_1 \mathrm{DT}_{it-1} + \sum \beta_i \mathrm{CV}s + \sum \beta_j \mathrm{Year} + \varepsilon, \\ \mathrm{Mediator}_{it} &= \alpha\prime + \delta_1 \mathrm{DT}_{it-1} + \sum \delta_i \mathrm{CV}s + \sum \delta_j \mathrm{Year} + \varepsilon, \\ \mathrm{MRS}_{it+1} &= \alpha + \gamma_1 \mathrm{Mediator}_{it} + \gamma_2 \mathrm{DT}_{it-1} + \sum \gamma_i \mathrm{Year} + \sum \gamma_j \mathrm{CV}s + \varepsilon, \end{aligned} \tag{2}$$

where "Mediator" means the group of mediating variables. The meanings of other variables are the same as above. Meanwhile, in order to improve the accuracy and precision of the mediating effect results, a further Sobel test was carried out on the basis of the three-step regression, and various indicators in the tests were reported in detail.

5.5.1. Internal Control. In this paper, based on the mediating effect path of "digital transformation⟶internal control⟶main business performance" of foreign trade enterprises, the "DIB China Listed Company Internal Control Index" (ICI) was adopted as the representative indicator of enterprise internal control [15].

According to Table 7, the Sobel coefficient is 0.0029, which is significant at the level of 5%, so it is concluded that the mediating effect is significant and accounts for 19% of the total effect. Therefore, it is judged that the mediating effect of "digital transformation⟶internal contro⟶main business performance of enterprises" is effective, and the digital transformation of foreign trade enterprises affects the main business performance of enterprises by improving the mediating effect of internal control, thus H2 holds. In practice, the digital transformation of foreign trade enterprises can effectively improve internal control, improve the transparency of internal information through digital means, help all internal departments improve communication efficiency, and make more reasonable and scientific decisions and strategies.

5.5.2. Innovation Ability. In the research on the mediating effect path of "digital transformation⟶innovation ability⟶main business performance" of foreign trade enterprises, the research method of Li et al. [16] was used for reference, and the total number of patent applications

Table 8: Mediating effect of innovation ability.

Model	(1)	(2)	(3)
Variables	MRS	PA	MRS
DT	0.0051***	0.0221***	0.0021**
	(3.56)	(5.79)	(2.76)
PA	—	—	0.0045**
			(3.42)
CVs	Yes	Yes	Yes
Year	Yes	Yes	Yes
Observed value	297	297	297
Adjusted R^2	0.152	0.158	0.171
Sobel test		0.0028***(3.32)	
Proportion of mediating effect		0.28	

of listed enterprises was treated as the representative indicator of the technological innovation ability of enterprises (PA).

According to Table 8, the Sobel test coefficient is 0.0028, which is significant at the level of 1%, and the mediating effect ratio is 28%, indicating that the digital transformation of foreign trade enterprises can enhance the innovation ability of enterprises, which indirectly affects the improvement of the main business performance of enterprises. Thus, H3 holds. As a matter of fact, digital transformation, as a comprehensive project integrating many technologies, not only has high requirements for the innovation of enterprises but also will encourage enterprises to continuously absorb and train relevant R&D personnel, continuously promote the systematic integration of digitalization and industry, and fundamentally improve the main performance of enterprises.

6. Conclusions and Enlightenment

In this paper, based on the publicly disclosed data of 27 foreign trade listed companies in Shanghai and Shenzhen A shares from 2010 to 2020, the digital transformation indicators of foreign trade enterprises were depicted by means of text recognition data analysis, and the impact of digital transformation on the main business performance of foreign trade enterprises was empirically analyzed, and the mediating role of internal control and innovation capability of enterprises was verified. The following conclusions are drawn: First, for foreign trade enterprises, digital transformation can effectively improve their main business performance, and the conclusion is still significant and robust after introducing control variables, marginal effect tests, and changing the statistical specification of core variables. Second, in the impact mechanism of digital transformation of foreign trade enterprises on enterprise performance, digital transformation of foreign trade enterprises can improve the internal control of enterprises, thus improving the main business performance, and also significantly improve the innovation ability of enterprises, thus improving the main business performance.

According to the above conclusions, the following suggestions are put forward in this paper: First, the government needs to further promote the cooperation between foreign trade enterprises and relevant research institutions, play the mediating role of foreign trade enterprises' innovation ability, and accelerate the application of digital technology to the ground. At present, many cutting-edge digital technologies are still in the incubation stage in the laboratory. In order to better promote the main business performance and enhance the competitiveness of foreign trade enterprises, foreign trade enterprises should cooperate with research institutions and jointly explore the R&D and application of digital transformation technologies applicable to them. Second, foreign trade enterprises should choose digital technology according to their own situation, better apply it to internal control of enterprises, and improve their main business performance by improving internal management. At the same time, foreign trade enterprises have different main business segmentation directions, so they should choose the digital transformation technology that matches the different development stages of enterprises according to their own situation, so as to maximize the role of digital transformation in improving the main business performance.

Based on the text analysis of digital transformation of foreign trade enterprises and the model of the influence of digital transformation of foreign trade enterprises on their business performance, this paper points out the role of internal control and innovation ability of enterprises in promoting the main business performance in the digital transformation of enterprises. The research bridges the gap between the theory and practice of digital transformation of foreign trade enterprises. In the current situation, improving enterprise performance is crucial to the sustainable development of China's foreign trade enterprises. This paper demonstrates the path and impact of the digital transformation of foreign trade enterprises on their performance improvement and puts forward suggestions to promote the digital transformation of foreign trade enterprises from the two aspects of government policies and enterprise behavior, which have important enlightened significance.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this article.

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Research Article

Application of Personalized Demand Based on Kano Model in Private Colleges

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In recent years, with the continuous growth of college students' personalities, the development of their personalized education needs has become more and more prominent, and how to meet those needs has become the focus of current research. From the perspective of Kano, this paper establishes a "student-centered" learning situation analysis system, based on the degree of support for graduation requirements and the training objectives for the individual needs of students. Furthermore, the paper builds a trinity of individual needs-oriented education evaluation mode, so as to realize the basic needs, expected needs, and attractive needs of students, and forms a teaching implementation plan for personalized needs from the perspective of Kano. Then, the established teaching implementation plan of individual needs from the perspective of Kano is applied to the "applied statistics" course of economic management students in a private college, and the experimental results of the undergraduate students and the students who are promoted to college are compared. The research shows the following: the application of the teaching implementation plan of personalized needs from the perspective of Kano can help improve the comprehensive performance of students; differentiated students can reduce differences through the teaching implementation plan of personalized needs from the perspective of Kano, so that personalized needs are more satisfied, so as to further improve the quality of teaching.

1. Background

More than 2,000 years ago in ancient China, the sage Confucius put forward the educational thought of "Teach students according to their aptitude, and there is no difference." This is the earliest concept and thought of individualized education in China. The idea of "teaching students according to their aptitude, there is no class" is the personalized education idea emphasized today. With the continuous changes of the times, the personalized needs of students are becoming more and more intense; in particular, the private education in China has the purpose of corporate profit. In essence, it is faced with more diverse students than public education, and the individual needs of students are stronger. However, the Kano model is a classic analysis model for analyzing consumers' product demand classification and demand satisfaction survey. Therefore, we use Kano model characteristics, according to the individual needs of students in private colleges and universities to formulate a better teaching system plan, so as to realize the real personalized needs-oriented teaching system reform, achieve a win-win effect for teachers and students, and truly achieve higher teaching quality.

2. The Model Design Basis of Personalized Needs in Education from the Perspective of Kano

With the continuous development of the economy and society, the personality of this generation of college students has been continuously publicized, and the students' ideas are no longer bound by traditional education methods. What students pursue is more of their own needs. Since there are no two identical people, students are more pursuing their own needs in education based on their native families. Especially in private education, students no longer simply pursue high scores and simply graduate like public

education students. With respect to research on education, Mei proposed in 2021 that the "five withdrawals and five standings" to promote the connotative development of local undergraduate education can promote the development of education [1]. Zhongbiao proposed in 2022 that ideological and political education should be added to education, adding objective factors [2]. Lu proposed that "self-directed learning" is an important educational basis for building lifelong learning for all people [3]. In 2021, Wu et al. constructed a teaching quality evaluation model in colleges and universities under the Kano model [4]. What students need more is the result of the experience process and learning process. At this time, education is actually a "regression." How to find a better teaching plan in the more intense changes of students' individual needs, so as to take into account the needs of students and achieve better teaching effect, is the important content of this paper. In fact, personalized needs, that is, nonmainstream, special, alternative needs, are nonuniversal needs for most users, which belong to partial customization needs.

The process of satisfying individualized needs in teaching is the reform of educational system engineering, and the process of educational system reform also requires the systematic design of educational programs. Higher education needs to know whether the talents cultivated by traditional education are in line with the talents that are about to be in line with the society. In response to individual needs, Yang proposed a trusted model of cloud manufacturing under individual needs in 2022 [5]. In 2022, Yin proposed to establish personalized needs corresponding to readers in university libraries [6]. In 2022, Yu et al. proposed the personalized requirements for building fuzzy Kano models [7]. In 2022, Qu proposed to establish "accurate recommendation" in the tourism industry to meet the personalized needs of tourists [8]. Jiang et al. proposed one-stop information for users' personalized needs in 2022 to meet users' needs [9]. At the same time, for the reform of education evaluation, it is currently advocated that the "formative evaluation" should be focused on and the evaluation standards and content should be more diverse. With such an evaluation form, we must pay more attention to how to make the evaluation more scientific and reasonable. Therefore, how to continue to improve the quality of school education and meet the individual needs of students is also the content of this study.

The Kano model is a useful tool for classifying and prioritizing consumer needs, invented by professor Noriaki Kano, Tokyo Institute of Technology. The result indicates that there is no linear relationship between the performance of products and the satisfaction of users. The Kano model considers the needs of consumers more. As private institutions, private colleges and universities have more characteristics of enterprises. Therefore, applying the Kano model to study the individual needs of students in private colleges and universities can better meet the fundamental demands of students in colleges and universities, which is more conducive to the improvement of teaching quality [10, 11]. Regarding the literature research on the application of the Kano model in education, Liang et al. proposed the functional requirements and design of the establishment of intelligent conference rooms in colleges and universities from the perspective of the Kano model in 2022 [12]. Dong et al. proposed in 2022 that the undergraduate education service of medical colleges under the Kano model should meet the needs of students [13]. As a demand-oriented classic model, the Kano model to study the personalization of students in private colleges can better reflect students' satisfaction and provide a new direction for the development of private colleges. From the perspective of the Kano model, this paper designs a teaching plan based on the individual needs of students in private colleges and universities, applies this teaching plan to a specific private college to test the effect of the reformed teaching plan, and then proposes the Kano model. The teaching system of private colleges and universities not only tries to build the personalized demand model of students under the Kano model, but also further tests the practical value of the model.

According to statistics, in 2020, the number of private schools in China will reach 186,700, accounting for more than 1/3 of the total number of schools in the country, with 55.6445 million students, accounting for nearly 1/5 of the total number of students. Therefore, private education has become an important part of education. In 2022, as a result of the epidemic, the enrollment of private schools was greatly impacted, and the survival crisis of private schools was even more severe. Then, in order to develop their own characteristics, private schools paid more attention to the individualized development of different students. Thus, how to meet the individual needs of middle school students in private colleges and universities and promote the development of private colleges and universities has become a problem that needs to be solved, and it is also a matter that China's educational undertakings should pay attention to. Therefore, this paper studies the personalization model of students in private colleges and universities from the perspective of Kano model, and it is of great significance to apply this model in experiments.

3. The Design of the Teaching Mode Implementation Plan for Personalized Needs from the Perspective of Kano

3.1. Basic Framework of Personalized Demand Model System from the Perspective of Kano. As an important part of private colleges and universities in China, the individual needs of students can be divided into basic needs quality, expected demand quality, and attractive demand quality. Therefore, the establishment of the personalized demand model system of private college students from the perspective of Kano is based on the basic needs of students, the quality of expected needs, and the quality of attractive needs. The multidimensional assessment of the realization of students' needs through the learning situation analysis system has formed an all-round and multi-angle basic model framework. Therefore, this article establishes a "student-centered" learning situation analysis system, based on the individual needs of students, the degree of support for graduation requirements, and the three dimensions of training goals, forming a personalized view from the perspective of Kano, so as to

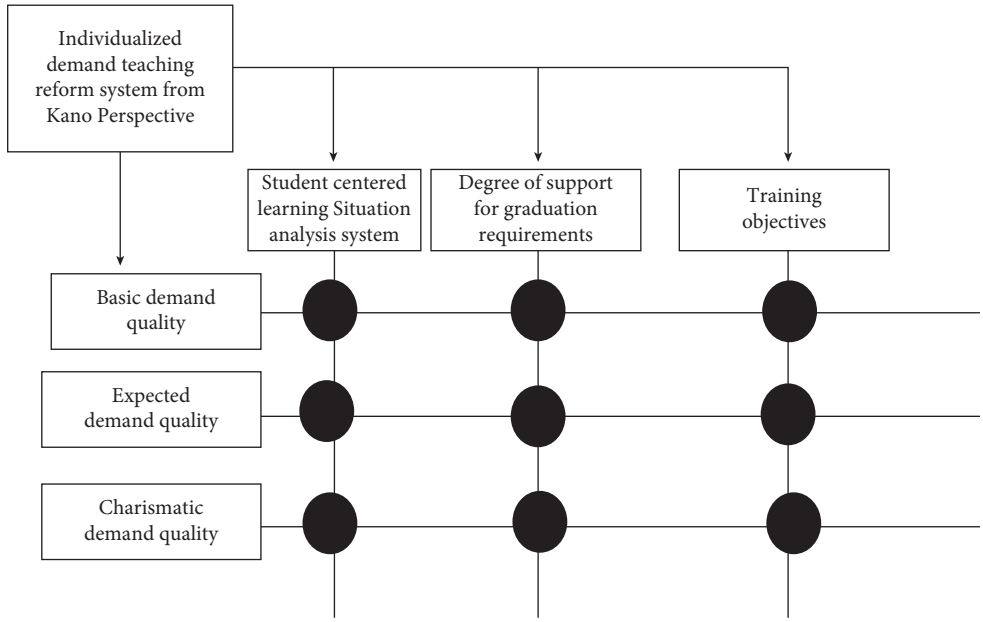

Figure 1: Individualized demand teaching reform system from Kano perspective.

achieve the purpose of improving the quality of teaching, as shown in Figure 1.

From Figure 1, it can be seen that the personalized needs of students in the personalized demand model system from the perspective of Kano are realized through basic demand quality, expected demand quality, and attractive demand quality. Analysis system, degree of support for graduation requirements, and training objectives are achieved. The teaching implementation plan is constantly updated with the teaching process and the results of the staged assessment.

3.2. Design of the Indicator System of the Personalized Demand Model from the Perspective of Kano. The traditional student teaching is based on teachers' teaching and final examinations to form the entire curriculum system. This method cannot fully reflect the individual needs of students, and the assessment method is also relatively one-sided. Therefore, the setting of the curriculum system should be based on the individual needs of students. The quality of students' basic needs is reflected in the "student-centered" learning situation analysis system, the quality of expected needs starts from the degree of support required for graduation, and the quality of attractive needs starts from the training goals, which changes the traditional course teaching method and forms a new model. From the perspective of Kano, this paper constructs a three-in-one personalized demand-oriented educational evaluation model from the perspectives of the "student-centered" learning situation analysis system, the degree of support for graduation requirements, and the training objectives, so as to achieve students' satisfaction. The dimensions of the three perspectives are as follows.

3.2.1. Dimension 1: Constructing a "Student-Centered" Learning Situation Analysis System. We build a "student-centered" learning situation analysis system, as shown in Figure 2.

The proposed learning situation analysis system can specifically include the following points:

(1) Analysis of existing knowledge. This includes the study of the prerequisite courses, which has laid a solid theoretical and practical foundation of the discipline, laid the foundation for the teaching of the subsequent courses, and promoted the teaching and application of the courses. Analyze the basic knowledge that students have learned, and conduct face-to-face analysis for some special students, such as those who have poor foundation and who have not studied corresponding basic courses (such as probability theory and advanced mathematics). The survey questionnaire is in the form of questionnaire analysis, such as the survey questionnaire made by students for the establishment of "applied statistics."

(2) Learning ability analysis. Through course study and chapter tests, we can grasp the class learning status, knowledge mastery, and students' learning ability in real time; dynamically adjust the course teaching method and teaching rhythm; and design the depth, difficulty, and breadth of the course.

(3) Diagnosis of the overall learning status of the teaching class. Build a four-dimensional integrated communication platform of "counselor-academic tutor-teacher-student" before class to fully understand the overall learning situation of the class. According to the results of the analysis of the learning situation, teach students according to their aptitude, stimulate the learning interest of students with poor foundations, and improve students with outstanding innovation skills to expand these skills.

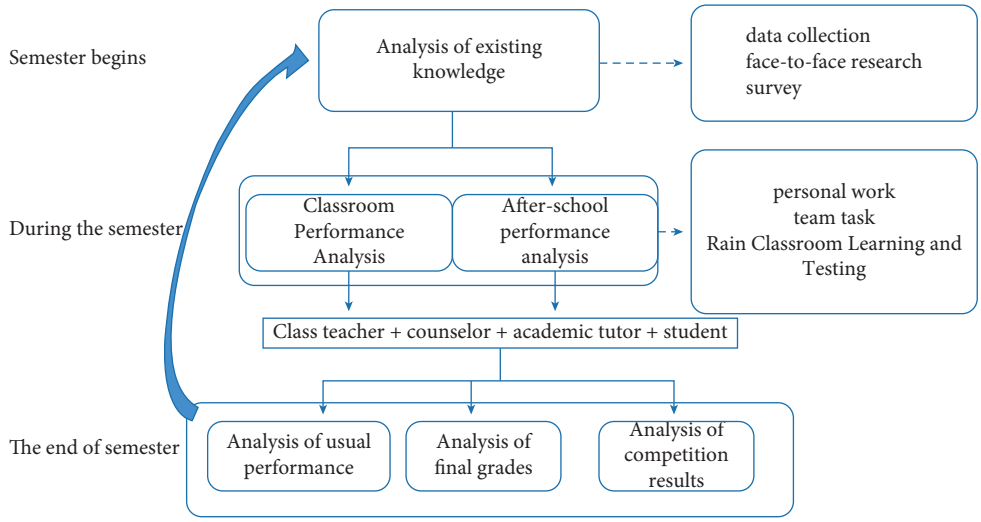

Figure 2: System diagram of academic situation analysis.

(4) Analysis of existing innovation ability. For example, most of the students in the two undergraduate classes of the 2019 e-commerce major in the first semester of 2021–2022 have participated in the national market research and forecasting competition, and some students have already won provincial and above competition awards. It can be seen that the 2019-level e-commerce students have a certain foundation of innovative thinking and practical ability, but the statistical professional knowledge and application ability need to be further improved. However, in the first semester of 2021–2022, the two undergraduate classes of the 2019-level logistics management majors have almost no foundation, and they have not even studied probability theory and advanced mathematics related to the "applied statistics" course.

3.2.2. Dimension 2: Degree of Support for Graduation Requirements. The degree of support of the course for graduation requirements can be divided into 4 points: First, this course mainly aims to train students to master the basic theoretical knowledge of the course while mastering the professional knowledge. Second, this course trains students to have corresponding ability goals while possessing professional basic knowledge. Third, this course trains students to form the analytical ability of their own professional characteristics based on the knowledge of applied statistics. Fourth, this course cultivates students with the knowledge and ability goals required for graduation, as well as the corresponding qualities. Ideological and political teaching points and a large number of employment guidance elements that are consistent with the teaching content are set up for each credit hour in the course design, which promotes the effective integration of the course content and the ideological and political education work for students and cultivates students' scientific, truth-seeking spirit. It effectively embodies the fundamentals of teachers' moral cultivation and helps to cultivate applied talents with innovative spirit.

3.2.3. Dimension 3: Training Goals. The construction of the curriculum system in this paper aims to enable students to understand the principles of the curriculum, master the basic methods and skills of the curriculum, and explore the regularity of the curriculum learning through the study of the curriculum, so as to achieve a scientific understanding of objective things. The curriculum system can cultivate students' literacy and skills in theoretical knowledge analysis. Let students have the spirit and ability of science and proof. The specific training objectives are divided into four levels:

(1) Knowledge goals. Through heuristic, practice, and discussion teaching methods and mutual promotion of knowledge, students can master the basic principles and methods of the course. Help students with course-related theoretical foundations.

(2) Ability target. Students can master the basic principles related to the course, understand the basic concepts related to the course, and use the theoretical knowledge of the course to complete the corresponding exercises.

(3) Process and method objectives. Through the connotative teaching of "theory + practical operation" and the "online + offline" mode in the learning process, students can learn courses based on their inner interests. According to the characteristics of teaching content and learning situation, the course teaching uses project-based teaching, flipped classroom, online and offline mixed teaching and other teaching modes, so that students have the independent learning, cooperative learning, and exploratory learning abilities.

(4) Emotional attitude and value goals. In addition to the corresponding content of the course, excavate high ideological and political elements; help students

establish a sense of science and justice; cultivate students' spirit of hard work and perseverance; cultivate students' spirit of seeking truth; and strive to cultivate students to be dedicated to their jobs, be excellent statisticians who are willing to give, and be applied undergraduate talents with ideals, ethics, knowledge, and high degree.

3.3. Constructing a Curriculum Reform System Oriented by Individual Needs from the Perspective of Kano. According to the indicator system of the personalized demand model from the perspective of Kano, curriculum teaching is guided by the personalized demand, and a teaching mode suitable for students is designed. With the characteristics of this course, teachers hope to have certain practical guiding significance in the implementation of the course teaching mode reform. The Kano result-oriented connotative teaching design aims mainly to improve the quality of the course and student satisfaction. The specific Kano result-oriented connotative teaching model is shown in Figure 3.

The teaching characteristics are mainly reflected in the transformation from the traditional "teacher-centered" to the new "student-centered" classroom teaching mode, the integration of ideological and political elements in curriculum design, a complete learning situation analysis system, and Kano results-oriented typical reform courses of connotative teaching, as well as the rich network teaching resources that have been established and used as the basis of Rain Classroom. Turn students from the audience of learning into the main body of teaching; based on scientific ideas, professional ability, and tasks driven as a supplement, the theoretical teaching content is based on the principle of sufficient use, and online and offline mixed teaching is carried out to improve the teaching effect. Formulate student online learning control measures, effectively monitor students' online learning, optimize course teaching resources, and improve teaching methods in a timely manner.

4. The Application of Teaching Reform of Individualized Needs in the Experiment from the Perspective of Kano

This paper takes the course of "applied statistics" in a private college as an example, through the teaching reform of personalized needs from the perspective of Kano, that is, based on the personalized needs of students proposed in Section 3, the training objectives, the degree of support for graduation requirements, and the three dimensions of the "student-centered" learning situation analysis system; the experimental results are obtained by comparing the final grades achieved by students. In order to ensure the fairness and impartiality of the experimental results and to build the same experimental environment as possible, the subjects of this experiment are the same class of students in a private college. There are a total of 124 students in 4 classes. The students in the 4 classes are all undergraduate students, but two of them are 31 and 36 undergraduates, and students who passed the college entrance examination in normal class 1 and 2, repectively. The other two classes have 27 and 29 undergraduate students who passed the college entrance examination in advanced classes. The number of samples is 124. Due to the epidemic, 1 person did not take the test and had no final comprehensive score. It is invalid to exclude 1 sample, so there are 123 valid data samples, and the effective rate is 99.19%, which meets the requirements of the number of samples.

4.1. The Experimental Basis of the Teaching Reform of Individual Needs from the Perspective of Kano

4.1.1. The Teaching Process of Personalized Needs from the Perspective of Kano: Taking the Course "Applied Statistics" as an Example

(1) Accurately grasp the course positioning and teaching objectives according to the degree of support required for graduation, and accordingly revise and improve the course syllabus, teaching plan, lesson plan, courseware, exercise set (library), test set (library), and other text-based teaching resources to. The online course platform, containing all of the above teaching resources, is efficiently connected with offline classroom teaching.

(2) The teaching of practical courses adopts the connotative task teaching method. The purpose is to let students understand the true connotation of applied statistics by completing the tasks of each link, and to independently complete the basic statistical methods in a relatively close manner to the real application situation. comprehensive ability.

(3) Evaluate the teaching effect of the course and the learning effect of the students in practice stages, summarize and reflect in a timely manner, and guide the improvement and perfection of the course construction.

(4) Strengthen the teaching of practical links. By combining the corresponding knowledge points of "applied statistics" and the study of computer software SPSS, the students' practical operation ability will be enhanced, and the corresponding knowledge points will be used to solve operational problems in life.

(5) Strengthen the integration of ideological and political elements in the course of applied statistics. According to the changes of national policies and social environment, for each of the 48 hours of teaching of the "applied statistics" course, case teaching of ideology and politics that is in line with the teaching content is set up, which promotes students' understanding of the course content. Effective integration with ideological and political education work cultivates students' spirit of science, truth-seeking, and verification and truly cultivates morality.

(6) Continue to improve and apply the "student-centered" complete learning situation analysis system.

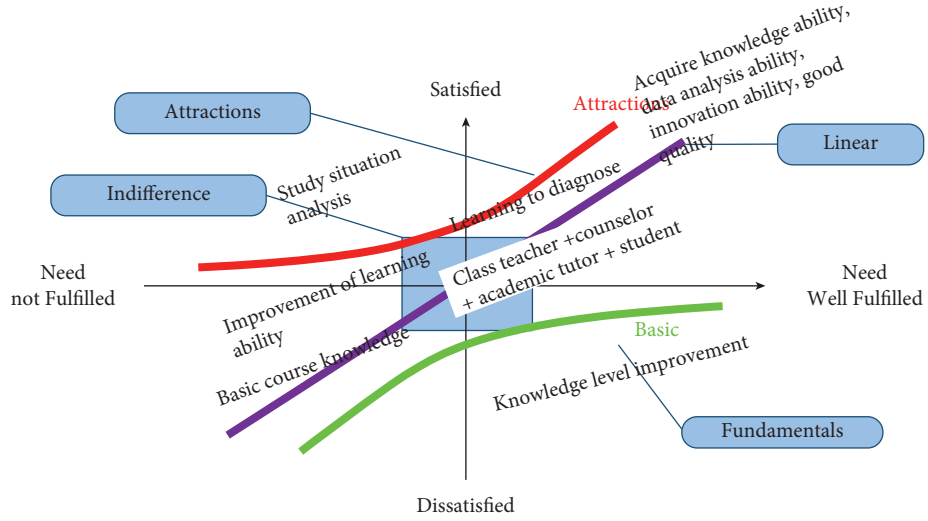

Figure 3: Individualized demand-oriented curriculum reform from the perspective of Kano.

① The teaching content is divided logically from shallow to deep: the entire teaching content is divided into logical and step-by-step modules, and the teaching arrangement and design are carried out in a step-by-step, planned, and connected manner. ② Simulation of teaching organization form: teaching combines theory and practice, and integrates individuals and groups to improve students' ability to cooperate, enhance course interest, and improve students' enthusiasm for learning.

(7) Strengthen the teaching reform of "applied statistics" course and update it continuously. Establish a curriculum reform of connotative teaching from the Kano perspective and the result-oriented perspective, and design a connotative teaching mode suitable for students. Based on the online resources,a variety of teaching methods and means are adopted, such as explanation type, practice + operation type, case type, discussion type, and flipped classroom. Carry out online and offline mixed teaching to improve teaching effect. Through the form of "competition to educate people," strengthen the students' learning of the knowledge points of "applied statistics."

4.1.2. Analysis of the Teaching Process of the Individual Needs of the "Applied Statistics" Course from the Perspective of Kano. From the perspective of Kano, the teaching process of the individual needs of the "applied statistics" course as an example combines online and offline learning. The experiment is conducted on the basis of the "student-centered" learning situation analysis system based on the individual needs of students, that is, on the basis of research and analysis of learning situation for each student participating in the experiment.

The teaching of this course is mainly based on offline teaching and supplemented by online teaching. The offline teaching is the main teaching, and the network is the form of tutoring teaching. Among them, offline teaching starts from the individual needs of students, and on the basis of investigating each student's academic situation through the Internet and grasping the real needs of students, teachers make corresponding offline and online course design and teaching plan design. Based on the principle of morality and the supremacy of law, teachers teach courses on the basis of students' needs and update their offline teaching at any time according to changes in staged teaching objectives, different degrees of support for graduation requirements, and changes in students' needs design. During the online teaching process, the network resources are adjusted and updated at any time according to the students' offline reactions and online learning, as well as the completion of homework. The construction of teaching video resources, including teaching videos, audios, micro-lectures (videos), high-quality classroom recordings, and other resources based on the difficult course chapters, is uploaded to the online course platform of Xijing College to further improve the construction quality of video teaching resources and make them a powerful auxiliary material for students to study after class. The following is the use of online teaching resources for students.

Note that 52 of the 176 people in Figure 4 belong to the data of restudy students and are not included in this experiment.

In this paper, the experimental process of the "applied statistics" course from the perspective of Kano is carried out in the way of online and offline integration, and the online mode is mainly applied through the Rain Classroom network terminal shown in Figure 4. At the beginning of the experiment, students are required to watch the relevant videos of this course in the Rain Classroom, and then conduct offline learning under the guidance of teachers. Some course knowledge points will also be added in the offline teaching process, and finally let the students complete the offline teaching through the Rain Classroom. In the after-school knowledge point exercises in the learning part,

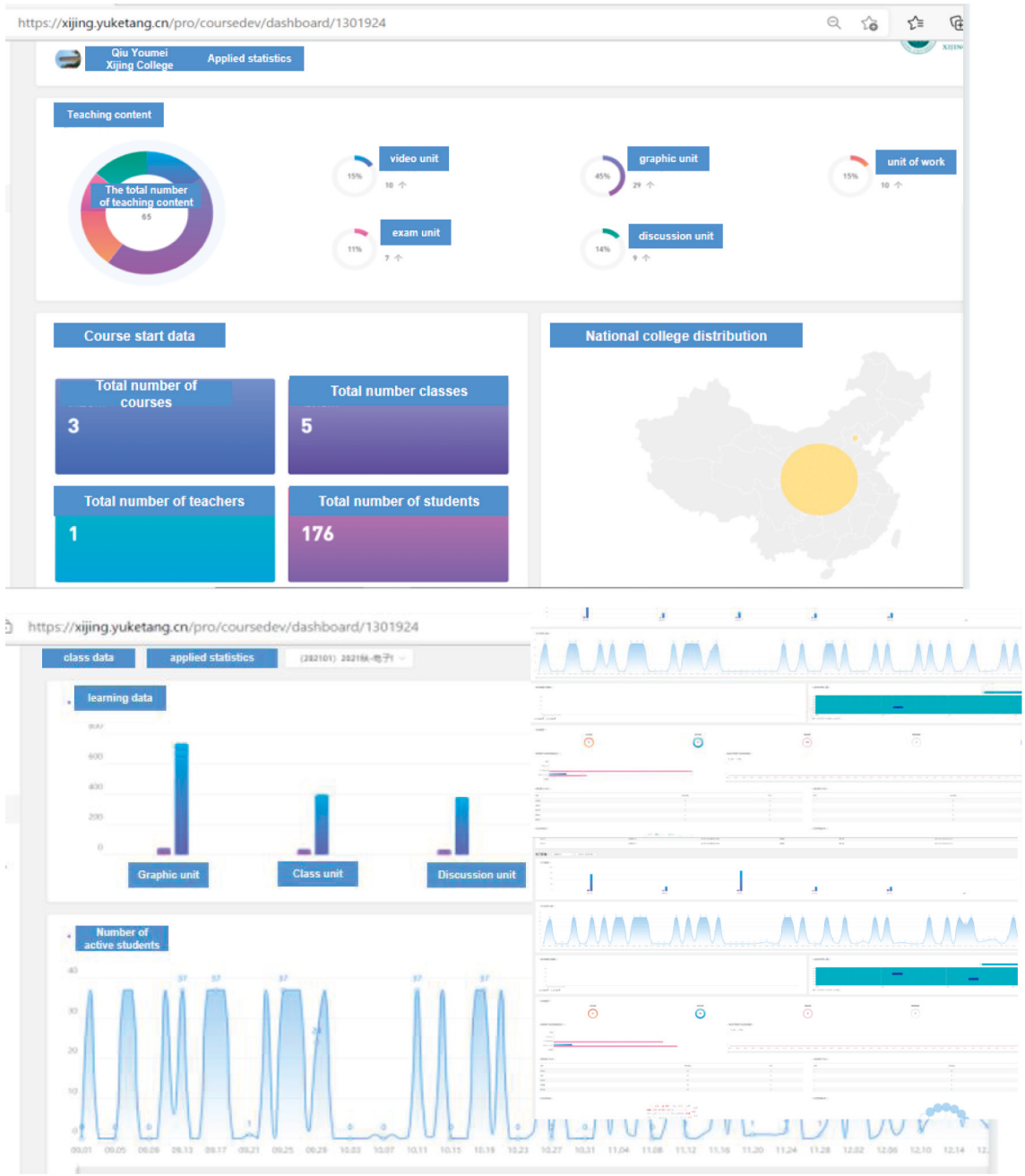

Figure 4: Rain Classroom curriculum resources.

the teacher will re-explain the content that the students do not know according to the effect of the students doing the questions in the Rain Classroom, thus forming a closed-loop model of teaching and learning.

The teaching syllabus and teaching plan used in the experimental teaching process of individual needs in the "applied statistics" course from the perspective of Kano are formulated on the basis of the degree of support for graduation requirements. The teaching objectives of the course are presented in detail in the syllabus, and the realization of each teaching objective is explained in detail in the lesson plan.

4.2. Comparison of the Results of the Teaching Reform of Personalized Needs from the Perspective of Kano after the Experiment. This experiment is actually carried out under the same environment, after analyzing the academic conditions of all students for two types of undergraduate students who are promoted to undergraduate and unified enrollment. Through the experimental research on the connotative teaching reform of the "applied statistics" course from the perspective of Kano, under the same assessment method, 4 classes (124 students in total) were designed for the implementation plan of the connotative teaching mode without using the Kano model, of which two classes are a

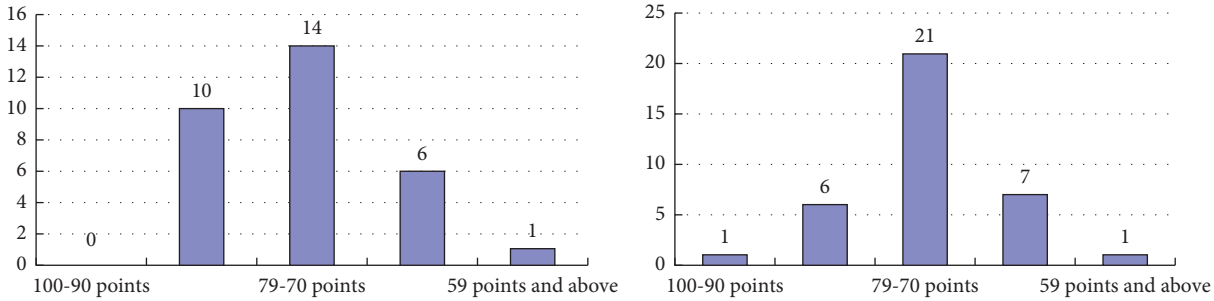

Figure 5: The comprehensive scores of students in two normal classes.

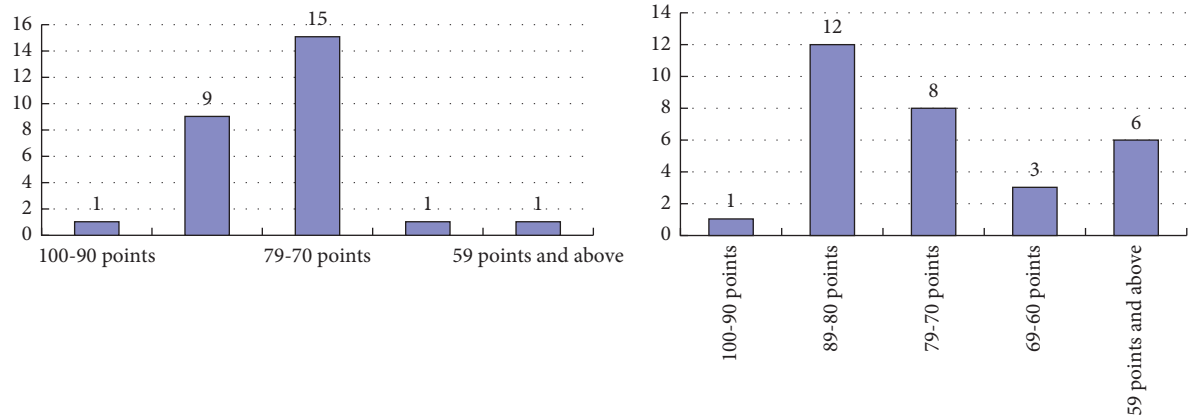

Figure 6: The comprehensive scores of the two students who were promoted to advanced classes.

Table 1: Grade details of students in two regular classes.

Class 1			Class 2		
Number of candidates	31		Number of candidates	36	
Number of absentees	0	0.00%	Number of absentees	0	0.00%
100–90 points	0	0.00%	100–90 points	1	2.78%
89–80 points	10	32.26%	89–80 points	6	16.67%
79–70 points	14	45.16%	79–70 points	21	58.33%
69–60 points	6	19.35%	69–60 points	7	19.44%
59 points and below	1	3.23%	59 points and below	1	2.78%
Average	75.26		Average	74.53	

normal class, and the other two are a special promotion class. The research results are shown in the next section.

4.3. The Teaching Reform of Personalized Needs from the Perspective of Kano Is Found in the Experiment. Through the teaching reform experiment of the "applied statistics" course based on individual needs from the perspective of Kano, after using the teaching plan in Section 3, we observed 4 teaching classes (124 students in total), of which 2 were normal and 2 were advanced classes. The research results are as follows:

(1) The evaluation score for teachers provided by students in 4 classes is above 90, which is excellent. It can be seen that the satisfaction of students is still very high, so from the perspective of Kano, the personalized needs framework of students in private colleges and universities can meet the needs of students.

(2) Figure 5 shows the comprehensive scores obtained by students in two normal classes after using the scheme in Section 3.

(3) Figure 6shows the comprehensive scores obtained by the students of the two advanced classes after using the plan in Section 3.

From the above two normal classes and two advanced classes, the results obtained after the teaching reform of the "applied statistics" course using the personalized needs from the perspective of Kano are presented: First, the high-level scores of the students who have advanced to the university are no better than the unified admissions. Undergraduate students have poor grades.

Table 2: The details of the grades of the two students who were promoted to adavanced classes.

Class 1			Class 2		
Number of candidates	27		Number of candidates	30	
Number of absentees	0	0.00%	Number of absentees	0	0.00%
100–90 points	1	3.70%	100–90 points	1	3.33%
89–80 points	9	33.33%	89–80 points	12	40.00%
79–70 points	15	55.56%	79–70 points	8	26.67%
69–60 points	1	3.70%	69–60 points	3	10.00%
59 points and below	1	3.70%	59 points and below	6	20.00%
Average	76.48		Average	73.27	

Even in the first unified enrollment class in Figure 6, there is no score between 90 and 100. Therefore, regardless of whether the student's starting point is high or low, using the personalized needs from the Kano perspective can help students improve their scores. Second, the impact of the personalized demand plan from the perspective of Kano on the students in the normal class is not as great as that of the students in the special class. The grades of the two normal classes tend to be more normally distributed, but the grades of the two advanced classes both show a skewed distribution.

(4) Table 1 provides the details of the grades obtained by the students in the two normal classes after using the scheme in Section 3.

(5) Table 2 presents the details of the grades obtained by the students in the twoadvanced classes after using the scheme in Section 3.

From the analysis of the students' detailed scores in Table 1 and Table 2, it can be concluded that after using the personalized demand plan from the perspective of Kano, the number of students with middle and high scores (i.e., 80–100 points) in the two specialization classes is more than that in the normal classes. After using the personalized demand plan from the perspective of Kano, the average score of the four classes can be more than 70, compared with the longitudinal average score of more than 60 [14], which is a relatively high level.

5. Conclusion and Outlook

5.1. Research Conclusions. The conclusion is obtained by establishing a personalized demand system scheme from the perspective of Kano and applying the scheme to four experimental classes. Based on the perspective of Kano, the individual needs of students, the student-centered academic situation analysis system, the degree of support for graduation requirements, and the training goals, we build a trinity of personalized needs-oriented education evaluation model, so as to realize the basic needs, expectations, and attractive needs of students, and we establish a teaching implementation plan for personalized needs from the perspective of Kano. Then, the established teaching implementation plan of individual needs from the perspective of Kano is applied to the "applied statistics" course of economic management students in a private college, and the experimental results of the undergraduate students and the students who are promoted to college are compared. The research shows the following: the application of the teaching implementation plan of personalized needs from the perspective of Kano can meet the personalized needs of students; it is helpful to improve the comprehensive performance of students; differentiated students can reduce differences through the teaching implementation plan of personalized needs from the perspective of Kano, so that individual needs are more satisfied, thereby further improving the quality of teaching. Therefore, it can be inferred that the promotion of the teaching implementation plan of personalized needs from the perspective of Kano has practical significance.

5.2. Research Outlook. The results obtained by comparing the experimental results of undergraduate students and students who have advanced to college can be applied to other disciplines and majors, and then an excellent student-centered curriculum system can be formed to meet the needs of more college students for personalized courses. And then it can be built into a standard "one teacher, one excellent course." Secondly, on the basis of the "one teacher, one excellent course" technology, it will continue improvement and reform and can be built into a high-level, high-quality college-level key course. On the basis of the key course, it will be built into a school-level key course. On the basis of the school-level key course, it will be built into a provincial-level quality course.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Port Logistics Function Evaluation Model Based on Entropy Weight TOPSIS Method

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Port logistics has developed rapidly, but due to late start, poor foundation, and other reasons, there are still some deficiencies in the development process; for example, some port logistics capacity is weak, and low efficiency has hindered the development of ports. Therefore, this paper puts forward the evaluation model of port logistics function based on entropy weight TOPSIS (Technique for Order of Preference by Similarity to an Ideal Solution) method. Analyze the factors that affect the operation effect of port logistics, extract four key indicators, and construct index evaluation factors. Entropy weight method and TOPSIS method are used to calculate the weight of each factor so as to quantify the indicators, thus determining the scoring standard of each indicator, obtaining the comprehensive scoring standard, and realizing the port logistics function evaluation. The experimental results show that to realize the effective use of port resources and the protection of the port environment, it not only needs to conduct port logistics function evaluation but also take into account the efficiency of port logistics. It is of great significance to study the capacity and efficiency of port logistics for improving the core competitiveness of port enterprises and driving the sustainable economic development of surrounding areas.

1. Introduction

Port logistics refers to the development of a comprehensive port service system with the characteristics of covering all links of the logistics industry chain by a central port city by making use of its own port advantages and relying on advanced software and hardware environment, strengthening its radiation capacity to logistics activities around the port, highlighting the expertise of the port in cargo collection, inventory, and distribution, taking the port-based industry as the basis, information technology as the support, and optimizing the integration of port resources as the goal [1, 2]. At present, more than two-thirds of the world's foreign trade cargo are shipped by sea. In order to meet the increasing service demands of customers and keep a foothold in the increasingly competitive market, we must constantly broaden the functions of port logistics, improve service efficiency, and develop towards providing all-round value-added services. Nowadays, more and more ports are changing the traditional single function of cargo handling and transportation and gradually developing towards providing modern logistics services [3, 4]. Relying on the port, developing modern logistics has become an important strategic measure for the port to seek long-term development and enhance competitiveness. As the node of the global comprehensive transportation network, the port plays a more and more important role in the development of modern logistics. The port realizes the function of modern logistics center with compound advantage, the port multiple identities have strategic status in the international logistics, and the port provides value-added services through the logistics system.

Zhang and Chen [5] mainly present the logistics reasonable degree, the logistics efficiency and the service level, and the external environment three angles to construct the Tianjin area logistics development level index system and have carried out the appraisal analysis. Hyland et al. [6], through the evaluation and ranking of the logistics industry

competitiveness of Shandong Peninsula urban agglomeration and its eight cities, found that the regional economic strength, the competitiveness of logistics enterprises, and the capability of scientific and technological innovation of logistics industry are the main factors affecting the competitiveness of logistics industry of cities. Although the port logistics has been widely concerned and the port logistics industry has made rapid development, the evaluation of the port logistics function is less studied. Therefore, an evaluation model of port logistics function based on entropy weight TOPSIS method is proposed. The level of port infrastructure, the scale of logistics industry, the level of hinterland economic development, and the level of informatization are the factors of the evaluation index system. The study shows that the proposed port logistics function evaluation model is of great significance to drive the sustainable economic development of the surrounding areas.

2. Entropy Weight TOPSIS Method for Port Logistics Function Evaluation Index Factors

2.1. Construction of Evaluation Index System. There are many complicated factors involved in the evaluation of port city logistics competitiveness. To reflect the status and characteristics of the comprehensive competitiveness system comprehensively and accurately, the evaluation index system should present a structural hierarchy. Hierarchical evaluation can not only get the overall evaluation results, but also understand the evaluation status of each level and reflect the whole picture of port city logistics competitiveness systematically [7–9]. In order to reflect the logistics competitiveness of port city, taking into consideration the availability of data, this paper constructs 4 first-class indexes, including port infrastructure, logistics industry scale, hinterland economic development, and informatization level.

2.1.1. The Level of Port Infrastructure. Port has been an important transportation infrastructure since ancient times, which is the window to realize economic and trade exchanges and cooperation and provides basic support for economic construction and foreign trade development [10–12]. For coastal port cities, port is the core and carrier of city logistics industry. Perfect infrastructure and superior conditions directly affect the operation capacity and efficiency of port and then affect the competitiveness of city logistics. This paper mainly chooses 5 secondary indexes, namely, dock length, berth number, 10000 berth number, port cargo throughput, and port container throughput.

2.1.2. Logistics Industry Scale. The scale of logistics industry and the competitiveness of logistics in port cities complement and influence each other to a large extent [13, 14]. The expansion of logistics industry in a city means that the city has a comparative advantage in logistics competitiveness, and the strong logistics competitiveness in turn accelerates the expansion of the city's logistics industry. Road mileage, road cargo transport, waterway cargo transport, road cargo turnover, and waterway cargo turnover are mainly selected as 5 secondary indicators.

2.1.3. Hinterland Economic Development Level. Hinterland economy plays a vital role in any industry, and the development of port city logistics industry cannot do without the support of hinterland economy. Hinterland economy provides support and guarantee for the development of logistics industry. The larger the hinterland economy scale is, the more developed the logistics industry in port cities is [15, 16]. This paper selects 5 secondary indexes: GDP, total import and export, secondary industry added value, tertiary industry added value, and total fixed asset investment.

2.1.4. Information Level. Logistics informatization is a series of processing activities, such as collection, classification, transmission, summary, identification, tracking, and inquiry of the information generated in the process of urban logistics. The informatization level of port cities reflects the efficiency level of the urban logistics industry and mainly selects four secondary indicators, namely, the total amount of postal and telecommunications services, the number of mobile phone users, the number of fixed-line telephone users at the end of the year, and the number of the Internet broadband users [17].

2.2. Entropy Weight-TOPSIS Model

2.2.1. Entropy Weight Method. Entropy weight method is an objective valuation method, which measures the effective information and index weight contained in known data by calculating the information entropy of indexes [18]. The calculation formula is

$$C_i = L_i + G_i + F_i + \lambda. \tag{1}$$

In the formula, i represents the total investment cost of the port logistics enterprise in the development stage; L_i, G_i, and F_i, respectively, represent the circulation cost, management cost, and service cost of the enterprise in the development i stage; and λ represents the other costs required by the enterprise's production and operation. The smaller the information entropy of an index, the greater the variation degree of the index, the greater the amount of information provided, and the greater the role of the index in the comprehensive evaluation, the higher its weight. Conversely, the greater the information entropy of the index, the lower its weight.

2.2.2. TOPSIS Method. TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), also known as approximate ideal solution ordering, is a multiobjective decision-making method [19]. The basic principle is that the ideal solution and the negative ideal solution of the decision problem are defined, and then the feasible solutions are compared with the ideal solution and the negative ideal solution. If one of the feasible solutions is the closest to the

ideal solution and is far away from the negative ideal solution, the solution is the satisfactory solution of the feasible solution set.

Basic Steps. Assuming that there are m coastal port cities and n cities' logistics competitiveness evaluation indexes, the corresponding original data matrix of each port city and logistics industry competitiveness evaluation index is as follows:

$$R = \left(r_{ij}\right)_{mn} = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \vdots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix}. \quad (2)$$

Calculate the proportion of PIPIJ for each indicator for each port city:

$$y_{ij} = \frac{r_{ij} - \min\left(r_{ij}\right)}{\max\left(r_{ij}\right) - \min\left(r_{ij}\right)}. \quad (3)$$

Calculate the proportion of the j index of the i port city p_{ij}:

$$p_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} r_{ij}}, \ (j = 1, 2, \ldots, n). \quad (4)$$

According to the relative proximity degree, the evaluation objects are sorted. The larger p_{ij}, the closer to the ideal solution; conversely, the smaller p_{ij}, the closer to the negative ideal solution.

3. Construction of Port Logistics Function Evaluation Model

The construction of port logistics function evaluation model mainly includes the construction of port logistics function evaluation index system, the measurement and weight of evaluation index, and the final evaluation standard.

3.1. Construction of Comprehensive Evaluation Model for Port Logistics Function. Only by establishing a reasonable evaluation model can the function of port logistics be evaluated effectively. Combining with the theoretical knowledge of port logistics function, the comprehensive evaluation model of port logistics function is constructed, as shown in Figure 1.

According to the comprehensive evaluation model of port logistics function, the evaluation index system of port logistics function is shown in Figure 2.

The comprehensive evaluation model of port logistics function includes quantitative index and qualitative index, and the meanings and functions of each index are different. In order to achieve better evaluation results, different evaluation criteria should be given to each index. This paper adopts fuzzy evaluation criteria set method, divides each index into five grades, puts forward the score corresponding to each grade, establishes fuzzy evaluation criteria set, realizes index quantification, and facilitates the implementation of comprehensive evaluation of port logistics function

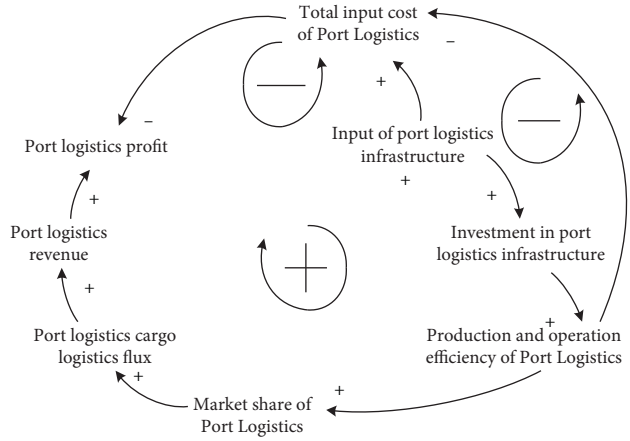

Figure 1: Comprehensive evaluation model of port logistics function.

[20, 21]. This set of fuzzy evaluation criteria is a kind of reference data. When adopting different comprehensive evaluation methods, we can use different quantitative methods and criteria according to specific conditions and needs. In order to embody the function, status, and importance of each index in the system, it is necessary to assign different weights to each index after the index system is determined [22, 23]. The judgment matrix is constructed by using AHP and the scale from 1 to 9 to determine the weights of each index. The calculation is carried out with the help of MATLAB mathematical software; the pseudocode of the process is as follows.

$$U = \begin{bmatrix} 1 & 3 & 5 & 4 & 7 \\ 1/3 & 1 & 3 & 2 & 5 \\ 1/5 & 1/3 & 1 & 1/2 & 2 \\ 1/4 & 1/2 & 2 & 1 & 3 \\ 1/7 & 1/5 & 1/2 & 1/3 & 1 \end{bmatrix}. \quad (5)$$

The criteria for evaluating specific secondary indicators in the model are as follows:

U11 port cargo throughput: Quantitative indicators, usually expressed as "10000 tons."

U12 port container throughput: Quantitative indicators, usually expressed as "Ten Thousand Bidding Containers (ten thousand TEU)."

U13 port foreign trade throughput: Quantitative indicators, usually expressed as "10000 tons."

U14 port routes: quantitative indicators, usually expressed in terms of "items."

The evaluation criteria are shown in Table 1 below.

To determine the weight of each indicator, the formula is as follows:

$$U_1 = \begin{bmatrix} 1 & 1 & 3 & 3 \\ 1 & 1 & 3 & 3 \\ 1/3 & 1/3 & 1 & 1 \\ 1/3 & 1/3 & 1 & 1 \end{bmatrix}. \quad (6)$$

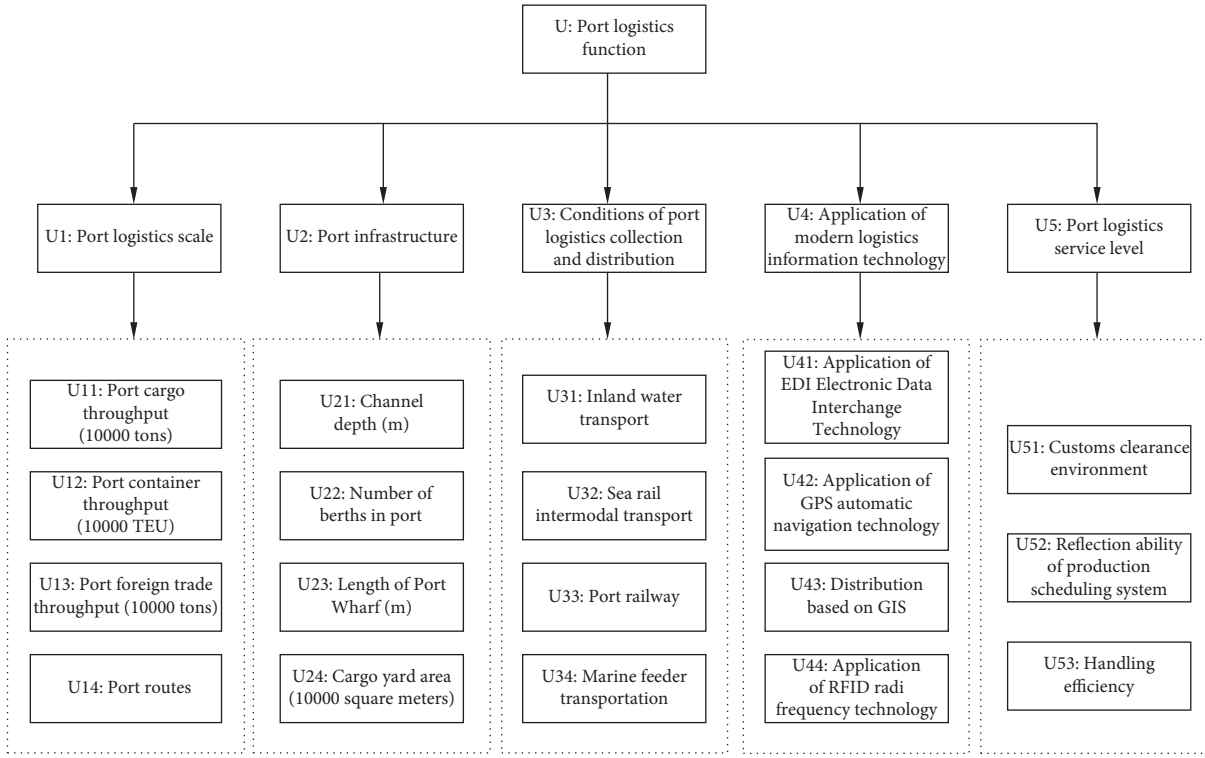

Figure 2: Port logistics function evaluation index system.

```
(1) function [s, ww] = shang (x, ind)
(2) %sReturns the score of each line (sample), w Returns the weight of each column.
(3) [n, m] = size(x); % n Samples, m Indicators
(4) Xx = guiyi (x, 1, 0.002, 0.996);
(5) %%Under the calculation of the j th index, the proportion of the i th sample in the index p (.)
(6) for i = 1:n
(7) for j = 1:m
(8) p(.J) = X (ij)/sum (X(ij));
(9) end
(10) end
(11) %%Calculate the entropy value e(j) of the jth index
(12) k = 1/log (n);
(13) e = ones (1, m);
(14) for j = 1:m
(15) e() = −k ∗ sum(p(:j).: ∗ o(:j))))
(16) end
(17) d = ones (1, m)-e; %Compute information entropy redundancy.
(18) w = d./sum(d); %Find the weight w.
(19) s = 100″w”X”; %Seek comprehensive score
(20) The specific results are as follows:
```

Algorithm 1

U21 channel water depth: quantitative indicators, usually expressed as “meters.”

Number of U22 berths: quantitative indicators.

U23 port and wharf length: quantitative indicators, usually expressed as “meters.”

U24 storage area of goods: quantitative index, usually expressed as “ten thousand square meters.”

The evaluation criteria are shown in Table 2 below.

To determine the weight of each indicator, the formula is as follows:

Table 1: Scoring standard 1.

Index	5	4	3	2	1
U11	U11 ≥ 30000	20000 ≤ U11 < 30000	U11 < 20000	U11 < 10000	U11 < 5000
U12	U12 ≥ 900	800 ≤ U12 < 900	U12 < 800	200 ≤ U12 < 700	U12 < 200
U13	U13 ≥ 18000	17000 ≤ U13 < 18000	13000 ≤ U13 < 17000	8000 ≤ U13 < 17000	U13 < 8000
U14	U14 ≥ 140	120 ≤ U14 < 140	100 ≤ U14 < 120	80 ≤ U14 < 100	U14 < 80

$$U_2 = \begin{bmatrix} 1 & 1 & 3 & 3 \\ 1 & 1 & 3 & 3 \\ 1/3 & 1/3 & 1 & 1 \\ 1/3 & 1/3 & 1 & 1 \end{bmatrix}. \quad (7)$$

U31 inland water transportation: qualitative indicators.

U32 seaborne and railway combined transport: qualitative indices.

U33 railway: qualitative indicators.

U34 maritime feeder line transportation: qualitative indicators.

The evaluation criteria are as follows: excellent, 5 points; good, 4 points; average, 3 points; fair, 2 points; and poor, 1 point.

To determine the weight of each indicator, the formula is as follows:

$$U_3 = \begin{bmatrix} 1 & 5 & 1/3 & 1/3 \\ 5 & 1 & 3 & 3 \\ 3 & 1/3 & 1 & 1 \\ 3 & 1/3 & 1 & 1 \end{bmatrix}. \quad (8)$$

U41EDI electronic data interchange technology application: qualitative indicators.

U42 GPS global positioning system technology application: qualitative indicators.

U43 GIS technology application: qualitative indicators.

U44 RFID application of radio frequency technology: qualitative indicators.

The evaluation criteria are as follows: excellent, 5 points; good, 4 points; average, 3 points; fair, 2 points; and poor, 1 point.

To determine the weight of each indicator, the formula is as follows:

$$U_4 = \begin{bmatrix} 1 & 1 & 3 & 3 \\ 1/2 & 1 & 1 & 2 \\ 1/2 & 1 & 1 & 2 \\ 1/2 & 1/2 & 1/2 & 1 \end{bmatrix}. \quad (9)$$

U51 customs clearance environment: qualitative indicators.

U52 production scheduling system capacity: qualitative indicators.

U53 loading and unloading efficiency: qualitative index.

The evaluation criteria are as follows: excellent, 5 points; good, 4 points; average, 3 points; fair, 2 points; and poor, 1 point.

To determine the weight of each indicator, the formula is as follows:

$$U_2 = \begin{bmatrix} 1 & 1 & 2 \\ 1 & 1 & 2 \\ 1/2 & 1/2 & 1 \end{bmatrix}. \quad (10)$$

3.2. Determination of Criteria for Comprehensive Evaluation Results. The final evaluation result shall be set as "good, better, general, poor, and poor." The above secondary indicators are sorted according to the score. When the number of indicators with a score of 5 points is the largest, the final evaluation result is 5 points. The final evaluation result is 4 points when the secondary index scores 4 points at most. The final evaluation result is 3 points when the secondary index scores 3 points at most. The final evaluation result is 2 points when the secondary index scores 2 points at most. When the number of secondary indicators with a score of 1 is the largest, the final evaluation result is 1. Thus, the standard set of final comprehensive evaluation results can be determined, as shown in Table 3.

4. Experimental Analysis

4.1. Selection of Sample Data. Port is located in the sea, rivers, lakes, and reservoirs along the water and land transport hub. It is the center for distribution of industrial and agricultural products, foreign trade import and export, vessel berthing, loading and unloading of goods, boarding and alighting passengers, and supplementary supplies. According to the overall competitiveness index of ports in the world, logistics efficiency, and the actual situation of major ports, this paper selects the top nine ports in the world in terms of throughput, namely, Zhoushan Port in Ningbo, Shanghai Port, Singapore Port, Tianjin Port, Kwai Chung Container Terminal, Busan Port in Korea, Guangzhou Port, Suzhou Port, and Qingdao Port, and then selects Dubai Port as the sample port for port logistics efficiency evaluation [24].

These nine ports are located in the regions with fast development of port logistics and developed port economy. In a year, the cargo throughput of these nine port cities is as high as the container throughput of the whole country [25]. Therefore, this paper will use these nine ports as experimental cases, which are representative to some extent, and can roughly represent the port development. The relevant data of the port comes from official website, a port operation company. Set the experimental environment as MATLAB 2.0 simulation platform, with 100 iterations, 20 allowable failures, and 2 clustering centers.

Table 2: Scoring standard 2.

Index	5	4	3	2	1
U21	U21 ≥ 18000	17000 ≤ U21 < 18000	13000 ≤ U21 < 17000	8000 ≤ U21 < 17000	U21 < 8000
U22	U22 ≥ 200	140 ≤ U22 < 200	90 ≤ U22 < 140	50 ≤ U22 < 90	U22 < 50
U23	U23 ≥ 35000	30000 ≤ U23 < 35000	200000 ≤ U23 < 30000	10000 ≤ U23 < 2000	U23 < 10000
U24	U24 ≥ 160	130 ≤ U24 < 160	100 ≤ U24 < 130	70 ≤ U24 < 100	U24 < 70

Table 3: Standard set of final evaluation results.

Result score	$U = 5$	$4 \le U < 5$	$3 \le U < 4$	$2 \le U < 3$	$1 \le U < 2$
Corresponding standard	Good	Better	GeneralRelatively	Poor	Difference

Table 4: Results of grade i evaluation of competitiveness of port city logistics function.

Port	Port infrastructure		Scale of logistics industry		Hinterland economic development		Informatization level	
	U	Ranking	U	Ranking	U	Ranking	U	Ranking
Zhoushan port of Ningbo	0.1607	5	0.1650	8	0.4849	2	0.1347	2
Port of Shanghai	0.1254	6	0.4016	2	0.1178	8	0.0612	6
Port of Singapore	0.1621	4	0.2110	6	0.2680	3	0.0699	5
Port of Tianjin	0.1227	7	0.2197	4	0.1732	5	0.0378	8
Kwai Chung container terminal	0.4863	2	0.2303	3	0.1756	4	0.0716	4
Port of Busan	0.1811	3	0.1895	7	0.0235	9	0.0165	9
Port of Guangzhou	0.9711	1	0.7894	1	0.7687	1	0.3065	1
Port of Suzhou	0.1064	8	0.1057	9	0.1281	6	0.0477	7
Port of Qingdao	0.0375	9	0.2187	5	0.1251	7	0.1209	3

Table 5: Results of data characteristics of input and output variables for 2018 and 2019.

Indicators	Minimum value	Maximum value	Median value	Mean value	Standard deviation
U_1	23.0	733.0	77	156.8	156.7
U_2	18.0	94.0	39.0	44.5	25.1
U_3	7.8	58.9	46.7	49.7	19.2
U_4	8.0	2619.2	196.8	484.7	583.5
U_5	8.9	79.0	47.2	45.7	24.1

4.2. Experimental Results. According to the index system, the paper analyzes the data according to the above steps and evaluates the competitiveness of logistics function of 9 port cities, as shown in Table 4.

Table 4 mainly analyzes the subindex of port city logistics competitiveness and analyzes the port infrastructure index. From Table 4, we can see that Guangzhou port has the highest degree of similarity U, and all of the four indexes rank first, which shows that Guangzhou port has great advantages over other port cities in port infrastructure construction and equipment supply. Kwai Chung container terminal, Korea Busan Port, and Singapore boat port ranked second, third, and fourth, respectively, in terms of infrastructure indicators [26–28]. Guangzhou port and Kwai Chung container terminal rank high in terms of wharf length, port cargo throughput, and container throughput. Both ports rely on good port infrastructure environment and have relatively strong competitiveness in logistics function. The payback period for port investment shall generally be five years and shall be combined with the actual conditions. Port planning shall be carried out once every five years. Data five years apart make sense if you want to measure how much dynamic efficiency has improved [25, 29, 30]. Calculate the description of the minimum, maximum, median, average, and standard deviation of the input and output indicator variables for 2018 and 2019 according to formula (1). The details are shown in Table 5.

According to the data in Table 1 and based on the extended model of DEAP software, the port logistics efficiency in 2018 and 2019 can be calculated, and various efficiency values and scale rewards in the two years can be taken as "reference index" and "current index," respectively, as shown in Tables 6 and 7.

As can be seen from Tables 6 and 7, the input-output efficiency column vertical comparison in the table, ranging from 0.3 to 0.9, shows a significant gap in the input-output efficiency of each port. While for the horizontal comparison of input-output efficiency of each port in 2018 and 2019, except for some ports that have developed rapidly in recent years, the values of most ports are closer. Data distribution trends are as shown in Figure 3.

The following is evident from Figure 3:

Table 6: Input-output efficiency levels of nine ports in 2018.

Port	Benefit value in 2018			
	Input output rate (crate)	Pure technical efficiency (vrste)	Economies of scale (scale)	Returns to scale
Ningbo Zhoushan port	0.756	0.596	0.902	Incremental
Shanghai port	0.596	0.718	1.000	Unchanged
Singapore port	0.342	0.754	0.549	Incremental
Tianjin port	0.414	0.522	0.645	Incremental
Kwai Chung container terminal	0.336	1.000	0.851	Incremental
Kwai Chung container terminal	0.851	0.961	0.426	Incremental
Guangzhou port	0.409	1.000	0.384	Incremental
Suzhou port	0.384	1.000	1.000	Incremental
Qingdao port	1.000	1.000	1.000	Unchanged

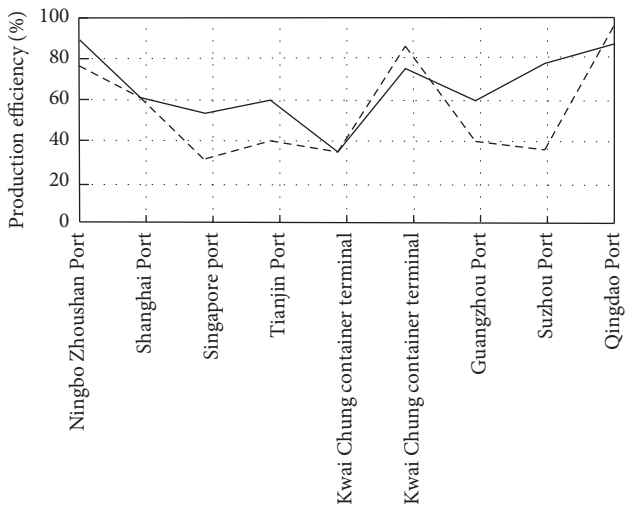

Figure 3: Distribution chart of "Reference Index" and "Current Index" of nine major ports.

(1) Among all the nine ports, Zhoushan port of Ningbo ranks first. Based on the analysis of the reasons, we can see that since the merge of the two pillar ports of Zhejiang province, Ningbo and Zhoushan in 2018, the cargo transport volume has also greatly increased, which has made the scale and potential of the port of Zhoushan port of Ningbo rapidly improved. Due to the location in the Yangtze River Delta economic zone and the rapid economic development of Zhejiang province, the port has been able to further increase the pace of opening up to the outside world, and the influx of more advanced management skills, experience and corresponding talents with high skills, which has greatly improved the logistics efficiency of the port [14]. Therefore, Ningbo Zhoushan port is not only a simple merger of the two ports, but also a forward-looking strategic merger, which leads to more economic derivatives of the port and makes the port economic zone more prosperous.

(2) Busan port of Korea is the only port where the "current index" is lower than the "reference index," which is due to the fact that the limited hinterland railway mileage is a restrictive factor, which makes the intermodal transport of Hong Kong and rail of Busan port of Korea stand still in the process of port development and there is no significant improvement. Only a small number of railways still maintain South Korea's Pusan port's intermodal rail transport, despite being highly efficient, it cannot solve the capacity, capacity constraints.

(3) The fastest rising port among the nine ports is Suzhou port, with the index rising from 0.385 to 0.756. This is due to the fact that, before 2019, Suzhou port is an unplanned port. And the first phase of the 10000-ton channel of Suzhou port starts to be put into use in 2018, which indicates that Suzhou port is one step closer to the international hub port, which essentially improves the function of the port, establishes its status as a major hub port, and provides favorable conditions for the large-scale heavy chemical industry to carry out in Suzhou port. At the same time, the port allows the future development of Suzhou port to open up a new situation [31].

In order to verify the effectiveness and feasibility of the evaluation model of port logistics function based on entropy weight TOPSIS method, Dubai port is selected as a sample port to investigate the port logistics profit in the recent 6 years. In the port logistics function evaluation model, the data of Dubai port logistics management are shown in Table 8.

According to the two management data tables, the application of the port logistics function evaluation model can stimulate the volume of logistics and transportation and increase the revenue. Table 9 shows the business indicators obtained from the survey.

According to the above investigation results, the economic benefit of the enterprise is improved. Therefore, three economic benefit evaluation models are used to evaluate the economic benefit of the enterprise. The effective use of port resources and the protection of the natural environment to evaluate the port logistics not only aim at the profit, but also consider the efficiency of port logistics so that the port to find constraints logistics capacity and efficiency of the constraints is conducive to the optimization of port resource allocation, increasing port competitiveness. It is of great significance to

Table 7: Input-Output efficiency levels of nine ports in 2019.

Port	Benefit value in 2018			
	Input output rate (crate)	Pure technical efficiency (vrste)	Economies of scale (scale)	Returns to scale
Ningbo Zhoushan port	0.857	0.857	1.000	Unchanged
Shanghai port	0.603	0.603	1.000	Unchanged
Singapore port	0.487	0.732	0.665	Incremental
Tianjin port	0.605	0.758	0.798	Incremental
Kwai Chung container terminal	0.366	0.581	0.631	Incremental
Kwai Chung container terminal	0.731	1.000	0.731	Incremental
Guangzhou port	0.626	0.843	0.743	Incremental
Suzhou port	0.756	0.821	0.689	Unchanged
Qingdao port	0.847	1.000	0.847	Incremental

Table 8: Operational data of logistics enterprises at Dubai port.

Business name	Index/ton	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Branch transportation	Container capacity	852876	1068876	1202556	1315448	1554262	1682439
	Bulk cargo volume	349965	315234	371485	400762	421503	43147
Land transportation	Container haulage	248857	232891	289704	323587	342875	35708
Dock handling	Container throughput	682452	1102279	1432956	1657844	1794325	190210
	Bulk cargo throughput	1325507	1899964	1765143	1923640	2018769	2148612

Table 9: Business indicators of logistics enterprises.

Index/10000 yuan	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Operating income	107877.92	119170.12	121571.14	128635.22	135753.86	149608.05
Operating costs	87942.08	96420.54	96004.74	100302.15	103846.33	110695.81
Gross profit	19935.84	22749.58	25566.41	28035.69	29712.95	30754.37
Gross profit margin (%)	18.48	19.09	21.03	22.03	22.51	26.01

study the capacity and efficiency of port logistics for improving the core competitiveness of port enterprises and driving the sustainable economic development of surrounding areas.

5. Discussion

In recent years, with the prosperity and development of economy, modern logistics industry has gradually developed from the start to prosperity. Port logistics, as an indispensable part of modern logistics, has gradually developed into a new supporting role of industrial departments and national economy. In addition, the evaluation index system of port logistics capacity and port logistics efficiency is established to evaluate the port logistics capacity in order to verify its scientificity and effectiveness. It is feasible to explore the influence of port logistics capacity and efficiency on port competitiveness, which is beneficial to the development of port itself and provides theoretical basis for port management. It is hoped that this paper can provide some suggestions for the future construction of the port so as to improve the logistics capacity and efficiency.

From the aspect of port logistics capability, we can strengthen port logistics competitiveness from the following four aspects: enlarge the scale of port logistics, standardize port logistics equipment and facilities, improve port logistics operation capability, and speed up the development of port economic hinterland.

In terms of port logistics efficiency, we can strengthen the competitiveness of port logistics from the following four aspects: increasing investment in port logistics infrastructure, strengthening the connection between port and its hinterland economy, innovating the port management system, and starting to specialize in compound talents in logistics. We should give full play to the advantages of urban logistics, constantly enhance their own strength, give play to the proliferation effect, drive the development of logistics in surrounding areas, and improve the regional logistics capacity and level. Medium-level cities shall rely on the advantages of port facilities, focus on strengthening the connection between ports and hinterland economy, actively expand hinterland economy, improve the total economic output of hinterland, and provide a solid economic foundation for the logistics industry. At the same time, we should develop the information construction, including the basic environment construction and the information platform construction, enhance the logistics efficiency, and enhance the logistics competition strength. Cities with relatively weak logistics competitiveness shall accelerate the construction of port infrastructure, increase the investment in port projects, improve the port operation capacity, and enhance the

logistics strength; learn from the development and operation experience of domestic and foreign advanced logistics enterprises, create a good environment and conditions for the logistics industry, and constantly expand the scale of the logistics industry; develop hinterland economy and provide a material and economic basis for enhancing the competitiveness of urban logistics; and strengthen the construction of external environment and platform for logistics informatization, accelerate the development of modern logistics, and constantly enhance the logistics competitiveness.

In the next stage of development, port enterprises should start from the actual situation, seize the development opportunities of the fourth generation of port, integrate resources from service, function, and other aspects, optimize resource allocation, and improve port logistics capacity and efficiency so as to comprehensively enhance the core competitiveness of port logistics.

6. Conclusions

In this paper, the entropy weight method and TOPSIS method are used to evaluate the logistics performance of ports, and a data analysis model applicable to many ports is constructed. However, this paper still has the following deficiencies: First of all, data collection, some data is not comprehensive; individual data collected by different ways of the results of the differences between them have certain gaps. Secondly, the establishment of the model has some limitations, the application of the model is still not very mature because the port logistics is a comprehensive complex whole, and there are still many factors affecting the port logistics capacity and port logistics efficiency cannot be considered in specific parts, so the model is not comprehensive. It is hoped that with the development of science and technology and the improvement of data collection, the evaluation model of port logistics capability and efficiency will be improved [32].

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

It is declared by the authors that this article is free of conflicts of interest.

Acknowledgments

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Research Article

Optimization of English Learning Mode under the Influence of Artificial Intelligence Translation

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With the development of social science and technology, artificial intelligence has been applied to many fields, and artificial intelligence translation has provided great help for language learners. This paper analyzes the necessity of artificial intelligence translation for English learning, explores the influence of artificial intelligence translation on English learning, and proposes optimized English learning modes which provide help to the people involved.

1. Introduction

With the continuous development of social technology, machine translation has become more and more mature and intelligent, which has brought great convenience to the current English teaching; however, many teachers and students are increasingly dependent on high technology. In this regard, English professors and learners should see this more clearly. With the help of the big data advantages of artificial intelligence, we can rationally use artificial intelligence translation, optimize learning modes, and promote the improvement of teaching quality.

2. The Development of Artificial Intelligence Translation

Language is a tool for communication between people, not only containing semantics but also carrying culture, emotions, and so on. Translation serves as a tool for normal human communication. There are structural, cultural, and other differences between different languages, so it is not easy to accurately express the source text. Machine translation is the study of how computers can be used to translate one language into another. "Machine translation, also known as automated translation or computer translation, has undergone more than 60 years of development since its introduction in the 1940s and has gradually transformed from the early optimistic fully automated high-quality machine translation to the more realistic and feasible computer-assisted translation" [1]. The computer-aided translation is dominated by human translation, using computer data as an auxiliary tool, and the computer data here is the corpus that translators build in their own translation work. The core technology of computer-aided translation is the extraction of translation memory technology [2], and the quality of the translation is controlled by the translator, which emphasizes human-computer collaboration in translation. Machine translation started out with phrases and statistics and then gradually evolved to be based on neural networks (Figure 1). The quality and efficiency of translation in neural machine translation methods have been greatly improved [3].

In 2017, the artificial intelligence translation box appeared, and the bilingual translation of everyday language using the product was amazingly fast and accurate. At the 2018 Boao Forum for Asia, Tencent simultaneous interpretation made its debut simultaneous interpretation at a large conference, setting a precedent of not using human translation and relying only on machines for translation. Artificial intelligence translation has become a hot topic. In simultaneous interpretation, speech-to-text speech

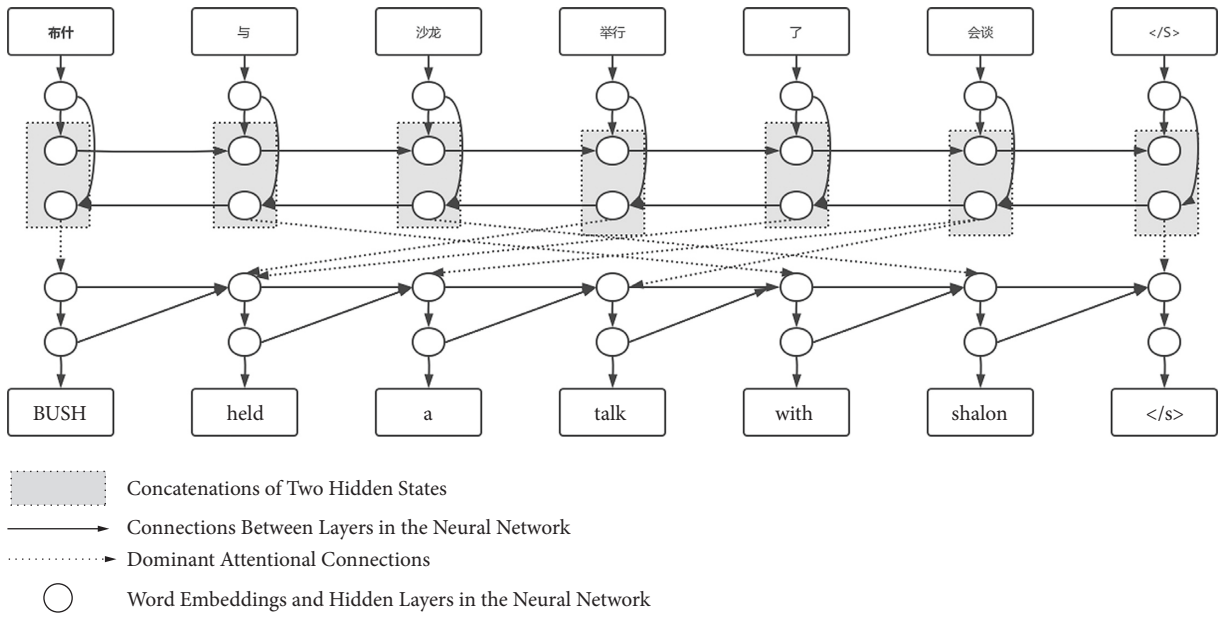


Figure 1: Neural network translation based on attention mechanism.

translation problems are more challenging than traditional text-to-text machine translation problems (Figure 2). First of all, there is a cross-modal language mapping between source-side speech and target text, and the difference between the two languages further increases the difficulty in learning this mapping. At present, the end-to-end speech translation model has received more and more attention, and the context information that is dependent on long distances can be compressed into an enhanced memory bank, which provides convenience for streaming decoding under low-latency conditions [4]. At present, most simultaneous interpreting decodes signals with the Wait-k strategy (Figure 3). Artificial intelligence translation relies on big data to extract and use the corpus contained in the database. The translation is fast and accurate, and the repetitive work is replaced by machines.

Artificial intelligence translation has the characteristics of high quality and high efficiency, but it also has its own limitations. It does not have human emotions and thinking, and there are still certain differences with the translation of human translators. [5] For example, as to the more common diplomatic style, which has a lot of unspoken meanings, vague language, etc., it is difficult to achieve the desired effect relying on machine translation. What cannot be denied in the translation process is the dominant position of man. Language is the carrier of culture, expressing human emotions, and these humanistic activities are by no means repetitive labor. Current AI is not yet competent for creative labor. Therefore, although the era of artificial intelligence is anticipated, it is still necessary to learn foreign languages.

3. The Necessity of Artificial Intelligence Translation

Machine translation could be viewed in this way: a language s is distorted due to passing through a noise channel and appears as another language t at the other end of the channel. The translation problem is actually how to recover the most likely language s according to the observed language t. Language s is the input in the sense of channel and the target language in the sense of translation; language t is the output in the sense of channel and the source language in the sense of translation [6].

From this point of view, any sentence in one language may be the translation of some sentences in another language, but the possibilities of these sentences are different. Machine translation is to find the sentence with the greatest possibility, that is, to calculate the one with the greatest probability for all possible target languages s, as the translation of source language t. Due to the huge number of s, the stack search method can be used. The main data structure of trestle search is the table structure, in which the most promising s corresponding to t is stored. The algorithm keeps cycling, and each cycle expands some of the most promising results until the table contains an s whose score is significantly higher than other results. Trestle search cannot guarantee the best results, and it will lead to wrong translation, so it is only a suboptimization algorithm. It can be seen that the task of a statistical machine translation system is to find the sentence with the greatest probability as the translation result in all possible sentences of the target language (target language in the sense of translation, that is, source language in the sense of noise channel model). Its probability value can be obtained by using the Bayes formula (t in the formula is the target language in the sense of translation, and s is the source language in the sense of translation):

$$P\left(\frac{T}{S}\right) = \frac{P(T)P(S/T)}{P(S)}. \tag{1}$$

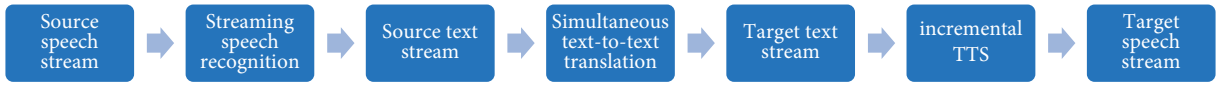


Figure 2: Cascade system.

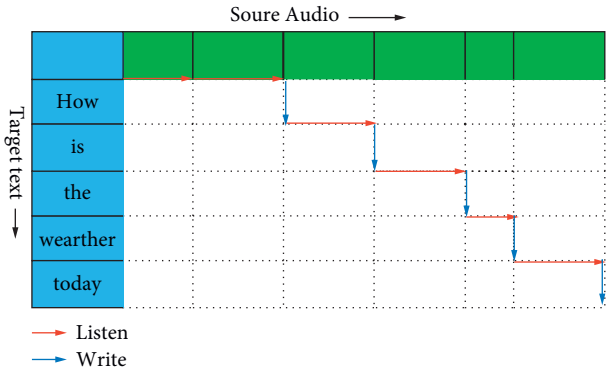


Figure 3: Wait-k decoding process.

Since the denominator $P(S)$ on the right side of the equation is independent of T, finding the maximum value of $P(T/S)$ is equivalent to finding a T, so that the two-term product $P(T)P(S/T)$ of the molecule on the right side of the equation is the maximum, that is,

$$T = \arg\max P(T)P\left(\frac{S}{T}\right), \tag{2}$$

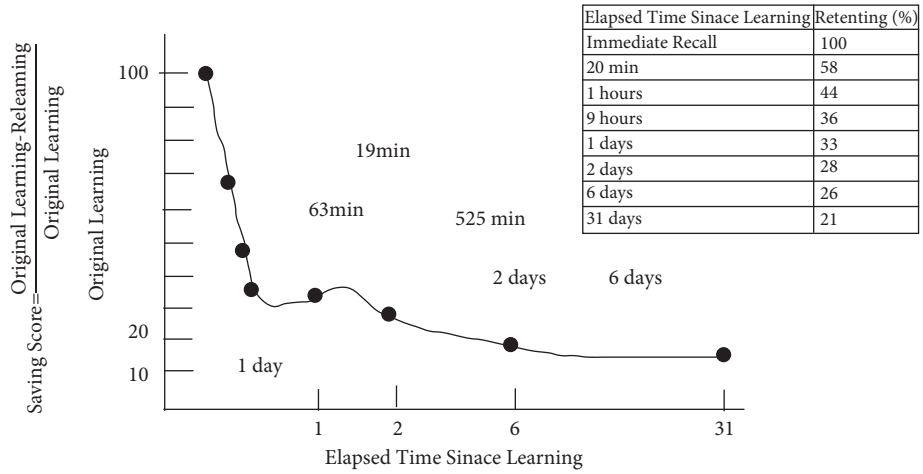
where $P(T)$ is the language model of the target language and $P(S/T)$ is the translation model of s given t. According to the language model and translation model, the process of solving the nearest real target language sentence t given the source language sentence s is equivalent to the process of decoding in the noise channel model.

For machine and human translation, although the quality of human translation is better, machine translation has attracted much attention because of its unique advantages. The efficiency of machine translation is high. A human translator can complete a translation of about 2,000 words in eight hours, and a machine translator can translate 3,000 words in one second. Therefore, for some majors with high repetition of terminology structure and strong controllability, it is possible to use machines for preliminary translation and then modify them by translators, which can reduce the work pressure of translators and improve the overall translation efficiency. Moreover, the machine is capable of mastering multiple foreign languages, which is difficult for translators to achieve. However, artificial intelligence translation also has certain shortcomings and cannot automatically verify the translated content. Therefore, the combination of man and machine can better meet the current needs of translation. Under the continuous advancement of globalization, even if it is not the translation industry personnel, such as college students and teachers, there are many occasions to deal with some foreign language materials in daily work and learning, and there are sometimes some limitations in their own ability, and artificial intelligence translation technology will provide great help. In the new era, the better use of science and technology is conducive to providing quality services for mankind.

Artificial intelligence translation technology relies on big data to achieve instantaneous translation, which has an important impact on consolidating their learning effects and improving learning efficiency for English learners. The "forgetting curve" proposed by Ebbinghaus explains the level of human memory, from which we learn that if people do not strengthen the memory of existing knowledge, they will forget the knowledge in their future learning and life (Figure 4). In short, after learning English knowledge, if students do not review the English knowledge they have learned in time, after a long time, students' memory of English knowledge will be less and less [7] and eventually they will forget . Therefore, in the English learning activities, students need to constantly review the knowledge they have learned, repeatedly deepen their understanding of the knowledge, and realize the long-term memory of knowledge. The advent of artificial intelligence translation makes many students have unlimited expectations for English learning. With the application and popularization of mobile terminal equipment such as smartphones, tablets, and computers, convenient learning tools are provided for students to learn English. Network electronic dictionaries, network cloud translation, and other network learning tools provide a lot of help in carrying out English learning activities, effectively improving students' learning efficiency, ensuring the quality of learning, and stimulating students' autonomy and initiative. By carrying out English learning activities with the help of artificial intelligence translation, students can learn more quickly, query the content that is not understood in English learning anytime and anywhere, and use the timeliness of the Internet to avoid mechanical learning.

4. The Optimization of the English Learning Mode by Artificial Translation

4.1. Efficient Learning. The forgetting curve of the German psychologist Ebbinghaus intuitively reflects that people will forget if they do not strengthen their memory. In other words, if they do not review after learning, the longer the time passes, the less they will remember, or even forget. With artificial intelligence translation software, students can quickly learn and review, breaking the time and space shackles of traditional learning. In case of incomprehension or uncertainty, you can use the software to check it out, and you can review it at any time and any place. At the same time, with the help of the advantages of all aspects of the Internet, English learners can also learn more effectively and meaningfully, avoid mechanical recitation, and promote the effective improvement of students' English level [8].



Elapsed Time Sinace Learning	Retenting (%)
Immediate Recall	100
20 min	58
1 hours	44
9 hours	36
1 days	33
2 days	28
6 days	26
31 days	21

Figure 4: The Ebbinghaus forgetting curve.

4.2. Interest-Based Learning. Some students prefer to use word lists or word books when learning English knowledge, but this learning method strips words from phrases, sentence patterns, and articles, and although students remember words, they do not use them. The use of intelligent translation to assist learning can avoid the occurrence of learning words without understanding its application. It can be faster and better to open the vocabulary barrier because intelligent translation skillfully combines words with phrases, sentence patterns, and articles, presenting learners with complete sentences instead of fragmented language. The advantages of intelligent translation can be based on big data to filter out the corpus that is closer to our lives and the corpus that is close to our favorite field to learn, which makes learning more interesting and more grounded. This is especially true for students with a slightly poor foundation. They can use translation software to make up for the personalized needs that cannot be met in the classroom, improve their interest in learning, make up for shortcomings, and let learning continue to occur [9].

4.3. Multisensory Participatory Learning. Taking advantage of the voice input and the output of artificial intelligence translation software, students can learn languages better. Intelligent translation provides complete sentences, which is extremely important for learners to correctly grasp grammar and syntax. For example, the machine learning group of Microsoft Research Asia applied their research results on dual learning and deliberation networks to the machine translation systems in 2018. Dual learning utilizes the natural symmetry of artificial intelligence tasks. After a Chinese sentence in the training set is translated into English, the system will translate the corresponding English results back to Chinese and compare them with the original Chinese sentence, so as to learn useful feedback from the comparison results and revise the machine translation model.

Deliberation networks are similar to the process of continuous deliberation and revision when people write articles. Through multiple rounds of translation, constantly check and improve the translation results, so as to greatly improve the quality of translation. Its purpose is to find a balance between deep learning and natural language. Through the research of machine translation, we can further understand machine learning from the perspective of natural language, find some intuition, and then use this intuition to affect the route of machine learning research and get out of the state of blind attempt. What is the intuition that researchers get from deliberation networks? It is found that when people are doing translation, after seeing or listening to the source language, they will form a point of view in their mind, which is actually the process of coding. However, when people really speak this sentence as a target language, they actually think twice before they act. People do not jump out word by word. They will first think about how to say it. If it is text translation, they may also constantly modify it to make the sentences more smooth or beautiful. Deliberation network is the decoder or text generator and puts some human intuition into it. There are multiple layers of decoders. The decoder may not translate well if it is done first, but after the translation from beginning to end, this sentence will be thrown to the next decoder to do it again. This process can be repeated constantly, constantly modifying the complete results of the previous translation, which is actually deliberating. The result after such deliberation is much better than that after only one time. The cost of time will increase, but the result will be better.

In the learning of the whole paragraph of translation, using artificial intelligence translation software, the result we get is complete, not just a single word or fragmented sentence. Based on the results of artificial intelligence translation, you can compare your own translation results with it, find out the problems of their respective words, language, and structure to correct and improve, and learn from errors. In addition, in the comparison, we can also find each other's highlights. We can carry forward our own highlights or borrow the strengths of the other to make up for our own shortcomings. Under the influence of the Internet and big data, language learning models need to change. Foreign language learners can no longer be limited to the learning of

words, phrases, and simple sentences but should develop more comprehensive abilities. Compared with the previous use of mobile apps to assist learning, access to web pages to improve listening or writing skills, the use of fragmented time to read English novels to improve reading ability, etc., intelligent translation is more comprehensive and effective to assist learning. Because of the use of intelligent translation, students can not only better grasp the words, but also improve their level of listening and speaking and even comprehensively train their ability to use words, grammar, syntax, and writing.

4.4. Seminar-Style Learning. The Internet is very time-sensitive, and the translation of the Internet greatly increases the probability that we will be exposed to the translation of hot words in learning, helping us to keep up with the pace of the times [10]. In the new era, English learners have been given new tasks, and foreign language learners shoulder the heavy responsibility of promoting Chinese culture abroad, requiring us not only to speak Chinese culture but also to speak well of Chinese culture, to express our views on current affairs and hot topics, and to discuss people's livelihood and people's feelings, so it is very important to keep up with the pace of the trend. With artificial intelligence translation software, students can conduct seminar-style learning and improve their English skills.

4.5. Critical Learning. Artificial intelligence translation is developing rapidly, and its shortcomings are obvious [11], so it is necessary for learners to have critical thinking ability and apply it reasonably. For the application of Chinese culture, the most important task is to understand the culture, to be able to define the essence and dross of culture, and to reasonably classify cultures. It is necessary for students to reasonably apply the critical learning model in English learning and view and spread cultures through critical thinking. For some mass culture and nonmainstream culture, it should not be blindly abandoned. It is reasonable to find out its highlights and actively learn from it. In this way, the role of artificial intelligence translation can be better played and the improvement of students' English level can be promoted. Although artificial intelligence translation has its limitations, it has obvious advantages in promoting better English learning over other technologies (Figure 5).

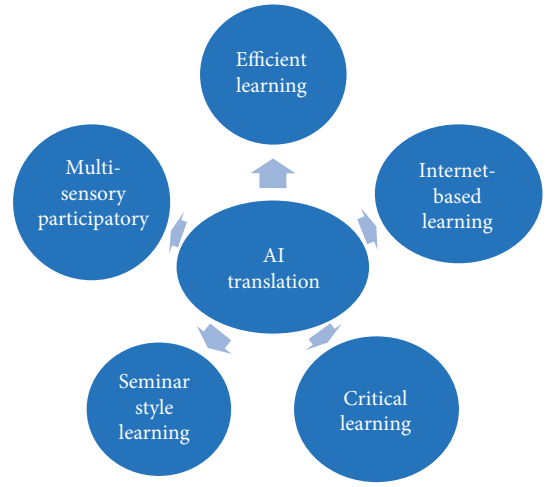


Figure 5: The optimized English learning modes by AI translation.

5. Suggestion for the Application of Artificial Intelligence Translation in English Learning

5.1. AI Translation Should Be Combined with Human Translation. Compared with human translation, some artificial intelligence translation software do have obvious advantages in some aspects, but there are some obvious disadvantages at the same time [12]. Machine translation has its basic process (Figure 6). In English learning, college students should not rely too much on machine or software translation; otherwise, the learning effect will be affected. For the scientific nature of English translation, it is necessary to ensure the accurate understanding of the translation content in the translation. Translators must have a solid foundation of foreign language knowledge and master some knowledge of stylistics, rhetoric, semantics, grammar, linguistics, and so on to achieve this requirement. Without an accurate understanding of the translation content, the translation process will be blind and random, and the ideal translation effect cannot be achieved. In addition, only when the translator understands the differences between the languages and cultures of the original text can he guarantee the preservation of the flavor of the original text in the translation process and avoid the problem of "translation cavity" [13], so as to produce high-quality translation. However, the current English-Chinese translation software have not reached a high degree of intelligence, cannot think like human beings, and do not have human emotions. Therefore, English-Chinese translation software should be combined with human translation to give full play to their advantages and improve the efficiency and effect of translation, so that it can be better applied in college students' English learning.

5.2. Basic Functions of Translation Software Should Be Strengthened. The most important function of English-Chinese translation software is the basic function of translation with its rule-based technical route (Figure 7). In recent years, with the continuous upgrading of various translation software, language appropriateness has been improved to a certain extent in terms of semantic expression and grammatical structure, but there is still a lot of room for improvement. In order to achieve further improvement for English-Chinese translation software in language appropriateness, it is necessary to conduct more in-depth research and exploration in language structures such as word order. Relevant studies show that many college students who apply English-Chinese translation software in English learning are not satisfied with the translation results and hope to combine the translation results with the corresponding cultural background to some extent. This demand of college students reflects the deficiencies of English-Chinese translation software at present. Generally speaking, it is still a problem

Figure 6: Basic process of machine translation.

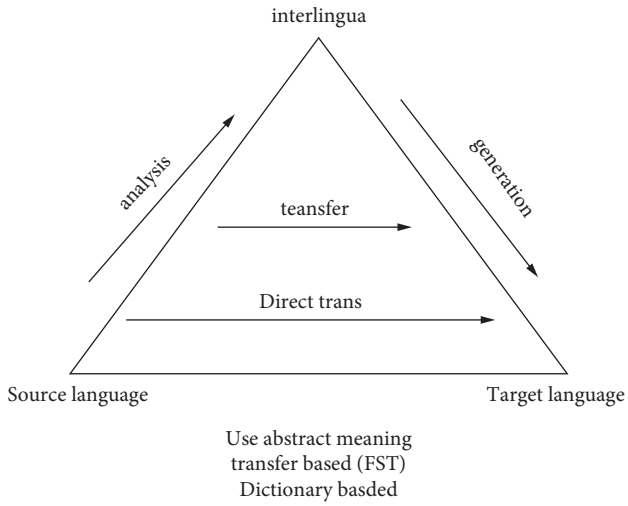


Figure 7: Rule-based model.

of the appropriateness of sentence translation. [14] Therefore, English-Chinese translation software should strengthen the translation base function and add more language environment and cultural background into the system and program background. In this way, the language appropriateness can be greatly improved in the process of translation, so that the translation results can be more accurate and more consistent with the practice of English application, so as to get a better application in the English learning of college students.

5.3. Diversified Services of Translation Software Should Be Enriched. At present, college students generally have a great demand for English-Chinese translation software in their English learning. Besides the need for basic translation functions, other functions are also involved. Survey results show that many college students hope that English-Chinese translation software can provide a translation error correction function, which can automatically proofread and correct the results of manual translation. This shows that students have high demand and expectation for manual translation proofreading in English-Chinese translation software [15]. Therefore, English-Chinese translation software should enrich the diversified service content of translation software based on the actual needs of college students' English learning and constantly update and launch a variety of new functions and contents so as to meet the application needs of college students and get a better application in college students' English learning.

5.4. Differences of Vocabulary Sentences in Different Professional Categories Should Be Distinguished. There are many polysemy phenomena in English. In different fields and specialties, the language is quite different. Even the same words or sentences may express completely different meanings. As a result, in the process of translation, the translation results of many English-Chinese software are not accurate and may even mislead college students' English learning. Therefore, translation software should make corresponding updates for this aspect to distinguish between different professional categories of words and sentences. Before translation, students can select the professional category and field of the translation content in the English-Chinese translation software, and the translation software will translate the content according to the corresponding professional language, so as to ensure more reasonable and accurate translation results. In addition, college students of different majors have different requirements for English-Chinese translation software in English learning [16]. Therefore, the differentiation of vocabulary sentences of different professional categories can also improve the degree of individuation of translation software, which can better meet the needs of college students and thus get a better application in college students' English learning.

6. Conclusion

Artificial intelligence translation is a double-edged sword, which has certain flaws in practical applications, but it has a positive impact on the English learning model. For the teaching of English teachers, it is necessary to use the advantages of artificial intelligence translation, so that English learning is no longer limited to the development of a certain ability, and the abilities of listening, speaking, reading, writing, and translating can be better organically integrated, so that language learning can return to the natural learning law; with the help of this, help students develop good independent learning habits and promote students to learn more effectively. At the same time, with big data, we can reasonably expand the scope of knowledge and arouse students' interest in learning, so that students can actively participate in the learning of English knowledge and achieve improvement in English proficiency. In this process, teachers must also pay attention to the closeness to the trend information and solve the problem of lagging content and singleness of the teaching materials. Teachers should strengthen the cultivation of students' critical thinking ability and rationally infiltrate traditional Chinese culture in order to effectively improve students' humanistic literacy and develop students' English language abilities.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Review Article

Review on Intelligent Governance of Physical Fitness of College Students under the Background of Big Data

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The advent of the era of big data has promoted the reform of sports governance, and intelligent governance is becoming a strategic choice and a new trend to promote the physical fitness development of college students. Based on the profound analysis of the current situation of college students' physical fitness, this study examines the great value of big data for the intelligent governance of physical fitness, and further constructs the model to achieve intelligent governance of college students' physical fitness. The study also provides specific strategies to promote this process. According to the study, although the current situation of college students' physical fitness is still not optimistic, data-driven intelligent governance of physical fitness provides a new solution to a personalized, refined, and diversified way of governance. By creating an intelligent governance concept with data thinking, building an intelligent governance platform supported by data, and by such measures as improving the data literacy of physical education teachers in colleges and universities and upgrading stadiums with intelligent techniques, the study seeks to break through the bottleneck of college students' physical fitness governance and open up a new path to realize the effective governance of college students' physical fitness.

1. Introduction

Physical fitness is the foundation of all physical activities [1]. As an important force in the construction and promotion of social progress, college students' physical fitness has a direct impact on China's socialist modernization and the great rejuvenation of the Chinese nation. However, under the dual pressure of study and employment, the physical fitness of college students is constantly declining and the trend has not been effectively contained under the dispersion effect of responsibility, and some indicators are even at a low level for a long time [2, 3]. In order to enhance the physical fitness of college students, governments at all levels have issued a series of policies and measures (Table 1). Although these policies and measures have improved their physical fitness to a certain degree, they have not achieved much effect, and the physical fitness indexes of some students are still declining. Consequently, it is essential to explore an effective governance model for college students' physical fitness in accordance with the national conditions of our country.

With the rapid development of the Internet and information industry, big data resources and information resources are increasing exponentially. As a modern information technology that explores new knowledge, creates new value, and promotes new momentum [4, 5], big data not only renders new meaning and value to many basic data [6], but also provides strong technical support for the intelligent governance of college students' physical fitness. In fact, countries around the world have already noticed the important value of big data in realizing intelligent social governance and incorporated it into their national development strategies. For example, the white paper "Big Data: Seize Opportunities and Protect Values" issued by the United States in 2014 [7], the "Dynamic ICT" strategy launched by Japan in 2012 [8], and the "Outline for Promoting Big Data Development" issued by China in 2015 [9].

Table 1: List of relevant policies for promoting college students' physical fitness since 2016 (excerpt).

Serial number	Name	Issue unit	Release time
1	"Opinions on strengthening physical education in schools to promote students' overall development of physical and mental health"	General office of the state council	2016–04
2	"Youth sports promotion scheme"	Seven departments, including the ministry of education the People's republic of China	2017–11
3	"Views on the implementation of the Healthy China initiative (2019–2030)"	State council	2019–06
4	"Opinions on deepening the integration of sports and education to promote the healthy development of adolescents"	General administration of the sport of China, ministry of education of the People's republic of China	2020–09
5	"Opinions of the general office of the CPC central committee and the state council on comprehensively strengthening and improving school physical education in the new era"	State council	2020–10
6	"Notice on further strengthening physical health management of primary and secondary school students"	Ministry of education of the People's republic of China	2021–04
7	"Opinions on comprehensively strengthening and improving school hygiene and health education in the new era"	Five departments, including the ministry of education the People's republic of China	2021–08

The practice of these countries has contributed to the development of big data technology as a way of governance. On this basis, the combination of the big data technology and college students' physical fitness, the comprehensive coverage of the big data technology and its service object, the accuracy of the supplying content, and the intelligent transformation of the governance process can empower the intelligent governance of college students' physical fitness. They can further break through the bottleneck of the traditional governance and provides a new path to reverse the decline of the physical fitness of college students. [4].

2. Concept of Regulation

The word "physical fitness" began to appear frequently in various newspapers and literature in China in the middle and late 1980s. In fact, physical fitness really came into the public's view in 1994, after the National Sports Commission conducted a physical fitness test for football players (it is stipulated that athletes must pass the physical fitness test before they can participate in professional leagues). At this stage, the discussion of fitness becomes very intensive. Up to now, the related research on physical fitness has been very rich, and the discussion on the concept of physical fitness has never stopped. In 2004, the editorial department of the JOURNAL of PLA Physical Education Institute launched a special discussion on the concept of "physical fitness". However, in different periods, different experts define physical fitness differently from different perspectives. From the perspective of sports training, for example, Tian Maijiu believed that physical strength is the basic athletic ability of athletes and an important part of athletic ability. For example, Yang Shiyong also clearly pointed out in his research that physical strength includes physical form, physical function, sports quality and other elements, and is an important part of athletes' competitive ability. It is aiming to improve athletes' competitive ability and obtain excellent competition results. Of course, some scholars have a different view that physical fitness is not only for improving competitive ability but also for social sports and mass fitness in a broad sense. The adaptation of sports training and sports competition is the advanced adaptation of physical fitness.

Through sorting out the existing concepts, it is found that the current academic understanding of physical fitness gradually falls into the following points: (1) Component elements. It includes three parts: body shape, body function, and sports quality. Body shape and function are the material basis of physical fitness, while sports quality is the external performance of physical fitness, including strength, speed, endurance, flexibility, and agility. (2) Approach to achieving: it comes in two ways: nature and nurture. In the history of Chinese characters, "neng" was originally derived from "xiong". The pictographs on oracle bone inscriptions also highlight some characteristics of "xiong", such as big mouth, sharp teeth, and claws. Physical strength and the ability to adapt to the jungle are both inherited and acquired. (3) Functional characteristics: although physical fitness originates from competition, it also applies to social sports, mass fitness, and school sports. Physical strength not only serves for competitive performance but also provides the necessary support for ordinary people to complete basic work, life, and study.

Based on the above factors, physical fitness is the basic motor ability of the human body to participate in physical activities on the basis of congenital inheritance and acquired, including three parts: body shape, body function, and athletic quality. Body shape and function are the physical basis of physical strength. Athletic quality is not only the external performance of physical strength but also the core of physical strength, showing strength, speed, endurance, flexibility and agility, and other qualities. This concept does not specifically refer to athletes, and of course, it does not deliberately highlight the function of physical

fitness serving competitive sports, so it is a universal concept.

3. Physical Fitness Status of College Students in the Era of Big Data

In order to understand the current situation of college students' physical fitness, 64,406 college students (36,348 males and 28058 females) from seven ordinary colleges and universities were randomly selected as test objects. After grouping by gender, the study measured each index of physical fitness, and the measured data were statistically analyzed. Specific methods are as follows:

Test content: Physical fitness is the ability of any basic sport manifested by speed, strength, flexibility, coordination, endurance, agility, and other qualities [10]. Therefore, indicators that can reflect the quality of various sports are selected for measurement, including 50 m race, 800/1000 m race, trunk bending forward, standing long jump, sit-ups, and other specific indicators.

Equipment: seat forward bend tester, tape measure, stopwatch, etc., the equipment is the national physical fitness monitoring equipment designated by the General Administration of Sport of China.

Standard for evaluation: The grading standard is based on the general textbook "National Standards for Students' Physical Health" [11, 12].

Statistical software: EXCEL and SPSS17.0 software are used for statistical analysis of the measured specific indicators.

3.1. Results and Analysis of Speed Quality Assessment. The 50-meter race can reflect the speed quality of college students. The measurement results of the 50-meter race of college students show that the excellent and good rates of female students from freshman to senior are 15.36%, 16.9%, 6.69%, and 2.96% respectively (Table 2). The excellent and good rates of male freshmen to seniors are 28.75%, 28.70%, 24.70%, and 12.5%, respectively (Table 3). As can be seen from the scatter chart, the grades of male and female students show the same trend. The grades of freshmen and sophomores are stable, while the grades of juniors are slightly better than the first two grades, with 0.1 seconds faster, and the senior grade is at the worst level (Figure 1). In terms of the average percentage of the grade table, the overall performance of boys is better than girls. The variance test results based on senior grade show that there were significant differences between senior grade and the other three grades ($P < 0.05$)

3.2. Explosive Force Assessment Results and Analysis. Standing long jump can reflect the explosive force of college students. The results show that the excellent and good rates of female students from freshman to senior are 24.28%, 26.78%, 36.95%, and 19.70%, respectively (Table 4). The excellent and good rates of male freshmen to seniors are 20.21%, 20.79%, 17.27%, and 11.81%, respectively (Table 5). The variance test results based on senior grade show that there are significant differences between senior grade and the other three grades ($P < 0.05$). As can be seen from the scatter chart, scores between boys and girls reflect the same trend. The data of the first three grades show a steady increase, while the senior grade is at the worst level, and the performance of boys is more rapid and stable (Figure 2). From the average grade table, the proportion of girls above average shows an increasing trend of 4.85%, while the proportion of boys shows a decreasing trend of 6.72%.

3.3. Flexibility Assessment Results and Analysis. Trunk forward bending can reflect the flexibility of college students. According to the results of trunk forward bending, the excellent and good rate of female students from freshmen to seniors are 38.07%, 41.94%, 32.06%, and 32.66%, respectively (Table 6). The excellent and good rates of male freshmen to seniors are 19.75%, 25.44%, 18.85%, and 14.96%, respectively (Table 7). The variance test results based on senior grade show that there are significant differences between senior grade and the other three grades ($P < 0.05$). As can be seen from the graph, female students' scores showed a wavy

Table 2: Performance and grade ratio of girls' 50 m race.

Level	Grade			
	One	Two	Three	Four
Excellent	294 3.52%	266 2.49%	10 0.27%	18 0.35%
Good	988 11.84%	1462 13.60%	242 6.42%	136 2.61%
Pass	6616 79.25%	8466 78.78%	3436 91.19%	4482 86.26%
Fail	450 5.39%	552 5.13%	80 2.12%	560 10.78%
	u1 : 0.00000	u2 : 0.00000	u3 : 0.00000	—

(*Note.* $u1$ is the comparison between senior and freshman, $u2$ is the comparison between senior and sophomore, $u3$ is the comparison between senior and junior; $P < 0.05$ indicates a significant difference, while $P < 0.01$ indicates a very significant difference. The same below).

Table 3: Performance and grade ratio of boys' 50 m.

Level	Grade			
	One	Two	Three	Four
Excellent	1575 13.74%	1743 13.27%	485 9.70%	247 3.66%
Good	1720 15.01%	2026 15.43%	750 15.00%	567 8.39%
Pass	7965 69.50%	9066 69.04%	3755 75.06%	5838 86.44%
Fail	200 1.75%	297 2.26%	12 0.24%	102 1.51%
	$u1$: 0.00000	$u2$: 0.00000	$u3$: 0.00000	—

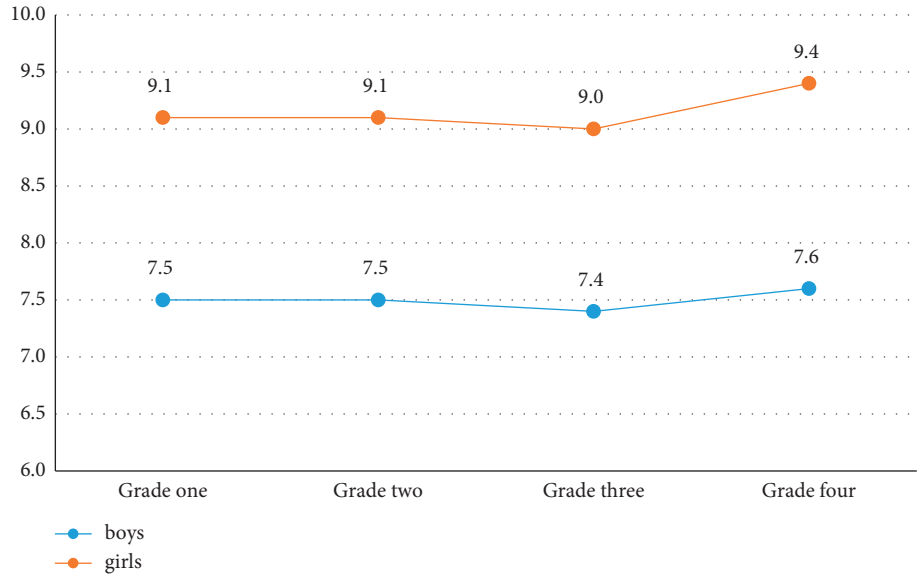

Figure 1: The change curve of the 50 m race result between boys and girls.

Table 4: Girls' standing long jump scores and grade ratio.

Level	Grade			
	One	Two	Three	Four
Excellent	661 7.92%	965 8.98%	411 10.91%	278 5.35%
Good	1366 16.36%	1913 17.80%	981 26.04%	746 14.35%
Pass	5748 68.86%	7160 66.63%	2228 59.12%	3810 73.33%
Fail	573 6.86%	708 6.59%	148 3.93%	362 6.97%
	$u1:0.00000$	$u2:0.00000$	$u3:0.00000$	—

Table 5: Boys' standing long jump scores and grade ratio.

Level	Grade			
	One	Two	Three	Four
Excellent	466 4.07%	525 4.00%	197 3.94%	152 2.25%
Good	1850 16.14%	2205 16.79%	667 13.33%	646 9.56%
Pass	7823 68.26%	9166 69.80%	3690 73.77%	5159 76.39%
Fail	1321 11.53%	1236 9.41%	448 8.96%	797 11.80%
	$u1:0.00000$	$u2:0.00000$	$u3:0.00000$	—

trend of first increase and then decrease, with the best performance in sophomore and the worst in junior, with a maximum gap of 0.8. Male students' scores are more stable than female students, with a smaller fluctuation range and a maximum gap of 0.4. In addition, female students' scores are generally higher than that of male students (Figure 3). In terms of grade ratio, boys' performance is lower than that of girls. Only two grades of boys are more than 50%, while the proportion of girls is more than 50% in all four grades.

3.4. Endurance Assessment Results and Analysis. The 1000-meter race can reflect the endurance of college boys, and the 800-meter race can reflect the endurance of girls. According to the results of 800 m running for girls, the excellent and good rates from freshmen to seniors are 15.54%, 17.3%, 26.73%, and 10.54%, respectively (Table 8). The results of 1000 m running for boys show that the excellent and good rates of male freshmen to seniors are 13.54%, 10.43%, 11.76%, and 5.32%, respectively (Table 9). The variance test results based on senior grade show that there are significant differences among senior grade and the other three grades ($P < 0.05$). The biggest gap between boys' and girls' scores is 12 seconds, and boys' scores is a wavy change, while girls' is a "U" shape change. Girls' scores in the first three grades are better in high grades than in low grades, and the worst in both boys and girls is in senior grades (Figure 4). There is little difference in the mean of the grade table. The proportion of female students and male students is about 55% and 56%, respectively.

3.5. Strength Assessment Results and Analysis. Sit-ups can reflect the strength of college girls, and pull-ups can reflect the strength of college boys. The results of female students show that the excellent and good rates from freshman to senior are 5.46%, 6.38%, 7.80%, and 4.66%, respectively (Table 10). The results of male students show that the excellent and good rates of male freshmen to seniors are 5.62%, 6.86%, 2.60%, and 2.84%, respectively (Table 11). The variance test results based on senior grade show that there are significant differences between senior grade and the other three grades ($P < 0.05$). As can be seen from the graph, the

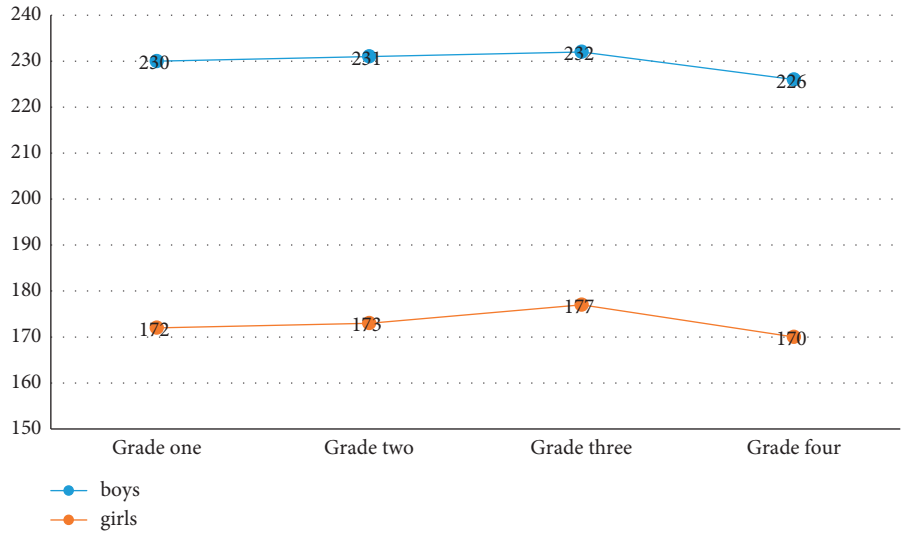

Figure 2: The result change curve of standing long jump between boys and girls.

Table 6: Girls' trunk forward bending scores and grade ratio.

Level	Grade			
	One	Two	Three	Four
Excellent	1292 15.48%	1712 15.93%	375 9.95%	380 7.31%
Good	1886 22.59%	2795 26.01%	833 22.11%	1317 25.35%
Pass	5016 60.09%	6070 56.49%	2442 64.81%	3388 65.20%
Fail	154 1.84%	169 1.57%	118 3.13%	111 2.14%
	$u1: 0.04931$	$u2: 0.01981$	$u3: 0.00001$	—

Table 7: Boys' trunk forward bending scores and grade ratio.

Level	Grade			
	One	Two	Three	Four
Excellent	1030 8.99%	1206 9.18%	427 8.54%	480 7.11%
Good	1233 10.76%	2135 16.26%	516 10.31%	530 7.85%
Pass	8921 77.84%	9321 70.98%	3704 74.05%	5338 79.03%
Fail	276 2.41%	470 3.58%	355 7.10%	406 6.01%
	$u1: 0.00253$	$u2: 0.00999$	$u3: 0.00780$	—

average score of sit-ups of girls is relatively stable from freshman year to junior year, with a gap of about 1, while the score of senior year is the worst, with a maximum gap of 3 (Figure 5). The grade with the best average pull-up performance of male students is sophomore, showing an inverted U-shape trend, while the grade with the worst grade is senior, with the largest gap of 2.1. In terms of average percentage, the first three grades show a slowly rising trend, and the senior grade is lower than the first three grades, with a decrease of 7.69% (Figure 6). In terms of the average percentage, the four grades show an overall downward trend, decreasing by 9.4%.

To sum up, the excellent and good rate of college students' physical quality is still at a low level, and each indicator shows a trend of gradual decline with the increase in grades. The decline in endurance and strength is more obvious. There are various reasons including both subjective and objective factors. However, the lack of effective governance measures that keep up with the times is undoubtedly one of the important reasons for the continuous decline of college students' physical fitness. For a long time, due to the lack of data collection, analysis, storage, and exploration, the intelligent governance of college students' physical fitness is unable to clarify the core root of their problems correctly, which leads to the passive governance concept of "treat the symptoms rather than getting to the root of the problem" and the result is not ideal [5, 13]. The arrival of the era of big data not only provides important technical support to realize the diversification, refinement, and intelligent governance of college students' physical fitness but also provides effective solutions for improving college students' physical fitness.

4. Value Review of the Intelligent Governance of College Students' Physical Fitness in the Context of Big Data

4.1. Big Data Can Ensure the Scientific Nature of Governance Decisions. Decision-making is about collecting, transmitting, processing, and outputting data and information. Accurate data is the basis for decision-making. The traditional data collection methods and quantities of college students' physical fitness are very limited. Simple statistical analysis that only reflects the physical status of college students in a certain period. It is unable to give full play to the predictive value of data and it cannot serve as the scientific basis to formulate policies that enhance the physical fitness of college students. Physical fitness data of college

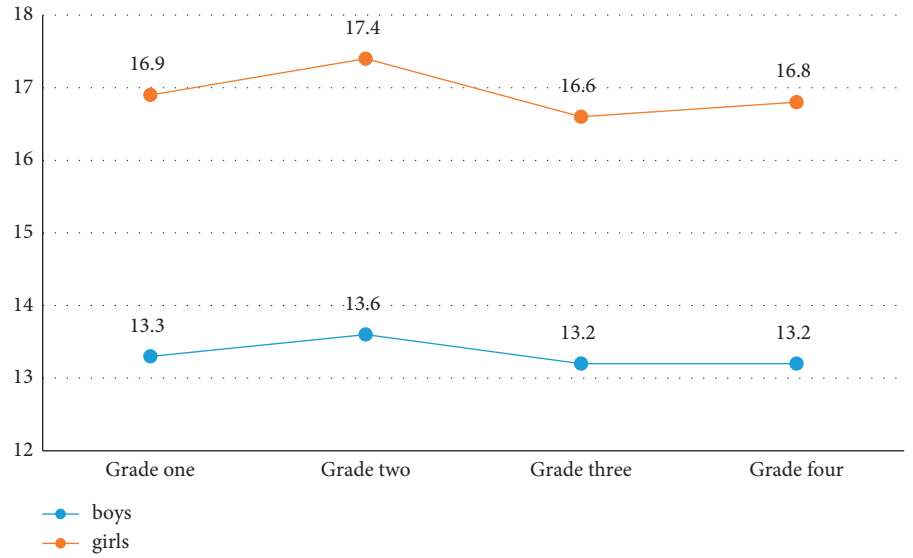

Figure 3: The result change curve of trunk forward bending between boys and girls.

Table 8: Girls' 800-meter race scores and grade ratio.

Level	Grade			
	One	Two	Three	Four
Excellent	289 3.46%	483 4.49%	221 5.87%	116 2.23%
Good	1008 12.08%	1348 12.54%	786 20.86%	432 8.31%
Pass	6210 74.39%	7954 74.03%	2571 68.23%	4049 77.93%
Fail	841 10.07%	961 8.94%	190 5.04%	599 11.53%
	$u1:0.00056$	$u2:0.00000$	$u3:0.00006$	—

Table 9: Boys' 1000-meter race scores and grade ratio.

Level	Grade			
	One	Two	Three	Four
Excellent	322 2.81%	299 2.28%	111 2.22%	54 0.80%
Good	1230 10.73%	1071 8.15%	477 9.54%	305 4.52%
Pass	8067 70.38%	9653 73.51%	3460 69.17%	4188 62.01%
Fail	1843 16.08%	2109 16.06%	954 19.07%	2207 32.67%
	$u1:0.00000$	$u2:0.00000$	$u3:0.00000$	—

students are changing all the time, so how to use these data efficiently requires the comprehensive collection and in-depth exploration of physical fitness data, and it is important to enhance the real-time, consistency and integrity of physical fitness data [5]. Big data is based on historical data, real-time data, associated data, and other data resources to clarify the feasibility, profitability, and risk of different alternatives. A big data analysis model is used to simulate the cause of events, development trends, decision results and other event tracks, and the predicted simulation results are used as the reference for decision-making, so as to make the formulation of policies more scientific. For example, there exists a controversy on NBA courts as to whether it is better to shoot the three-point shot or the two-point shot. Because in the era without data support, most decisions are made based on experience and lack of scientific basis. When the data was introduced and analyzed, it was found that the benefit of a 3-point shot was greater than the benefit of 2-point shot. With the support of data, these decisions become more scientific, so it can directly cover the training, competition every link. As a result, offensive zones throughout the NBA are now expanding beyond the three-point line.

4.2. Big Data Can Ensure the Accuracy of Governance Information. In the precise governance of college students' physical fitness, it is necessary to pay more attention to the vulnerable groups and college students with seriously declining physical fitness indicators. The key is to accurately identify the object of attention. However, as the traditional technology is limited by time and labor cost, so it is very difficult to identify. Through real-time record, analysis, and application of the physical fitness level, behaviors, emotions, cognition, living habits, and physiological changes of individuals, it is plausible for big data to find the root of the problem accurately, discover the rule of the change of things, so as to improve the pertinence of intervention, and then achieve governance. Big data technology points the direction for administrators to accurately capture the key points and difficulties in the work to promote college students' physical fitness. In this way, administrators can analyze from a more comprehensive, objective, and specific perspective, so that their work will not be stuck in "empiricism" [5]. It can be said that big data provides strong technical support for the accurate identification and governance of college students'

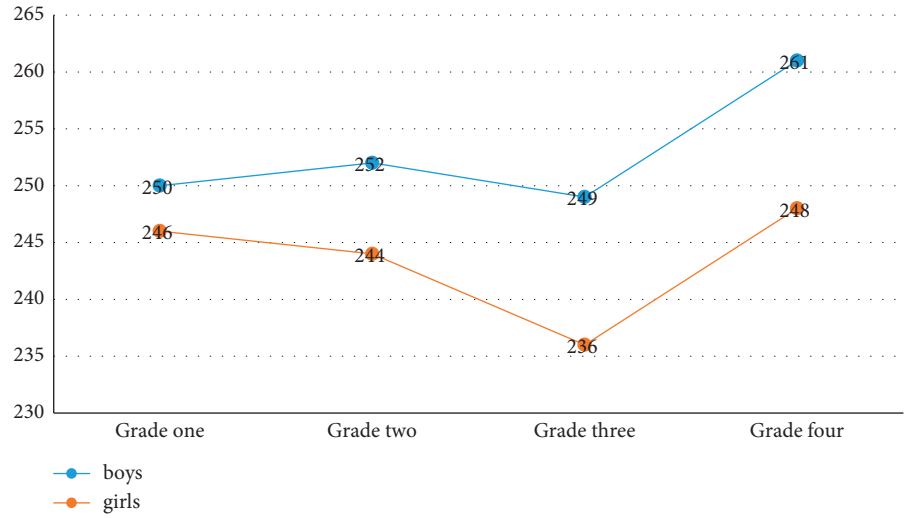

Figure 4: The change curve of boys' score at 1000 m and girls' score at 800 m.

Table 10: Girls' sit-up scores and grade ratio.

Level	Grade			
	One	Two	Three	Four
Excellent	92 1.10%	152 1.41%	58 1.54%	70 1.35%
Good	364 4.36%	534 4.97%	236 6.26%	172 3.31%
Pass	7358 88.14%	9482 88.24%	3124 82.91%	4192 80.67%
Fail	534 6.40%	578 5.38%	350 9.29%	762 14.67%
	$u1:0.00000$	$u2:0.00000$	$u3:0.00000$	—

Table 11: Boys' pull-up scores and grade ratio.

Level	Grade			
	One	Two	Three	Four
Excellent	290 2.53%	342 2.60%	56 1.12%	86 1.27%
Good	354 3.09%	560 4.26%	74 1.48%	106 1.57%
Pass	2034 17.75%	3020 23.00%	434 8.68%	528 7.82%
Fail	8782 76.63%	9210 70.14%	4438 88.72%	6034 89.34%
	$u1:0.00000$	$u2:0.00000$	$u3:0.04520$	—

physical fitness. Such as the "magic note" during Germany's penalty shootout in the 2006 World Cup quarterfinal. Through the analysis, statistics, and judgment of 13,000 point data, at that time, Professor Bushman led 40 college students at the Physical Education Institute in Cologne to create the note. The computer they used is still in a football museum in Cologne, Germany. In the end, they accurately predicted who would take the penalty and how, and won the shootout. Eight years later, the same piece of paper appeared in the hands of *Argentina* goalkeeper Romero. It was also the same accurate judgment, which in turn helped *Argentina* through to the final on penalties. This is the embodiment of the precision advantage of big data.

4.3. Big Data Can Ensure the Controllability of the Governance Process. Different college students have different internal and external characteristics, such as gender, age, physiology, psychology, heredity, personality, and growth environment. The key issue of governance is how to provide personalized governance services in accordance with the different characteristics of college students. Through big data technology, the governance of college students' physical fitness can vary from person to person, progress timely and innovate according to the current situation. Targeted quantitative regulation and control allow the entire governance to work under governance decisions. With the help of big data technology, the traditional "top-down" governance path is transformed into an intelligent path that is "bottom-up". In this way, the needs of college students can be fully expressed and satisfied to the maximum, which is the inevitable requirement and trend of the times of "student-based" intelligent governance. The data exploration technology can find the group characteristics of the evolution of college students' physical fitness and the general rule of effective governance, and finally, realize the new governance pattern of data sharing and multi-party collaborative participation. Through multi-dimensional analysis of effective data, the controllability of the governance process is guaranteed according to the real situations and demands of college students.

4.4. Big Data Can Ensure the Timeliness to Process Governance Information. The data on college students' physical fitness is produced very quickly, which reflects the real-time situation of their physical fitness. For big data storage platforms, data storage requires a certain cost. Generally, only the recent data can be saved, and it would cost too much to save all the

Figure 5: Change curve of sit-up scores of girls.

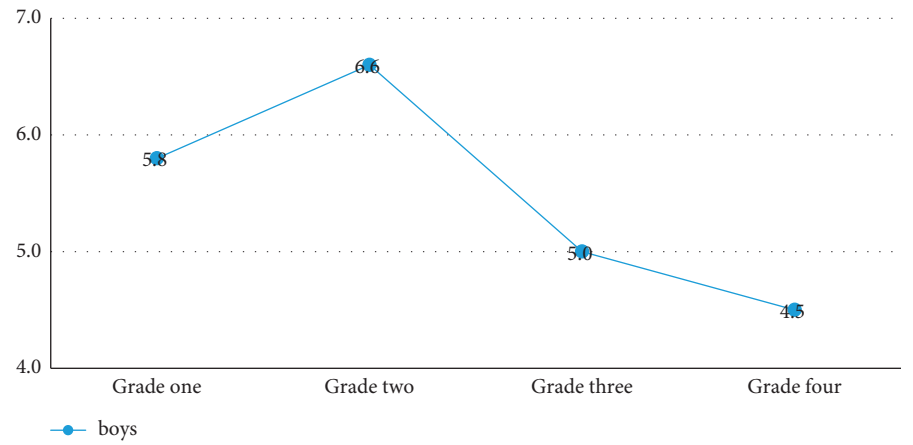

Figure 6: Pull-up performance curve of male students.

historical data. In this case, the processing speed of the big data storage platform is very important. In order to save costs and relieve storage pressure, the big data platform needs to analyze data in a timely manner. The real-time analysis capability of the big data platform makes it likely to process information about college students' physical fitness.

Every college student produces a large number of physical fitness data every day, and these physical fitness data are constantly changing. Moreover, the use value of these data will decline rapidly with time. Big data technology can process the physical fitness data of college students in real-time, ensuring the timeliness of big data.

5. Implementation Framework of Data-Driven Intelligent Governance of College Students' Physical Fitness

At present, the big data-driven paradigm composed of data integration, data cognition, decision optimization, search and mining, prediction, intervention, and other processes has been widely applied in many fields such as process control, information management, decision support, trend prediction [14]. When it comes to the governance of college students' physical fitness, the goal is not mastering the complete data information. The ultimate significance is to process these data in an intelligent manner to form a set of personalized, accurate, and diversified governance of the new form. The intelligent governance model of college students' physical fitness constructed in this study is mainly composed of the physical fitness data center, physical fitness intelligent intervention engine, physical fitness data security governance, and other links (Figure 7).

5.1. Physical Fitness Data Center. The physical fitness data center is built on the basis of modern digital technology, which guarantees the intelligent governance of college students' physical fitness. The physical fitness data center collects explicit data and implicit data both automatically and manually. Its value is reflected in the standardization, regulation, and model governance of data, so as to make decision-making more precise, personalized, and intelligent. The physical fitness data center mainly integrates, analyzes, and semantically processes physical fitness data of college students. First of all, it is necessary to integrate diversified data based on different sources and different ways to build a full data storage room. Second, the integrated data in the data storage room should be processed and analyzed by the intelligent algorithm, cloud computing, and other technologies combined with the actual demand. Finally, it is plausible to present the results of big data analysis to the participants in an intuitive and intelligible form through

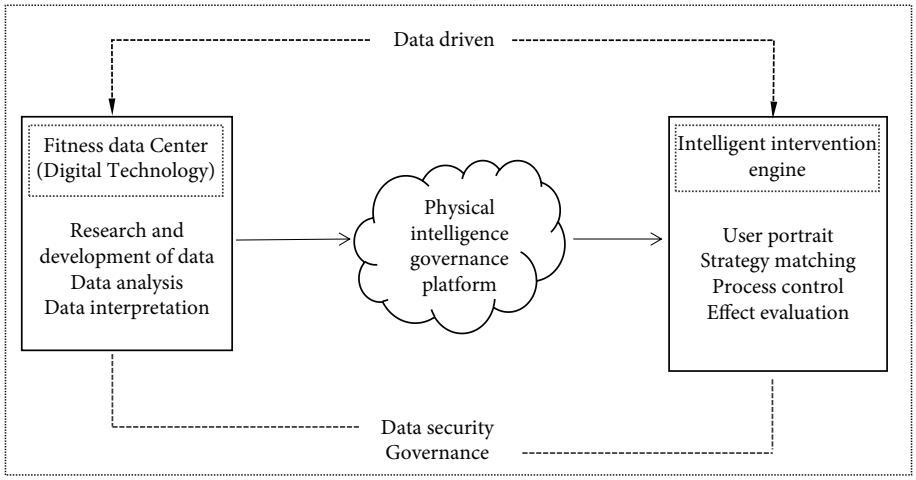

Figure 7: Implementation framework of data-driven intelligent governance of college students' physical fitness.

data visualization, virtual reality, and other technologies. At present, with the continuous development of digital technology led by big data, the technical problems of physical data centers have been basically solved, and the current difficulties mainly focus on port docking. The information of the responsible subjects directly related to the physical fitness of college students fails to be exchanged in real-time, which is an important factor restricting the effective mining, analysis, and judgment of the physical fitness data of college students. For example, the plates of many colleges and universities have been transformed and upgraded to be intelligent, so that students' energy intake can be accurately calculated. However, there is no connection with the sports APP port, so students only know how much energy they have consumed today, but not how many calories they need to burn to achieve the goal of physical strength. Similarly, excessive exercise may have the opposite effect. In addition, due to the failure to connect with the educational administration system of the school and the port of the campus supermarket, students also lack data support in sports time recommendation and sports drink selection, so the accuracy of the physical fitness management of college students is not enough.

5.2. Physical Fitness Intelligent Intervention Engine. Physical fitness intelligent intervention engine is a cyclic structural intervention model with "user portrait, strategy matching, process control, and effect evaluation" as the core (Figure 8). It can provide strong support for the intelligent governance of data-driven physical fitness. On the one hand, the intelligent intervention engine can gather massive high-quality physical training resources and build a scientific and high-quality intervention program database with the help of artificial intelligence, cloud platform, and other advanced digital technologies. On the other hand, the intelligent training intervention engine can grasp the physical state of college students in real-time and provide dynamic, accurate, and personalized guidance to college students in time through testing and evaluation, dynamic monitoring and analysis, and mining of the real-time data of college students' behavioral characteristics. (1) User portrait is the starting point of intelligent intervention. Accurate insight and diagnosis are carried out on college students' exercise habits, body state, exercise experience, and physical fitness level, so as to find the foothold and powerpoint for intelligent governance of individuals. (2) Strategy matching makes governance decisions transform from experience to data intelligence driven. Governance decisions always point to more optimized and more effective training programs, which is the key to ensuring the effect of the intervention on college students' physical intelligence. Based on the key representation of the real-time dynamic portrait of college students, the intervention plan or optimization strategy with the highest matching degree with the reality of college students can be extracted from the intervention plan database using multiple matching algorithms. The premise and basis for the accurate matching of the construction strategies of the intervention plan database is also the key for college students to achieve intelligent governance. When a user portrait appears and all kinds of data are collected in the early stage, the system needs to find the appropriate physical exercise program immediately from hundreds or even tens of thousands of databases. Of course, this huge database requires the pooling of multi-disciplinary knowledge. First of all, we have to classify college students according to their gender characteristics. Second, different solutions were given based on the different physical characteristics of students of different genders, such as body fat rate, endurance, flexibility, explosive power, and other factors, combined with their energy intake of the day and the time to effectively participate in physical exercise. For physically disadvantaged students, we should consider their specific physical characteristics, whether due to being overweight or super light, physical disability or disease caused by physical weakness. Further, build a database of interventions that are appropriate for them. For example, for overweight students, the database can match some physical exercise programs for strength and explosive force of upper limbs; for students with physical disabilities, the database can match some physical exercise programs for balance and coordination; for students with heart and lung diseases, the database can match some physical exercise programs of flexibility and

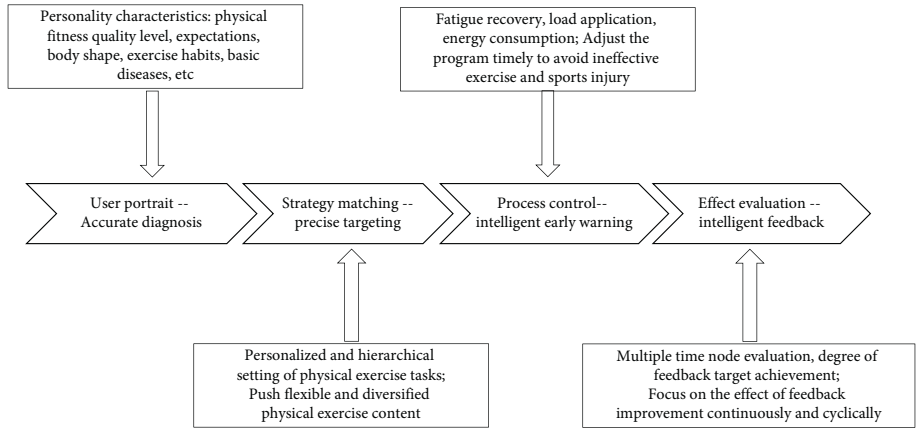

Figure 8: Progression chart of data-driven physical smart governance of college students.

aerobic fitness. The construction of a physical intervention database needs a process, and it also needs to be combined with multi-disciplinary research. It can be improved gradually from easy to difficult and from less to more. Of course, once the physical intervention database is built, the key nodes of the intelligent governance of college students' physical fitness will be opened. (3) Process control is based on the optimal matching of intervention strategies to timely identify the key points in promoting students' physical fitness promotion and to deal with them precisely. For example, through real-time feedback and early warnings of big data, targeted and timely adjustment of physical intervention programs can avoid the occurrence of ineffective training and sports injuries. (4) Effect evaluation is not only a process of testing and evaluating the periodic effect of the intelligent governance of students' physical fitness, but also a process of summary and feedback. Quantification of intervention effects through data can help students clearly understand the problems existing in physical intervention, so as to make timely and targeted improvements in the next cycle.

5.3. Physical Data Security Governance. The security governance of college students' physical data plays an important role in the whole governance system, which involves not only network security but also the physical and psychological safety of college students. Therefore, the bottom line and basis of physical data management are to ensure the security of data. Physical fitness data not only involves health status or sports preference but also involves public personality characteristics, identity privacy, and other information. College students' physical intelligent governance system is relatively open, and the subjects used are complex and diversified, which is likely to lead to the disclosure and illegal use of this information. On the whole, in the process of data-driven intelligent governance of college students, due to the immaturity of technology, the imperfection of relevant data governance system, and the inability to share, problems such as algorithm failure and data fallacy are inevitable at the present stage. These problems may bring some security risks to governance, which requires high attention to data security supervision.

6. The Promotion Path of Intelligent Governance of College Students' Physical Fitness under the Background of Big Data

At present, "no data, no training" has become the basic criteria for high-level elite athletes to improve their physical fitness [15], and it is also applicable to the intelligent governance of college students' physical fitness as well. However, problems on how to grasp the opportunity of data-driven technology, how to give full play to the advantages of modern information technology, and to realize the intelligent governance of college students' physical fitness are a subject that the sports academia must face at present.

6.1. Create an Intelligent Concept Led by Data Thinking. The philosophy of governance is the prerequisite for governance actions. If the philosophy of the governance subject is insufficient in the practice of physical fitness governance, the process and effect will become seriously deviated. Therefore, in the intelligent governance of college students' physical fitness, the philosophy of governance is supposed to be changed first. The traditional inherent thinking should be broken, the dissemination of the philosophy of intelligent governance with big data as the carrier should be continuously promoted, and the philosophy leading the modernization process of governance with big data thinking should be created to promote the smooth implementation of intelligent governance. In addition, it is also important to provide clearance on the philosophy of intelligent governance, take the strategic needs of national intelligent governance as the guidance combined with the physical status of college students, and speed up the development of schools as the carrier of the top-level design of intelligent sports. Colleges need to promulgate relevant policies on the intelligent governance of college students' physical fitness from the macro level, and guide the understanding of governance subjects on the philosophy of governance from the top level. At the same time, it is necessary to create a cultural atmosphere of intelligent governance, and guide the philosophy of governance subject from "extensive" to "intelligent" from the aspect of public opinion publicity. In addition, the relevant reward and punishment system should

be improved to commend outstanding teachers who are responsible and effective in the process of physical and intellectual governance of college students.

6.2. Build a Data-Driven Intelligent Governance Service Platform. The construction of a data-driven intelligent governance service platform is the cornerstone of data-driven improvement of physical fitness. The platform should provide multi-source data mining and decision-making services on the basis of universal data acquisition and fusion functions, and realize real-time monitoring and visualization of dynamic data. First, technological development should be strengthened. From the perspective of the trend of data-driven intelligent governance in sports, most of the current research focuses on basic theoretical systems and applied generic technology research. Future technological innovation should fully consider the behavioral research of intelligent application of big data. Through the application of deep learning and other technologies, a systematic and scientific governance model is developed to make the model more intelligent to understand massive data. Second, it is necessary to build a complete physical database of colleges. For the intelligent governance of college students' physical fitness, the development of a complete physical fitness database is not to simply centralize the traditional data, but to form a sequence through the database group, so that the traditional data can be acquired, integrated, decomposed, stored, processed and used in a small data subsystem. The collection of database information should be voluntary, legal, and comprehensive.

6.3. Accelerate the Intelligent Transformation and Upgrading of School Sports Venues. The development of information technology, such as big data, the Internet of things, and cloud computing has accelerated the exchange and cooperation of all walks of life. It also provides a material basis for the effectiveness of the intelligent governance of college students' physical fitness. At present, school sports venues under the traditional management system are difficult to adapt to the requirements of the intelligent governance of national fitness service in school sports venues in terms of the organization mechanism, management mechanism, and operation mechanism. Therefore, it is urgent to upgrade the school sports venues to an intelligent level. In recent years, with the help of modern science and technology, some of China's basic health programs have achieved comprehensive development and progress. This also intensifies the desire and demand for physical fitness big data, intelligent training venues, and digital physical fitness training centers in physical education of schools. Therefore, it is imperative to speed up the upgrade of school sports stadiums; build up intelligent physical fitness training venues that capture motion feedback; quantitatively evaluate multiprocessing, strength, and speed strength indexes; prevent and intervene in sports injury; and allow shared data mining and cloud sharing. This is the prerequisite to achieving progress in enhancing the physical fitness of college students with the help of technology as well as the best way for accurate data-driven physical intervention.

6.4. Improve the Data Literacy of Physical Education Teachers in Colleges. The data literacy level of PE teachers in colleges and universities is the key factor restricting the intelligent governance of college students' physical fitness. However, many teachers do not have the ability to use big data for accurate diagnosis, scientific policy-making, and effective training. Therefore, teachers need to be trained by both online and offline methods. Only teachers with good data literacy can fully excavate and utilize the potential of data in college students' sports activities. First of all, it is imperative to make teachers clear about the concept of data and the driving benefits of data for college students' physical fitness. Second, it is necessary to set up a data literacy certification mechanism for PE teachers, and put data literacy into PE teachers' professional ability evaluation. Finally, it is necessary to establish a perfect pre-service and post-service training mechanism for physical education teachers, improve their data processing ability, analytical ability and collection, interpretation and application skills, improve their ability to integrate data literacy and physical fitness governance practice, and form the awareness of using data to explain and solve the difficulties, blind spots and specific problems in promoting the physical fitness of college students [4, 16].

7. Conclusion

As Viktor Mayer-Schönberger says, "Big data is a huge transformation of the times." Data-driven transformation of intelligent governance of college students' physical fitness is an inevitable choice for effective physical fitness governance. Based on the in-depth analysis of the current physical fitness of college students in the era of big data, this study, through a rational review of the value of big data to the intelligent governance of physical fitness, discovers that big data can ensure the scientific nature of governance decisions, the accuracy of governance information, the controllability of governance process, and the timeliness of governance information processing. On the basis of fully affirming the importance of big data to the intelligent governance of physical fitness, this study further builds the model to realize the intelligent governance of physical fitness of college students and makes specific strategies to promote it under the background of big data. Through the development of the model and the formulation of the strategy, this study provides a new perspective and an important tool for promoting college students' physical fitness. What's more, it serves as a beneficial enlightenment for the development and improvement of the intelligent governance model of college students' physical fitness.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Design of the College Students' Music Big Data Management System Based on Computer Assistance

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With the rapid development of science and technology, the college music big data management system also needs a computer-aided data model for optimization. In order to improve the efficiency of computer-aided teaching of the music big data management system in colleges and universities, this paper analyzes and processes the music database of music software based on the computer-aided Bayesian algorithm and establishes a Bayesian model. Firstly, this paper introduces the principle and function theorem of the Bayesian algorithm. The data is divided into original music and new music, and a college music data management system with search recommendations as the core is established. We iteratively calculate the optimal hidden semantic matrix and we finally select ReLU function as the activation function of this experiment. After the model of the music management system is established, it is applied to a university. The experimental results show that the experiment has reached the expected standard. When the hidden factor dimension is 11, the system model has the best representation of music features. Students' use of the music search and the recommendation system has greatly improved their music literacy and music coverage.

1. Introduction

The 21st century is an era of rapid development of computer technology. At the same time, with the popularization of computers and smartphones, the number of Internet users has shown explosive growth. Technological progress has also led to the rapid development of the Internet. Today's human beings get dozens or even hundreds of times more information every day than before. Mankind has fully entered the era of big data. According to the report of the International Institute of Data, the total amount of data in the world is expected to reach 50zb by 2030 [1].

Massive information brings convenience but also brings the problem of information overload. Both producers and users of information are facing great challenges. For information producers, the content they produce is easy to be submerged in a huge amount of data and cannot stand out without attention. Faced with a large amount of information, it is difficult for information users to screen out really useful information, which wastes time and energy. This problem is particularly prominent in colleges and universities. Teachers can use too many information resources and need to work hard to screen out the content suitable for teaching. Students have not yet formed a stable world outlook, outlook on life, and values. The information they receive is mixed, and it is difficult to distinguish between good and bad [2]. The computer-aided search and the recommendation system came into being, which provides users with certain convenience, but users have various needs, especially efficient students have their unique requirements for the search and recommendation of music data. Music, as the carrier of expressing human emotions and transmitting information, is also developing with human history [3]. It has become an indispensable spiritual food for many people. With the advent of the era of big data, storage and communication media have also undergone revolutionary changes. From black glue to magnetic tape, then to CD, until today's electronization (usually MP3 and AAC format), music and audio-visual show ease of availability and convenience with the development of science and technology [4]. For college students, especially teachers and students majoring in music, the search and recommendation of music data is the key to

the growth of academic and personal ability. Music computing science came into being under this background. It is a new discipline based on the algorithm, which carries out theoretical research, information storage, intelligent analysis, and fuzzy recognition of music audio and video [5].

2. Related Work

At present, search engines are widely used in daily life, except that traditional search engines provide users with basic and comprehensive search services [6]. The built-in search engines of social software, knowledge Q&A software, video software, and music software have also attracted more and more attention. Providing faster, more convenient, and more accurate search results is a great challenge for this software [7]. A computer-aided college music system is the basis of search function. Only by doing a good job in the search of music data, teachers and students can benefit from it. The recommendation system is developed from streaming the media service, and now it is most commonly used in commodity recommendation of e-commerce software [8]. The application in the music market and the addition of a recommendation system not only improve the good degree of user experience but also increase the number of active users of the product. It also increases user stickiness, so that more different music works can be heard by users, and finally, it greatly improves commercial interests [9]. In the college students' music system, with the continuous development and application of computer multimedia technology, many music industries prefer to provide online music services. Teachers and students can easily obtain music resources through music platform online listening, online downloading, and other ways. However, the music database is becoming larger and larger. It takes a lot of time and energy for college students to find their own music. In the past, users can only search music through keywords, such as music name, singer, and genre, and then the search results do not take into account the differences of users, so there is a deviation in the results [10]. A college music recommendation system makes up for the shortcomings of the search system. This intelligent recommendation system can predict the behavior preferences of teachers and students according to the behavior information and music data characteristics of teachers and students and actively push music that meets their tastes and learning needs to college students.

The two main functions of music computing science are search and recommendation, which are two important aspects of music management in urgent need of upgrading and optimization, so it has aroused great interest in academia and music industry [11]. Music computer-aided is not only an important means to obtain music semantic information but also an important part of music management. Traditional music audio-visual search is based on the general information of songs, such as song name, singer or band name, word author, song author, and file format [12]. This search method is accurate and efficient, but it can no longer meet the needs of the current music market. Nowadays, users of online listening software prefer to get retrieval and recommendation based on personal preferences, which requires a more humanized intelligent search of music audio-visual in terms of style, emotion, genre, and song theme. Before entering the era of big data, classification based on style, emotion, genre, and song theme was carried out manually. Although the accuracy can meet the requirements, it is inefficient and the cost of manpower and time is huge [13]. And with the development of data explosion, labor has been increasingly unable to keep up with the growth of data. The use of computer-aided automatic classification began to enter the public's field of vision and began to play its own efficient and irreplaceable role [14].

The increasing amount of music data and the demand of teachers and students in colleges and universities pose a more stringent challenge to the research of music search and recommendation algorithms. Traditional recommendation systems include content-based recommendation, collaborative filtering recommendation, and hybrid recommendation combining the two [15]. Although the three basic recommendation methods have been developed and mature, they have some problems to be solved, such as slow startup. In addition, with the development of social media, recommendation based on the emotional state has also entered the public's vision, which is the result of in-depth learning in the computer industry and full mining of users' potential hobbies [16]. Based on the naive Bayes theory, starting from the analysis of the characteristic data of college teachers, students, and music, this paper designs an accurate music search system and a personalized music recommendation system, which can not only bring great convenience to the daily learning of teachers and students but also the goal that every college hopes to achieve. Therefore, it has an important research significance and broad application prospects.

3. Principle and Selection of the Bayesian Algorithm

In the last century, people usually thought that the probability of something happening was 50%, and the probability of not happening was 50%, that is, non-0 was 1. I do not think about the probability that this thing will happen and the probability that it will not happen. For example, a bag contains a number of black balls and white balls. People in the past thought that taking a ball, the probability of getting a white ball and a black ball was half, and they would not consider the impact of other factors on the results [17]. In academic circles, such a theory was called the frequency experiential school, which was a simple and limited theory until Thomas Bayes proposed the Bayesian theorem. Returning to the example of taking a black-and-white ball from a bag, Bayes believes that the probability of obtaining a ball of a certain color is uncertain and affected by many factors. The frequency experiential school believes that the factors affecting the probability are unknown, but the value is a fixed value. At the same time, the frequency school believes that the samples are random, and its research focuses on the distribution of samples. Bayesian believes that the sample is a random variable, so it is necessary to calculate to understand its distribution [18]. The distribution

determined before the experiment is called a priori distribution. Bayesian theory is based on the priori distribution and then deduces the posterior distribution of the sample [19]. So, the Bayesian theorem is also called a posteriori probability, which is the probability of event A after event B, which can be expressed by the following formula:

$$P\ (A|B) = \frac{P(A \cap B)}{P(B)}. \tag{1}$$

The joint probability and a priori probability are different from a posteriori probability. It represents the probability that two events A and B occur at the same time [20]. Contrary to a posteriori probability is a priori probability. The Bayesian theorem can get another expression by marginalizing a priori probability, that is, as shown in the following formula:

$$P\ (A|B) = \frac{P(B|A)P(A)}{P(B)}, \tag{2}$$

where $P(A|B)$ represents the probability of event A when event B occurs.

4. Using the Bayesian Algorithm to Establish the Management System

4.1. Overall Design of the Music Data System. The data warehouse comprehensive project of music data center in colleges and universities is mainly aimed at the data collected in the past, such as students' on-demand and music purchase (including business data and user behavior data). It provides decision-making service support for the healthier development of colleges and universities. In intelligent management, more reports are mainly displayed for the reference of school operators. Another application is data service, which is mainly used to provide the analysis result data to the business system in the form of interface for access. It recommends songs according to singers or students.

At present, the Bayesian algorithm has been widely used in text, image, and video recommendation systems. The college students' music content search and the recommendation system in this study is actually a hybrid recommendation model based on college students' user behavior and music data information. The core content of this set of search and recommendation is to use the Bayesian algorithm to iteratively calculate the implicit features of music data, and then get the low-dimensional vector information of music data through marginalization [21]. These low-dimensional vector information can be added to the search to optimize the search results and can also be combined with the implicit preference characteristics of college student users to make reasonable music recommendation. This experiment directly extracts the music features from the audio files, which can fundamentally avoid the problem of cold start and be as close to the user's intuitive feeling of music as possible. This hybrid system is based on the traditional matrix decomposition model, and it is improved in the algorithm. The flowchart of the overall system design is shown in Figure 1.

As can be seen from Figure 1, this model uses the hidden semantic matrix to project the user's hidden features and music audio information into a shared space through the Bayesian algorithm and finally outputs the search and recommendation results. The college music data system includes user feature module, music audio information module, search engine module, and recommendation algorithm module. The main function of the user feature module is to collect and store the behavior history data of college student users in the music system and then establish the student user preference model. Due to the preprocessing of music data and the extraction of frequency and other features, music audio information prepares for training the Bayesian dynamic model to calculate search and recommendation data. The search engine module outputs the user's personalized search results according to the extracted features. The recommendation algorithm module is applied to calculate the matching degree between hidden features and student users, and finally, it dynamically recommends music that users may be interested in. The operation of the whole system can be divided into two parts: Bayesian model training and search recommendation. The arrow in the figure shows the process of collection, prediction, and collection. The specific process can be divided into the following steps: first, the system collects the historical behavior of college student users using music software and unifies it, so as to use the appropriate semantic matrix for analysis; then the original music data is restored, and the spectrum features are extracted; using the data obtained in the first two steps to build a Bayesian dynamic model, and then input the obtained data to continuously carry out machine learning to obtain a more perfect Bayesian model. Finally, if the system adds new music data, it also restores the spectrum characteristics first, then uses the perfect Bayesian model to calculate the user's interest in the new music data combined with the preferences of college student users, and finally judges whether to recommend it to the user.

The system also needs to classify the original music and new music data. The traditional music audio-visual classification is based on the song name, singer or band name, lyric author, composer, and file format. It has some similarities with the automatic music classification method based on genre and emotion, that is, it needs three steps: the Bayesian algorithm to extract features, select optimal features, and classification training. However, there are great differences between the two. The definition of music by genre and emotion is abstract, which is different from the qualitative characteristics of traditional music classification. Music genre and emotion are based on human subjective feelings. It is an advanced way of music description. The establishment of genre is classified according to the common points and starting points of different artists when creating music works, which can be used as a simplified summary of some artists' works. As the theme of music expression, emotion plays a decisive role in arousing the feeling of the audience. According to the setting of melody and section, it can also be used as a simplified summary of the common points of some music works. With the development of the music industry, the number of music materials also

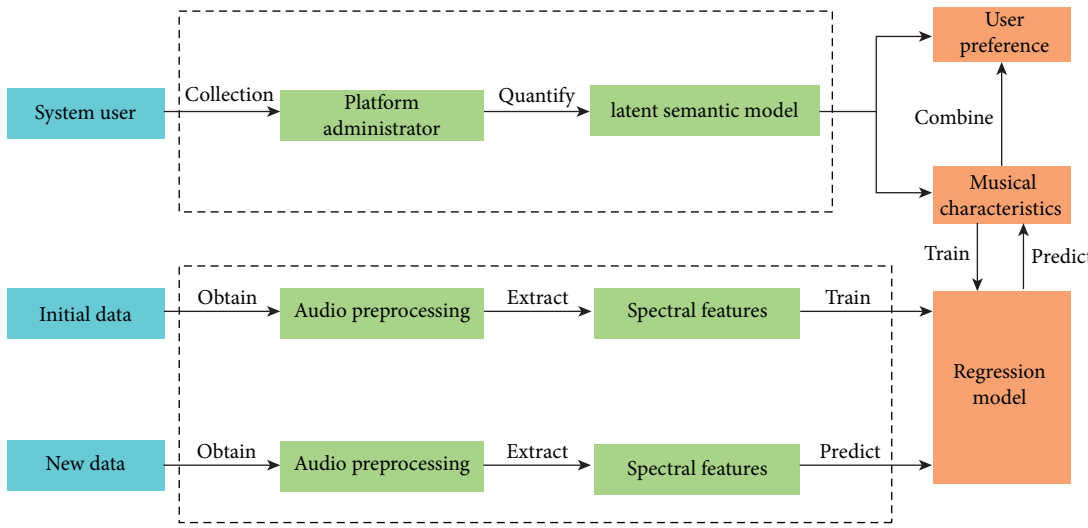

FIGURE 1: Flowchart of the overall design of the music big data management system for college students.

increased. When searching the required music, college teachers and students quickly associate and list the data based on genre and emotional classification, which determines the advantages and disadvantages of a music database, which is of great significance to the development of the music industry. The music works created by the same artist in different periods will have different styles and belong to different schools. The subsets of features extracted by the Bayesian algorithm can form a hierarchical relationship graph of music audio-visual cognition based on genre and emotion.

4.2. System Hidden Semantic Matrix. The hidden semantic matrix used in the college students' music big data management system is a basic factorization matrix (BFM). Unlike the classical singular decomposition matrix, it no longer decomposes the scoring matrix into the form of the product of three matrices. The hidden semantic matrix decomposes several users and several items into the hidden factor matrix corresponding to users and the hidden factor matrix corresponding to items, and there is no need to complete the original matrix. Finally, the obtained hidden factor is used to fit the matrix to obtain the prediction score. This process can be expressed by the following formula:

$$R_{m\times n} \approx R^2_{m\times n} = P_{m\times k} Q^T_{n\times k}, \tag{3}$$

where m is the number of student users, n is the number of music, and $R^2_{m\times n}$ is the approximate square matrix of the decomposed two matrices, also known as the estimated score matrix. To calculate the predicted score of a student user on a song, we can use the following formula:

$$p_u q_i^T = \sum_{k=1}^{K} p_{uk} q_{ki}. \tag{4}$$

Hidden semantic matrix can make good use of hidden factors to express the preferences of students and users for the potential characteristics of music, and reduce the complexity of matrix decomposition. The next step is to calculate the two hidden factor matrices P and Q. First we initialize them and then use the random gradient rising method to iterate continuously until the local optimal value is reached. The scoring error of each student user can be defined by the following formula:

$$e^2_{ui} = \left(r_{ui} - \sum_{k=1}^{K} p_{uk} q_{ki} \right)^2. \tag{5}$$

In this study, the square error is used to reduce the difference between the predicted score and the actual score. Firstly, the loss function is defined as

$$\text{argLoss} = \sum e^2_{ui} = \sum \left(r_{ui} - \sum_{k=1}^{K} p_{uk} q_{ki} \right)^2. \tag{6}$$

Then find out the positive gradient direction of the current value and use the variables in two directions to distinguish.

$$\begin{cases} \dfrac{\partial}{\partial p_{uk}} e^2_{ui} = -2q_{ki} = -2e_{ui} q_{ki}, \\ \dfrac{\partial}{\partial q_{uk}} e^2_{ui} = -2q_{ki} = -2e_{ui} q_{ki}. \end{cases} \tag{7}$$

Then, formulate update rules to iterate the rising direction of the gradient.

$$\begin{cases} p_{uk} + \alpha \dfrac{\partial}{\partial p_{uk}} e^2_{ui} = p_{uk} + 2\alpha e_{ui} q_{ki}, \\ q_{uk} + \alpha \dfrac{\partial}{\partial q_{uk}} e^2_{ui} = q_{uk} + 2\alpha e_{ui} p_{ki}. \end{cases} \tag{8}$$

α in the above formula is a constant with a small value, which determines the minimum value of the machine learning rate. Continue the iterative operation of gradient rise until the minimum error is reached. When the error of

the loss function is less than the set threshold e, the iteration stops, and finally two matrices are obtained as

$$E = \sum e_{ui}^2 = \sum \left(r_{ui} - \sum_{k=1}^{K} p_{uk} q_{ki} \right)^2 \le e. \quad (9)$$

The above formula is the most basic method for hidden semantic matrix decomposition and cannot directly optimize the loss function because it is easy to lead to overfitting. In this experiment, the regularization term is added to the original loss function, that is, regularization is introduced, and the subsequent loss function is expressed as

$$e_{ui}^2 = \left(r_{ui} - \sum_{k=1}^{K} p_{uk} q_{ki} \right)^2 + \lambda \left(\|p_u\|^2 + \|q_i\|^2 \right), \quad (10)$$

$$\text{argLoss} = \sum \left(r_{ui} - \sum_{k=1}^{K} p_{uk} q_{ki} \right)^2 + \lambda \left(\|p_u\|^2 + \|q_i\|^2 \right). \quad (11)$$

λ in the above formula can be obtained through systematic experiments and is a regularization parameter. The random gradient rise method is used to optimize formula (11). Firstly, the partial derivatives of the two matrices are carried out.

$$\frac{\partial \text{Loss}}{\partial p_{uk}} = -2 \left(r_{ui} - \sum_{k=1}^{K} p_{uk} q_{ki} \right) q_{ki} + 2\lambda p_{uk}, \quad (12)$$

$$\frac{\partial \text{Loss}}{\partial q_{ki}} = -2 \left(r_{ui} - \sum_{k=1}^{K} p_{uk} q_{ki} \right) p_{uk} + 2\lambda q_{ki}. \quad (13)$$

Then, use the least square method alternately to make the parameters p_{uk} and q_{ki} in the above two formulas rise along the minimum value of speed for iterative optimization, and the optimal parameter value can be obtained as

$$\overrightarrow{p_{uk}} = p_{uk} + \alpha (e_{ui} q_{ki} - \lambda p_{uk}), \quad (14)$$

$$\overrightarrow{q_{ki}} = q_{ki} + \alpha (e_{ui} p_{uk} - \lambda q_{ki}). \quad (15)$$

In this way, the optimal hidden semantic matrix is obtained, and then the parameters of various functions are selected.

4.3. Selection of Music System Activation Function. If an activation function is not added to a Bayesian model, it is only equivalent to a linear regression model and cannot deal with more complex logical problems. In the process of introducing the activation function into the dynamic system, the single thread processing mode is changed into nonlinear, which can represent and calculate more complex music data. At present, the commonly used monotone functions mainly include sigmoid function, tanh function, and ReLU function. Their respective function diagrams are shown in Figure 2.

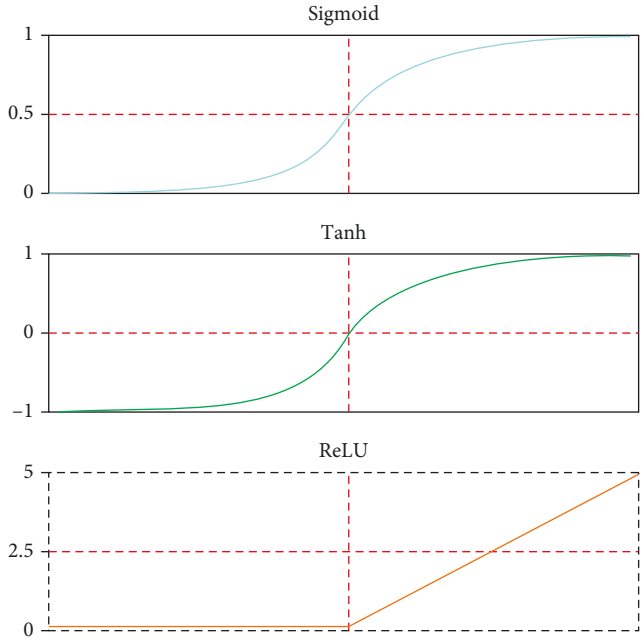

Figure 2: Schematic diagram of sigmoid function, tanh function, and ReLU function.

This design attempts to use JSP to build an online music website management system on the network, so as to promote the development of electronic information management process and intelligent management of music websites. From the perspective of theory and practice, this paper analyzes the design and implementation of a music website management system with data analysis function. Choosing different activation functions to apply to the music management system will affect the training and prediction and then affect the search and recommendation results. When using sigmoid function or tanh function to calculate large-scale data, it will produce large errors, while using ReLU activation function can converge quickly, so as to save the amount of calculation and improve the training efficiency. Moreover, for the dynamic deep music model, the gradient of ReLU function is constant, and the gradient will not disappear like sigmoid function. As mentioned above, this study finally selects ReLU function as the activation function of the music management system.

5. System Experiment and Result Analysis

In the deep learning of machine dynamics, there are many free and open benchmark databases, but most of them are text and pictures. The music data required in this experiment usually involves the ownership of copyright, so it was authorized with music software and applied to a university for the practical use of the system. First, the predicted characteristic coefficients are substituted into the Bayesian algorithm to preprocess the data of a music library. The steps are shown in Figure 3.

As can be seen from Figure 3, firstly, the original music data is randomly divided into two parts, and data set 1 is trained by the Bayesian algorithm to obtain a strong

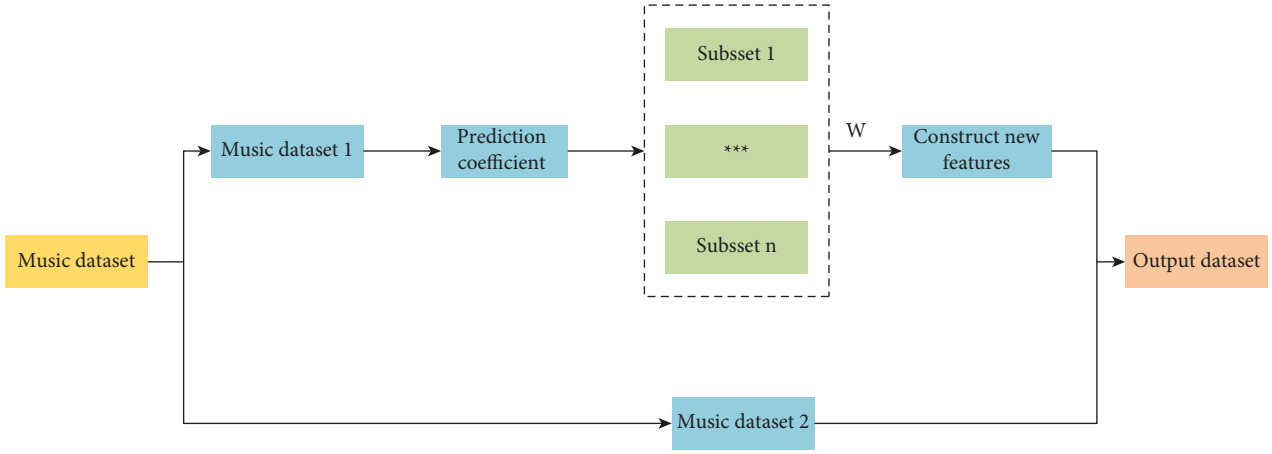

Figure 3: Prediction feature coefficients and the logistic regression algorithm processing the data steps diagram.

classifier composed of several data subsets. Data set 2 is reconstructed directly using output vector W and then merged with data set 1. Finally, the combined data set is classified into two categories to predict the search and recommendation of college students in the music audio-visual data set.

As described in the previous section, this experiment uses the square error as the loss function and uses the preprocessed music data above to train the Bayesian dynamic music model. The training results are shown in Figure 4.

It can be seen from the result chart that the loss error decreases rapidly in the initial stage of training. When the iteration round epoch exceeds 10, the downward trend of the function slows down obviously. Compared with the ideal loss value, the experimental results meet the expected standard, and the prediction error of the Bayesian algorithm model is within the acceptable range. In theory, the naive Bayesian model has the least error rate compared with other classification methods. However, this is not always the case because naive Bayesian models assume that attributes are independent of each other. This assumption is often not true in practical applications. When there are many attributes or the correlation between attributes is large, the classification effect is not good.

Then, the hidden factor dimension is used to comprehensively evaluate epoch. The output dimension of the hidden factor is directly determined by the number of feature vectors of the music audio file. The number of college students using the music data system is 130, and the number of iteration rounds affected when the dimension of the hidden factor increases from 3 to 11. The results are shown in Figure 5.

As can be seen from Figure 5, when the hidden factor dimension is 3, the maximum RMSE value is obtained, indicating that the representation of music features is insufficient when the dimension is small. As the dimension increases, the RMSE value also decreases steadily. When the hidden factor dimension is 11, the system model has the best representation of music features. The timbre effect of music is the best and the classification is the clearest.

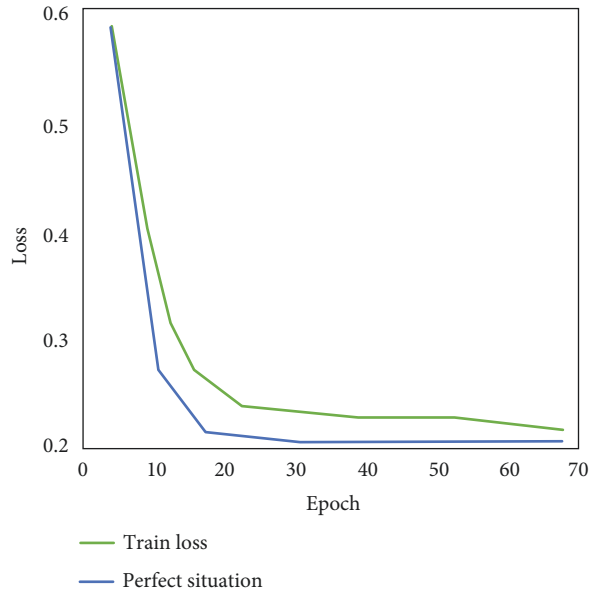

Figure 4: The relationship between the ideal value and the loss value of the training model.

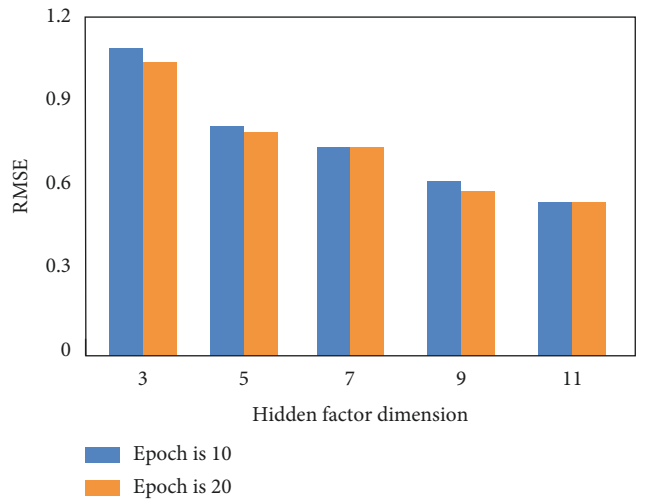

Figure 5: RMSE of predicted scores at different k and epoch.

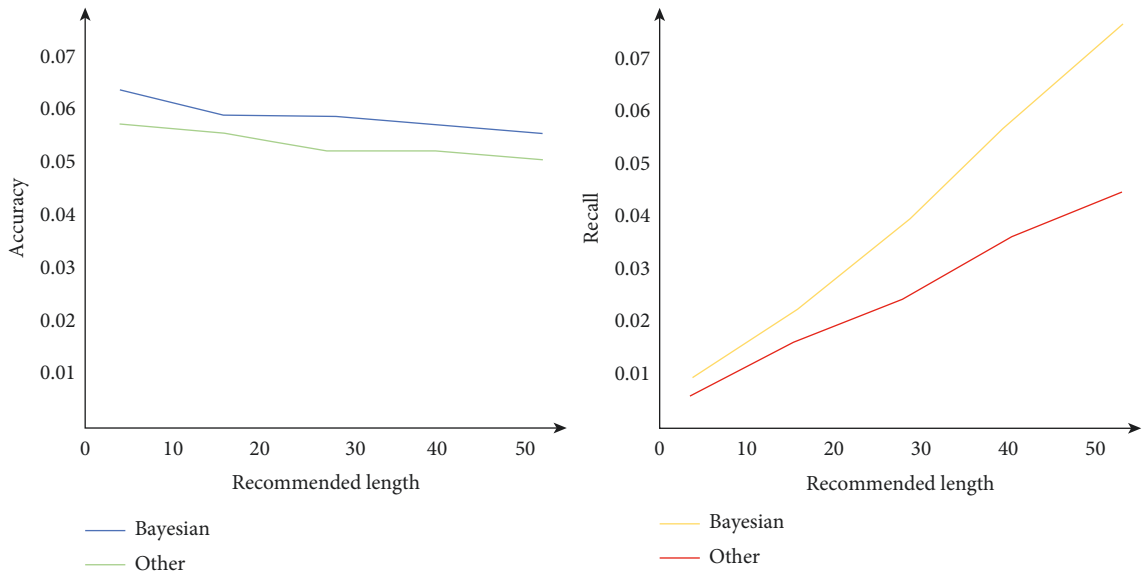

Figure 6: Comparison plot of precision and recall for two different algorithms.

In order to verify the feasibility of the Bayesian algorithm in this experiment, the accuracy and recall of system models under different search and recommendation lists are tested. The results obtained are plotted as shown below.

On the left side of Figure 6 is the comparison of accuracy. It can be found from the figure that the Bayesian algorithm model is used to filter the characteristics of music audio and recommend directly without this method. The accuracy of the recommendation effect of the Bayesian algorithm model is significantly higher than that of the standard collaborative filtering recommendation. On the right side of Figure 6 is the comparison of recall rates obtained by two different algorithms. It can be seen from the figure that with the growth of the music search and the recommendation list, the recall rate of both algorithms gradually increases. When the recommendation list is 45, the acceptable recall rate is reached. At this time, the music data search and the recommendation recall rate using the logistic regression model is 4.62%, while the music data search and the recommendation recall rate of nonstandard collaborative filtering is about 6.29%. The comparison shows that the recommendation effect filtered by the Bayesian algorithm model is better than that of the nonstandard collaborative filtering recommendation system.

After putting the music data management system for college students based on the Bayesian algorithm into use for decades, the ability of music majors was tested through the music classroom test. It can be found from the results in Figure 7 that students majoring in music have greatly improved their sound sense, music literacy, music scope, and music performance level by using this system.

College students' music data has the characteristics of three dimensions. In order to optimize management, the dimension of the data is reduced so that the database can be represented by one-dimensional data. It is faster and more convenient to calculate the search and recommendation results based on the data because the one-dimensional data has no redundant features and can accurately reflect the results, as shown in Figure 8.

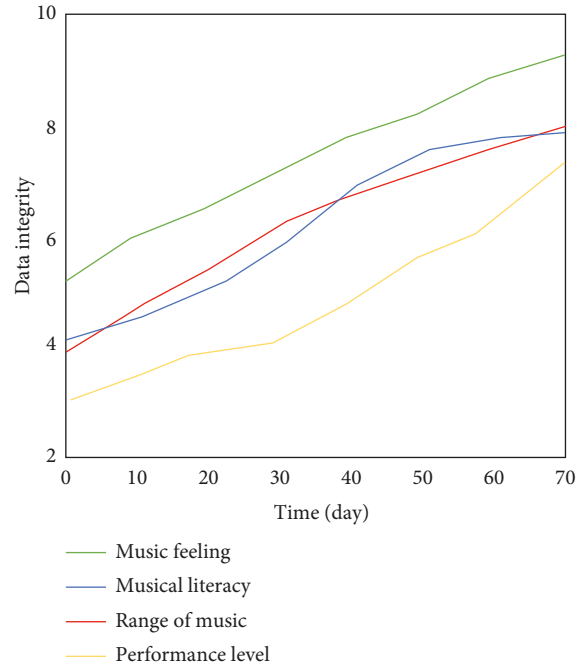

Figure 7: The relationship between the students' music scores and days under Bayesian model data mining.

Figure 8 describes the peak value of search and push data of music in the whole day. It can be seen that the peak value of recommendation data of college students in the whole day remains at about 40%. This shows that the data system of this experiment is stable and can use low resources to calculate and output recommendation results, which meets the needs of teachers and students. The peak value of search data will appear two peaks at 15 : 00 and 21 : 00. This paper infers that these two periods may be the most frequent periods of

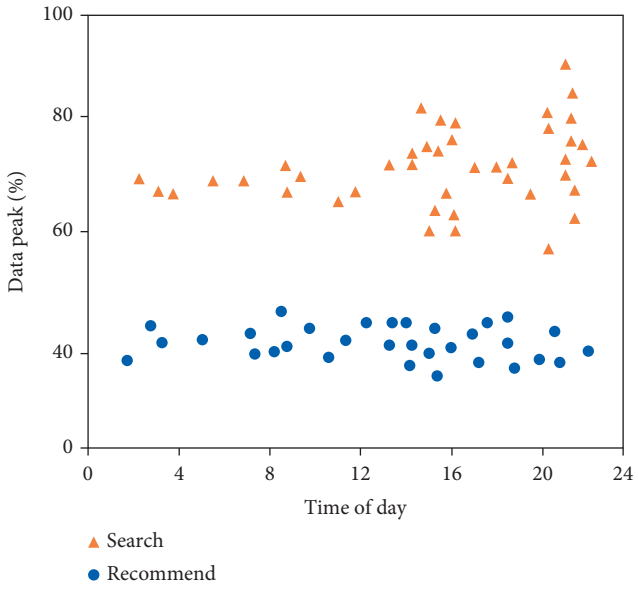

Figure 8: Graph of peak data searched and pushed over an entire day.

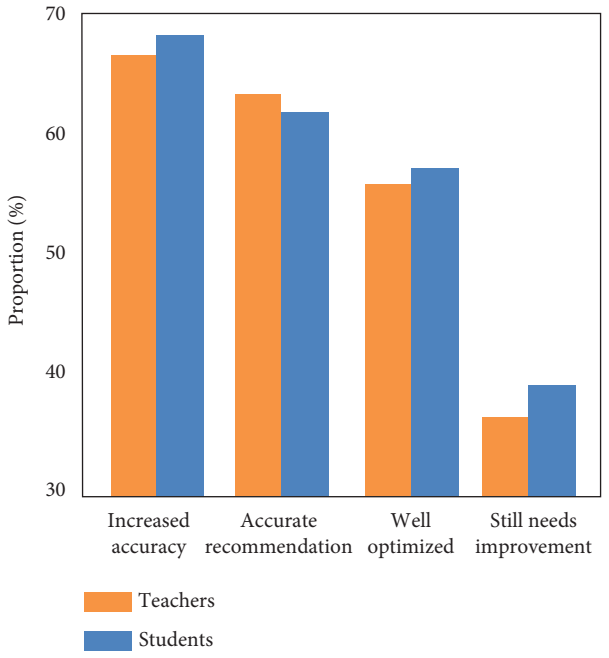

Figure 9: New archives music audio and video teachers and students satisfaction survey results chart.

students' demand for entertainment, so there is such a peak value of search.

Results after a period of use, the feedback of teachers and students in a university was obtained through the questionnaire survey. The results are shown in Figure 9.

As can be seen from the data in the figure, more than 67% of teachers and student users actually feel the improvement of the new system for music audio-visual archives management, and about 62% of users think the optimization effect is obvious. At the same time, less than 40% of the respondents said that the system needs to be further improved. This shows that the model based on the Bayesian algorithm has made a good optimization of the college music big data management system.

6. Conclusion

In today's era, with the progress of computer technology, the university music big data management system also needs to introduce a scientific and an effective data model for optimization. Based on the computer-aided Bayesian algorithm, the music database of music software is analyzed and processed, and a Bayesian model is established, which provides a scientific research method for this complex system. Firstly, this paper introduces the principle and function theorem of the Bayesian algorithm. Then, different from the classification of traditional music, the data is divided into original music and new music, and a college music data management system with search and recommendation as the two core is established. The optimal hidden semantic matrix is calculated iteratively, and the advantages and disadvantages of sigmoid, tanh, and ReLU, the three most commonly used functions, are compared. Finally, ReLU function is selected as the activation function of this experiment.

After completing the establishment of the music management system model, we obtained the authorization of music software and applied it to a university. Firstly, we preprocessed the original data. Compared with the ideal loss value, the experimental results meet the expected standard, and the prediction error of the Bayesian algorithm model is within the acceptable range. With the increase of the hidden factor dimension, the RMSE value also decreases steadily. It can be seen that when the hidden factor dimension is 11, the system model performs best in the representation of music features. The comparison shows that the recommendation effect filtered by the Bayesian algorithm model is better than that of the nonstandard collaborative filtering recommendation system. By using the experimental music search and the recommendation system, music majors have greatly improved their sound sense, music literacy, music coverage, and music performance level. The final questionnaire survey shows that college students are satisfied with the system as a whole.

However, the efficiency of the Bayesian mining algorithm needs to be further improved. There is also the risk of data leakage. When the number of Bayesian attributes is large or the correlation between attributes is large, the classification effect is not good. There are still many actual situations where the feature correlation is very small, so this model still needs further analysis and modification. In the future, college music users should also use the analysis results reasonably. Further analysis is needed.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Application of Balanced Scorecard in Performance Management and Evaluation of Listed Companies

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A reasonable enterprise performance evaluation system not only is conducive to the scientific nature of enterprise internal management, but also can accurately reflect the shortcomings in development and provide effective guidance for the high-quality and efficient development of enterprises. Therefore, based on the relevant theories and research of performance evaluation and balanced scorecard (BSC), this paper analyzes the shortcomings of the current performance evaluation system of enterprises and the necessity and feasibility of applying BSC to design performance evaluation system. Then, we design a performance evaluation system with the characteristics of listed companies (LC). Finally, we use the analytic hierarchy process (AHP) to conduct a comprehensive performance evaluation of enterprise A and propose corresponding safeguards for the smooth implementation of the system according to the evaluation results.

1. Introduction

As an important part of nonpublic economy, LC play a positive role in economic development and are the subject of numerous scholars [1]. Enterprise performance evaluation is an analysis method to study the current situation and sustainable development capacity of enterprises, which has a guiding role in internal self-examination and the formulation of further development strategies of enterprises [2]. Enterprise performance evaluation methods are constantly developing and changing, and their application effects may vary depending on the specific research methods used. Therefore, an appropriate method to evaluate LC has a significant impact on reflecting the real performance level of enterprises [3]. However, there are some problems in the performance evaluation system of LC. On the one hand, the types of performance indicators are single and one-sided [4]. At present, the performance evaluation system of LC is mainly based on various financial indicators, reflecting the profitability, solvency, asset status, and operating growth status of enterprises. For the factors that affect the development of enterprises, such as customer opinions, internal process efficiency, employees' learning and growth potential, and industrial policy requirements, enterprises are not included in the scope of performance evaluation. Although such a performance evaluation method is simple and convenient enough, the financial data reflect more of the enterprise's past operating conditions, leading to the enterprise to ignore the ability of sustainable development to a certain extent [5]. On the other hand, corporate management's participation in performance management is not enough [6]. Although the management participates in the formulation of the annual target of the enterprise, the follow-up work is mainly carried out by the human resources department, which mainly focuses on the supervision and evaluation of performance, and the evaluation results are only used as the basis for salary payment [7]. The lack of communication and feedback between management and employees leads to low enthusiasm of employees. The important purpose of performance evaluation is to improve the work enthusiasm of all employees and then improve the operation and production efficiency of enterprises, and the realization of these goals depends on the active participation of all employees [8]. Therefore, enterprises should help employees find the relationship between performance appraisal and their own career planning, so that employees' goals are clearer and

strive to keep consistent with the development direction of the enterprise [9].

Currently, commonly used performance evaluation methods include Management by Objectives (MBO), Key Performance Indicator Assessment (KPI), Economic Value Added (EVA), and Balanced Scorecard (BSC) [10–13]. Among them, as a performance management tool with strategy as the core, BSC has many advantages and has been widely used in performance evaluation [14]. The evaluation dimensions of BSC are mainly divided into four dimensions, that is, financial, customers, internal processes, and learning and growth, which represent the interests of the shareholders, customers, employees, etc. The important degree of each dimension depends on the content of index to the importance of the strategic objectives of the enterprise, namely, the size of the index weight. The dimensions of BSC are linked to each other and have certain causal relationship between each other [15]. The core content of each dimension is shown in Figure 1. Therefore, it is necessary for LC to introduce BSC to construct performance evaluation index system. Firstly, it helps improve the enterprise performance evaluation system [16]. The current performance evaluation of enterprises is mainly based on financial indicators, but the factors that affect enterprise performance come from all aspects, which leads to the performance of some functional comprehensive departments that cannot be properly evaluated. The application of BSC can make managers pay attention to other aspects besides financial indicators, which can significantly improve the efficiency of enterprise operation and management. Secondly, it contributes to the realization of corporate strategic goals [17]. Although the enterprise has clear strategic goals and corporate vision, the strategic planning of the enterprise is not detailed and implemented and cannot be integrated with the specific work and actions of ordinary employees. BSC is not only a scientific method of strategic performance evaluation, but also an effective performance management tool [18]. It can decompose strategic objectives and refine them into specific performance evaluation indicators, which is conducive to strengthening strategic implementation and monitoring strategic objectives of enterprises. In addition, it helps stimulate employees' work enthusiasm [19]. The current performance evaluation system of LC does not solicit opinions and suggestions from employees in the process of formulation and implementation. If there is no effective communication and feedback link between managers and employees, performance evaluation will not accurately reflect the actual needs of employees, thus reducing the enthusiasm of employees to participate [20]. BSC can connect all departments and employees at all levels of an enterprise through the layered decomposition of strategic objectives, so as to improve employees' understanding of the enterprise's business planning and strategic objectives [21].

Based on BSC, this paper studies the performance evaluation of LC. Combined with the production and operation characteristics of LC and related industry policies, a new performance evaluation system is designed from the four dimensions of finance, customers, internal processes, and learning and growth. It can not only help improve the business performance management of LC and promote the early realization of strategic objectives, but also provide reference for the construction of enterprise performance evaluation system.

2. Related Work

Some scholars have used different methods to study the performance of LC, including operating performance, financial performance, and comprehensive performance. For example, Li et al. [22] used DEA model to study the operating efficiency of agricultural LC. Different from previous studies, this paper innovatively added two input variables into the analysis of factors that may affect the operating efficiency of agricultural LC, namely, asset impairment loss (AIL) and business tax and surcharge (BTS). Ban et al. [23] studied the performance level of LC by using Fuzzy Analytic Hierarchy Process and TOPSIS method. The index system constructed in this paper had 15 indexes, including 8 financial indexes and 7 nonfinancial indexes. And the results showed that nonfinancial indicators will also have a significant impact on the overall performance of LC. Ban et al. [23] focused on the financial performance evaluation of listed retail enterprises and selected 18 financial indicators and calculated the weight of indicators by standard deviation method (SD). Through empirical analysis, they found that leverage ratio has the most significant impact on listed retail enterprises among these financial indicators. Nguyen et al. [24] introduced BSC in the construction of corporate performance evaluation indicators. The advantage of this approach is that it takes into account not only traditional performance indicators, including financial indicators, quality indicators, and service objectives, but also internal and external process indicators. Then, in order to solve the fuzziness and uncertainty that managers tend to have in the decision-making process, they adopted the grey system theory and combined the decision experiment and evaluation laboratory and network analysis process method to evaluate performance.

3. Performance Evaluation Index System of LC

3.1. Basic Principles and Design Ideas of Index System Construction. In constructing the performance evaluation index system of LC, we follow some basic principles, including objective, systematic, authenticity, and accessibility, so the index system has the characteristics of wide coverage and strong applicability. The details of the indicator building principles are shown in Figure 2.

We use BSC to design the performance evaluation system of LC as shown in Figure 3.

First, we need to clarify the strategic objectives of LC. The strategic goal of the enterprise is the basis of designing the performance evaluation system. We use BSC to design the evaluation index system, which is always oriented by the enterprise strategy, and then combine the enterprise strategy with the short-term goal of the individual and transform the organizational strategy into measurable indicators, so as to promote the effective implementation of the strategy. Then, we

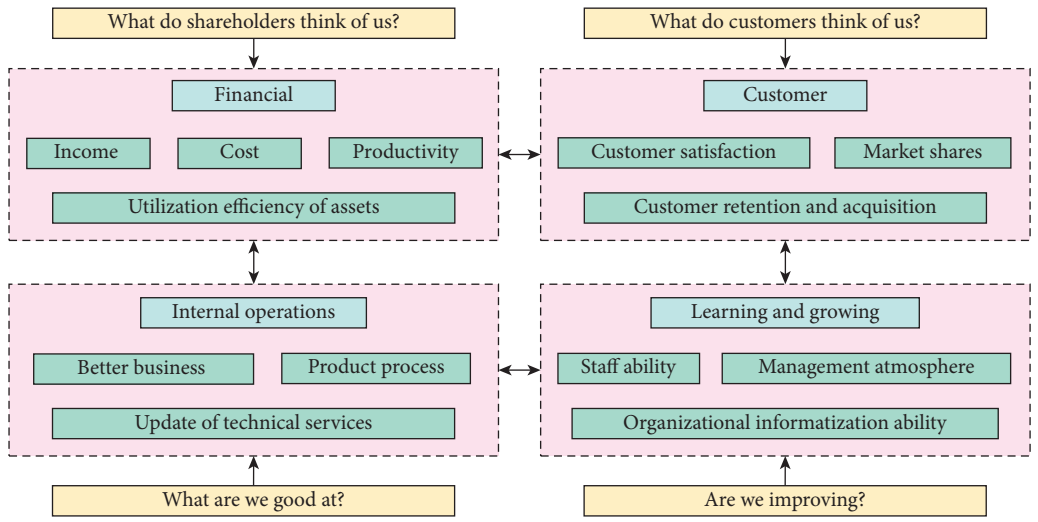

Figure 1: Evaluation dimension of BSC.

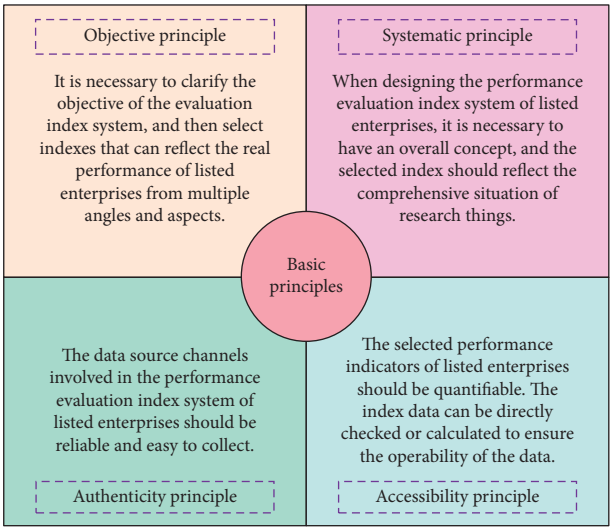

Figure 2: Construction principles of performance evaluation index system for LC.

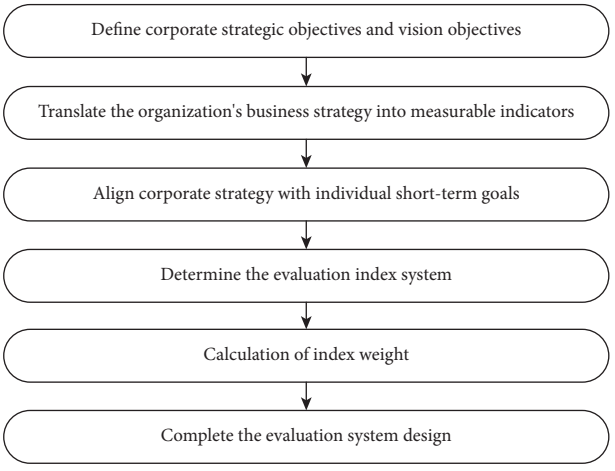

Figure 3: Design ideas of performance evaluation system for LC.

determine the performance evaluation index from the four dimensions of BSC and combined with the actual situation of enterprises. Finally, the weight of indicators is determined. This paper adopts AHP to determine the weight of indicators at all levels. So far, BSC performance evaluation index system of LC has been designed, but it should be noted that the system needs to be revised and improved according to the development and change of internal and external environment.

3.2. Construction of Performance Evaluation Index System of LC. At the level of organizational and personal performance, performance management can effectively promote the simultaneous development of enterprises, departments, and employees. On the one hand, the management can communicate effectively with the working layer and provide some guidance. On the other hand, employees further enhance themselves according to these guidance and information resources. Therefore, when constructing the performance evaluation index system of LC, we choose BSC to consider the factors affecting the performance of LC, including finance, customers, internal processes, and learning and growth. There are four first-level indicators and 24 second-level indicators in the final performance evaluation index system of LC, as shown in Figure 4.

Among them, the specific explanation of financial indicators is as follows:

Growth rate of business income and growth rate of total assets reflect the growth ability of LC. The higher the former represents the faster revenue growth of LC, the better the market prospects are. The latter reflects the expansion speed of enterprise capital scale, and it is an important indicator to measure the change and growth of enterprise total scale.

Return on net assets reflects the profitability of LC. It can reflect the earnings level of shareholders' equity to measure the efficiency of companies using their own capital. The higher the index value, the higher the return on investment.

Speed ratio and asset-liability ratio reflect the solvency of LC. The former measures the ability of LC to immediately cash in their current assets to repay current liabilities. The

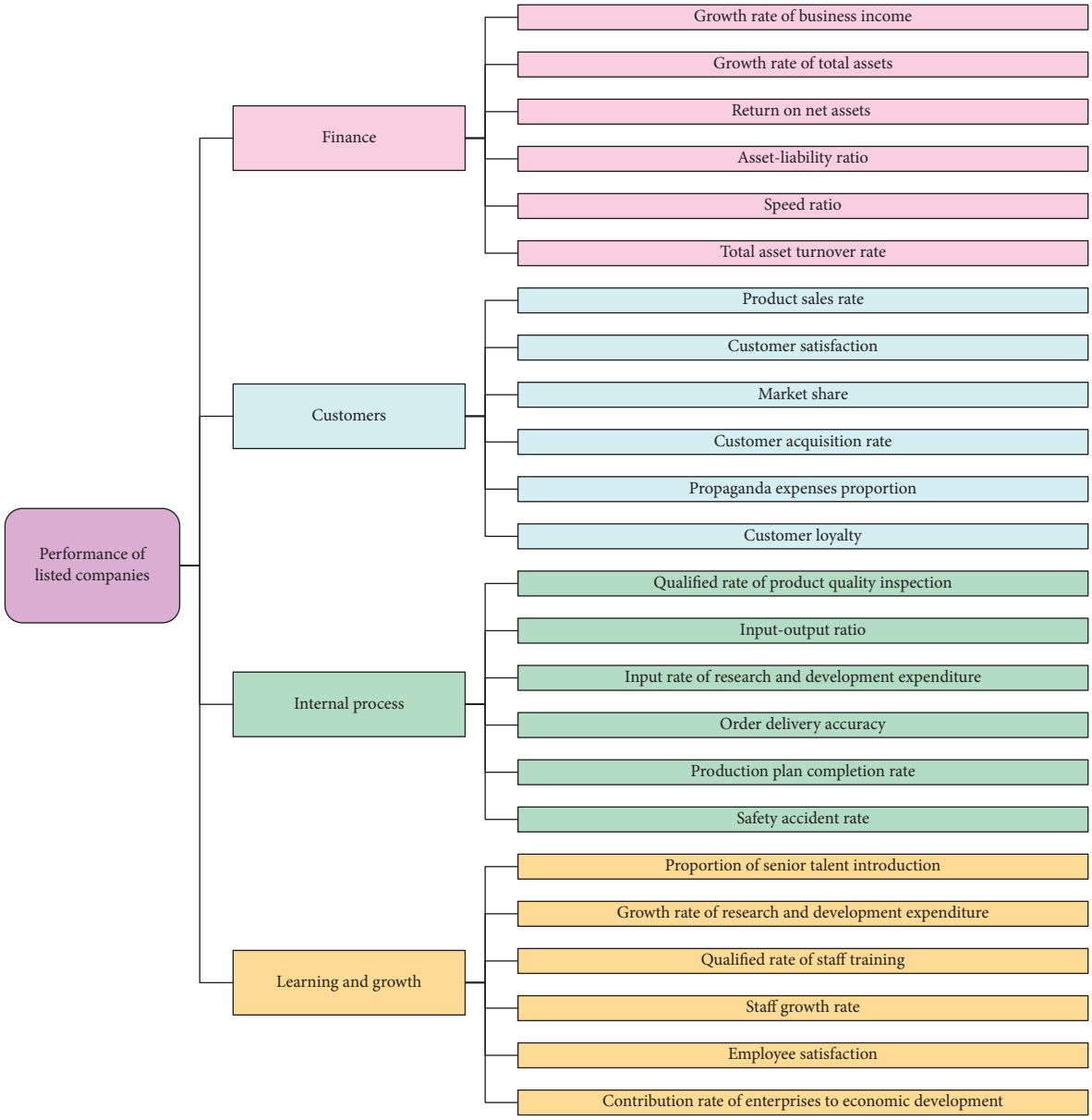

Figure 4: Performance evaluation index system of LC.

latter refers to the percentage of total liabilities divided by total assets. It measures the ability of LC to raise debt and reflects the risk of creditors lending.

Total asset turnover rate reflects the operational capacity of LC. It is a comprehensive index to investigate the operational efficiency of enterprise assets, which reflects the transfer speed, management quality, and utilization efficiency of all assets from input to output.

4. Performance Evaluation of LC

4.1. Method Selection. It is an important step for determining the weight of performance evaluation index in designing BSC evaluation system. Because the balance of the relationship between the various levels of indicators will directly affect the effectiveness of the dimension objectives, scientific and reasonable index weight setting can make all the inspection contents clearly reflect the specific situation of enterprise finance, customers, internal operation, and growth and learning. This paper uses AHP to calculate the weight of each index. Our basic idea is to divide the problem to be analyzed and then decompose the problem layer by layer according to the nature of the problem and the overall goal to be achieved. Finally, the problem is decomposed into different components, and the hierarchical structure model is formed according to the relationship between the elements, so as to determine the weight value of each element [25, 26].

4.2. Determination of Performance Evaluation Index Weight of LC

4.2.1. Build Hierarchical Structure Model. According to the performance evaluation index system of LC, this paper divides the hierarchical structure model from top to bottom

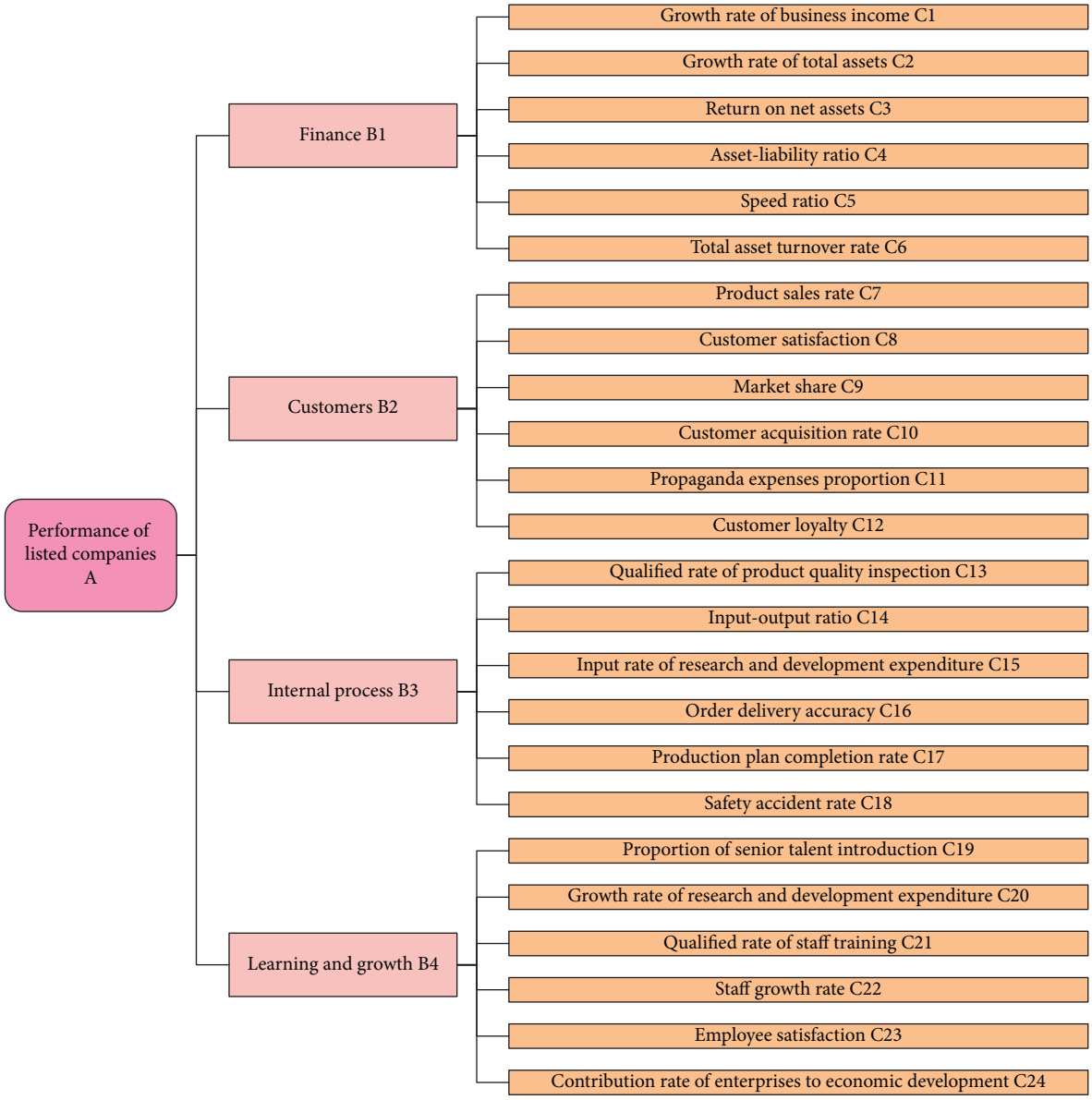

Figure 5: Hierarchical structure model.

into three levels, namely, the target layer, the criterion layer, and the scheme layer, and each layer of indicators is a gradual decomposition of the upper layer of indicators. Specifically, we take the strategic objectives to be achieved by LC as the target layer, then the key factors corresponding to the four dimensions as the criterion layer, and the specific indicators under each dimension as the scheme layer. The hierarchical structure model is shown in Figure 5.

4.2.2. Construct Judgment Matrix. According to the research requirements of comprehensive analysis and performance evaluation of LC, this paper invited 10 experts to carry out the index weight calculation of performance evaluation of LC. The panel members we invited include managers of LC and managers of various departments. Then, according to the established performance evaluation index system of LC and combined with their own theory and practical experience, the expert group constructs a criterion layer judgment matrix and four index layer judgment matrices. Special attention is paid by the experts to the 1–5 scale method for the importance of each index pairwise comparison and scoring. We summarize the results of expert scoring and construct the corresponding judgment matrix. The scoring criteria of 1–5 scale method are shown in Figure 6.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \quad (1)$$

$$a_{ij} = \frac{a_i}{a_j},$$

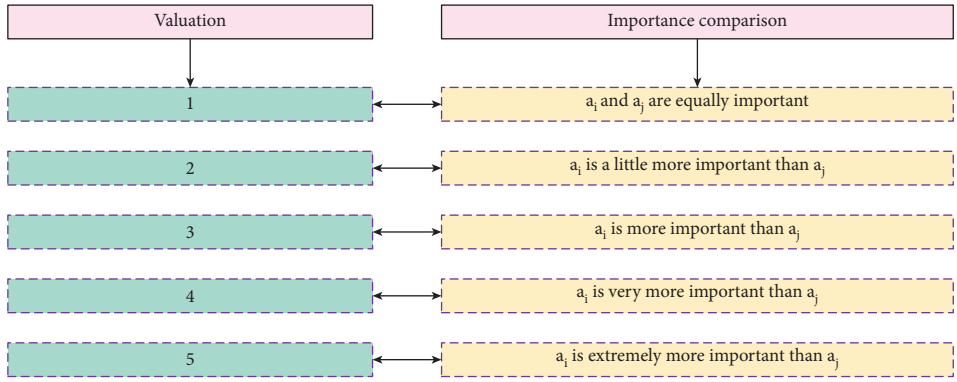

Figure 6: 1–5 valuation meaning.

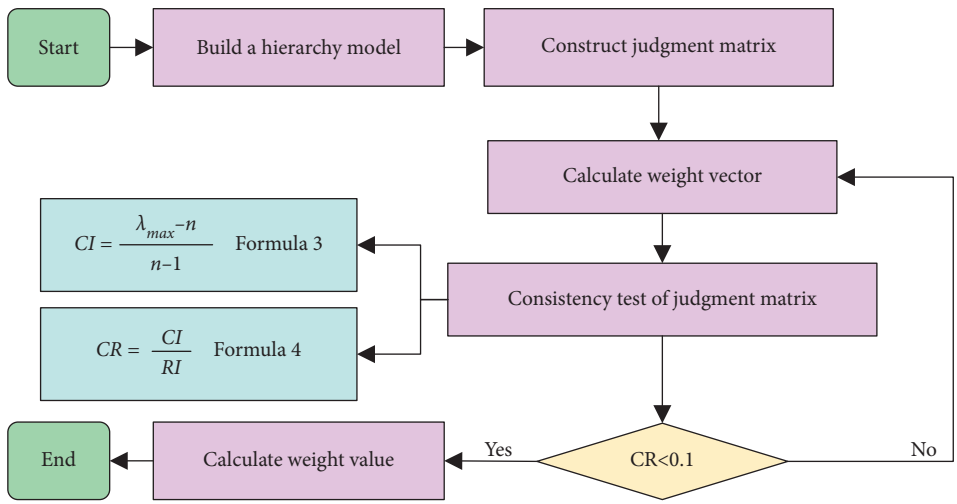

Figure 7: Process of determining index weight of performance evaluation of LC by AHP.

where A is the judgment matrix. a_i and a_j represent the elements in the hierarchy. a_{ij} represents the relative importance of the right.

4.2.3. Index Weight Calculation and Consistency Test. After discussing the establishment of multiple judgment matrices in the criterion layer and the indicator layer by the expert group, we also need to perform the consistency test of judgment matrices. The calculation formula and test standard of consistency test are shown in Figure 7.

The scoring results of performance, the calculation results of index weight, and the consistency test results by experts are shown in Figures 8 and 9. It can be seen that all the judgment matrices pass the consistency test, indicating that the weight value of performance evaluation index of LC is reasonable. Then, we summarize the above calculation results and finally obtain the weight value of the performance evaluation index of LC, as shown in Table 1.

It can be seen from Table 1 that the weights of financial dimension, customers dimension, internal processes dimension, and learning and growth dimension are 43.19%, 31.27%, 11.50%, and 14.04%, respectively. We find that the financial dimension accounted for the highest proportion of the four dimensions, indicating that LC to improve the operating efficiency and obtain more profits is still the focus of future development. The second is the customer dimension, where customers are the source of corporate profits. In order to obtain more profits, LC must pay attention to the acquisition and maintenance of customers and improve customer satisfaction. Internal process dimension and learning and growth dimension are relatively small, but cannot be ignored. Efficient internal operation is the embodiment of the competitive advantage of enterprises, and the learning and growth of enterprise employees provide human resources support for the long-term development of enterprises, while enhancing enterprise cohesion. In the scheme layer, the comprehensive weights of growth rate of business income and return on net assets accounted for the highest proportion, which are 13.9% and 12.5%, respectively. However, the combined weights of input rate of research and development expenditure and input-output ratio are relatively low, 0.5% and 0.8%, respectively. Return on net assets and growth rate of business income account for a large proportion, which is consistent with the goal of maximizing enterprise value. Input rate of research and development expenditure and input-output ratio relatively reflect the internal operating efficiency of enterprises. Although the proportion is relatively small, it cannot be ignored.

U	B_1	B_2	B3	B4	W_i
B_1	1	2	5	3	0.471
B_2	1/2	1	3	2	0.278
B3	1/5	1/3	1	1/2	0.087
B4	1/3	1/2	2	1	0.164
Total					1

$\lambda_{max} = 4.021$, CI = 0.007, CR = 0.008

Figure 8: Weight of criterion layer index.

B_1	C_1	C_2	C_3	C_4	C_5	C_6	W_i
C_1	1	3	2	2	4	3	0.295
C_2	1/3	1	1/2	1/2	2	2	0.125
C_3	1/2	2	1	2	5	3	0.266
C_4	1/2	2	1/2	1	3	2	0.177
C_5	1/4	1/2	1/5	1/3	1	1	0.065
C_6	1/3	1/2	1/3	1/2	1	1	0.072
Total							1

λ_{max}= 6.212, CI = 0.042, CR = 0.034

B_2	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	W_i
C_7	1	3	2	2	5	3	0.304
C_8	1/3	1	1/2	1/3	2	2	0.117
C_9	1/2	2	1	2	5	3	0.257
C_{10}	1/2	3	1/2	1	3	2	0.190
C_{11}	1/5	1/2	1/5	1/3	1	1	0.062
C_{12}	1/3	1/2	1/3	1/2	1	1	0.070
Total							1

λ_{max}= 6.255, CI = 0.051, CR = 0.041

B_3	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	W_i
C_{13}	1	2	3	2	1/2	1	0.191
C_{14}	1/2	1	2	1/2	1/4	1/3	0.092
C_{15}	1/3	1/2	1	1/2	1/4	1/3	0.059
C_{16}	1/2	2	2	1	1/3	1/2	0.127
C_{17}	2	4	4	3	1	2	0.321
C_{18}	1	3	3	2	1/2	1	0.211
Total							1

λ_{max}= 6.298, CI = 0.060, CR = 0.048

B_4	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	W_i
C_{19}	1	1	1/4	1/2	1/3	1/2	0.069
C_{20}	1	1	1/5	1/3	1/4	1/2	0.064
C_{21}	4	5	1	2	2	3	0.329
C_{22}	2	3	1/2	1	1/2	2	0.174
C_{23}	3	4	1/2	2	1	2	0.242
C_{24}	2	2	1/3	1/2	1/2	1	0.123
Total							1

λ_{max}= 6.275, CI = 0.059, CR = 0.048

Figure 9: Weight of schematic layer index.

4.3. Performance Comprehensive Evaluation of LC. Taking enterprise A as an example, this paper uses the index weight value calculated above to conduct a comprehensive performance evaluation. The specific calculation process is as follows:

4.3.1. Determine the Target Value. In the performance evaluation work, enterprises should be clear to achieve the performance target value as the motivation to enhance performance and judge whether to achieve the target standard. Common performance evaluation criteria include historical value, enterprise target value, and industry average standard. In order to reflect the long-term strategy, the financial data indicators in this paper are based on the development of enterprises in the past three years and are adjusted according to the strategic objectives of enterprises. Other indicators are based on the target value of enterprises.

4.3.2. Determine Scoring Standards. In order to clarify the score of each indicator, this paper first divides the specific performance evaluation level and then uses equations (2)–(5) to calculate the comprehensive evaluation results of enterprise A. The level of performance evaluation is shown in Table 2.

$$P = C_1 \times W_1 + C_2 \times W_2 + \cdots + C_{24} \times W_{24}, \tag{2}$$

$$C_n = R \times 100. \tag{3}$$

Among them, P is the final score of enterprise A performance comprehensive evaluation. C is the score of each index of enterprise A. W is the comprehensive weight of each index. R is the relationship ratio. The calculation method of relationship ratio is divided into two cases. Assuming the target value is TV, and the actual value is AV, when the index is positive, the relationship ratio is calculated by formula (4). When the index is negative, the relationship ratio is calculated by formula (5).

$$R = \frac{\mathrm{AV}}{\mathrm{TV}} \times 100\%. \tag{4}$$

$$R = \frac{\mathrm{TV} - (\mathrm{AV} - \mathrm{TV})}{\mathrm{TV}} \times 100\%. \tag{5}$$

4.3.3. Comprehensive Evaluation Score of Enterprise A. Quantitative indicators are calculated based on enterprise A data for 2021, such as financial data. For indicators such as

Table 1: Index weight of performance evaluation of listed companies.

Criterion layer	Weight	Schematic layer	Weight	Total weight
B1	0.471	C1	0.295	0.139
		C2	0.125	0.059
		C3	0.266	0.125
		C4	0.177	0.083
		C5	0.065	0.030
		C6	0.072	0.034
B2	0.278	C7	0.304	0.085
		C8	0.117	0.033
		C9	0.257	0.071
		C10	0.190	0.053
		C11	0.062	0.017
		C12	0.070	0.019
B3	0.087	C13	0.191	0.017
		C14	0.092	0.008
		C15	0.059	0.005
		C16	0.127	0.011
		C17	0.321	0.028
		C18	0.211	0.018
B4	0.164	C19	0.069	0.011
		C20	0.064	0.010
		C21	0.329	0.054
		C22	0.174	0.029
		C23	0.242	0.040
		C24	0.123	0.020

Table 2: Performance evaluation scale of LC.

Number	Score P	Scale	Description
1	$P \geq 90$	Excellent	Performance is very good and even better than expected
2	$80 \leq P < 90$	Good	Basically achieving enterprise goals
3	$70 \leq P < 80$	General	General performance and larger room for improvement
4	$60 \leq P < 70$	Qualified	Qualified performance and need to be improved in time
5	$P < 60$	Unqualified	Poor performance and difficult to improve

customer satisfaction and employee satisfaction, we use questionnaires to obtain data. By summarizing the scores of each performance evaluation index, we can get the overall performance results of enterprise A, as shown in Table 3.

4.4. Analysis on Comprehensive Evaluation Results. According to the calculation, the total performance evaluation score of enterprise A in 2021 is 107.52. We compare the calculation results with the performance evaluation standard value of LC in Table 2 and find that the enterprise reaches the excellent standard. Overall, enterprise A has a good performance. The following is a detailed analysis from various dimensions. Firstly, from the financial dimension, the total score of performance evaluation is 58.41, which contributes nearly half of the total score. On the one hand, the weight of the financial dimension index is relatively large; on the other hand, it also shows that the financial situation of enterprise A in 2021 is very good. Among them, the growth rate of business income, return on net assets, and growth rate of total assets exceeded the target value and contributed additional scores to the financial dimension. Secondly, from the perspective of customers dimension, the total score of performance evaluation is 27.63, in which market share, customer acquisition rate, and satisfaction have achieved good results. On the one hand, it shows that the customers of enterprise A are satisfied with the products and services of the enterprise; on the other hand, it also benefits from the better market development. However, the propaganda expenses proportion did not reach the target value, indicating that enterprise A needs to enhance the attention of product publicity. Thirdly, from the perspective of internal processes, the total score of performance evaluation is 9.27, among which the index of production plan completion rate contributes a lot. This is mainly due to the fact that enterprise A grasps the development opportunities of the industry, and the sales revenue of the enterprise increases significantly, which promotes the improvement of personal performance of employees. In addition, the input rate of research and development expenditure of enterprise A have also increased but remain to be improved. Finally, from the perspective of learning and growth, the total score of performance evaluation is 12.21. There is a certain gap between the actual value of this dimension and the target value of the enterprise,

Table 3: Application results of BSC performance evaluation system of enterprise A.

Dimensions	Evaluation indicators	Total weight	TV (%)	AV (%)	R	Index score	Dimension score
Financial dimension	C1	0.139	25	36.55	1.46	20.33	58.41
	C2	0.059	32	38.43	1.20	7.05	
	C3	0.125	24	36.21	1.51	18.88	
	C4	0.083	18	21.54	1.20	9.98	
	C5	0.030	3	3.12	1.04	3.17	
	C6	0.034	25	18.56	0.74	2.52	
Customers dimension	C7	0.085	97	95.82	0.99	8.36	27.63
	C8	0.033	80	78.25	0.98	3.19	
	C9	0.071	6	6.46	1.08	7.69	
	C10	0.053	5	5.23	1.05	5.54	
	C11	0.017	3	2.05	0.68	1.17	
	C12	0.019	60	52	0.87	1.68	
Internal processes dimension	C13	0.017	97	96.59	1.00	1.65	9.27
	C14	0.008	94	72.16	0.77	0.61	
	C15	0.005	1	2.33	2.33	1.19	
	C16	0.011	99	97.34	0.98	1.09	
	C17	0.028	67	69.57	1.04	2.90	
	C18	0.018	0	0	1.00	1.83	
Learning and growth dimension	C19	0.011	10	6.56	0.66	0.75	12.21
	C20	0.010	5	2.35	0.47	0.49	
	C21	0.054	90	85	0.94	5.09	
	C22	0.029	13	3.12	0.24	0.69	
	C23	0.040	95	78	0.82	3.26	
	C24	0.020	80	77	0.96	1.93	

especially the growth rate of research and development expenditure and employee growth rate. So, enterprises need to pay attention to the real needs of employees and further improve the salary system and incentive mechanism.

4.5. Guarantee Measures for Implementing Performance Evaluation System with BSC

4.5.1. Establish and Improve the Organizational Responsibility Mechanism. Enterprises should establish a scientific and effective organizational responsibility mechanism to ensure the effective implementation of BSC performance appraisal system. Firstly, enterprises need to set up special performance evaluation groups. It can be by high-level enterprises as team leader and grasp the overall direction of performance evaluation and timely solve the problems encountered in the implementation process of performance evaluation. Secondly, enterprises also need to establish standardized business operation processes. It is conducive to simplifying the complex and cumbersome work of enterprises, thereby improving work efficiency and optimizing internal management level. Finally, enterprises allocate rights and responsibilities to make employees aware of their rights and obligations by clarifying the responsibilities of various departments and employees.

4.5.2. Improve Employee Awareness and Participation. BSC performance management system decomposes the strategic objectives of enterprises into departments and even individuals, which is a large-scale and difficult project. Therefore, its effective implementation requires the active participation of all employees of enterprises. First of all, the enterprise management should give full play to the leading role. Secondly, the employees of various departments are the main force to create corporate performance and comprehensively improve employees' understanding of BSC performance evaluation system and their jobs. Only when departments and levels work together and supervise each other can the performance evaluation system be successfully implemented. At present, the employees of company A have limited understanding of BSC, so the management can deepen their understanding by carrying out thematic training or knowledge competition.

4.5.3. Improve the Performance Evaluation Results Application Mechanism. The results of enterprise performance evaluation should be closely combined with the incentive mechanism, such as the application of performance wages and bonuses, job promotion, training and selection, awards, and evaluation of the reference. Only with the real demands of employees being closely integrated can we play the role of performance evaluation, so as to fully mobilize the enthusiasm of employees. At the same time, enterprises should timely open and transparently feed back the results of performance evaluation to help employees find shortcomings and improve them. In addition, leaders should also strengthen the daily communication with subordinate staff, pay attention to the needs and ideas of subordinate staff, understand their working status and progress, and listen carefully to the opinions and suggestions of staff, so as to improve the problems existing in the performance evaluation in time.

5. Conclusions

Through the research on the current performance evaluation system of LC, this paper finds that there are some problems in the current performance evaluation methods. After consulting a large number of literature, we have developed a new performance evaluation system for enterprise A with BSC as a tool and put forward some corresponding safeguards. We hope that the new performance evaluation system can provide support for the future development of LC and improve their market competitiveness. The research conclusions of this paper are as follows:

Firstly, by analyzing the current performance evaluation methods of LC and combining with their strategic objectives, we refine the company's strategic objectives to 24 indicators from four dimensions and then use BSC method to establish a performance evaluation system for LC.

Secondly, we construct a comprehensive performance evaluation model of enterprise A, and the final evaluation score is 107.52, indicating that the performance of enterprise A is good.

Thirdly, in order to make BSC better implemented in enterprise A, we put forward the relevant guarantee measures; namely, establish and improve the organizational responsibility mechanism, improve employee awareness and participation, and improve the performance evaluation results application mechanism.

In this paper, the design of the performance evaluation system for enterprise A is only for the enterprise level, and the performance evaluation system at the department and individual levels has not been studied in depth. There is still a large research space, and it is expected that further research can be carried out in the future. In addition, the method of determining the weight of evaluation index in this paper is mainly the expert scoring method. Although the opinions of industry personnel and experts are consulted, it is subjective to some extent. How to improve the accuracy and objectivity of the weight of performance evaluation index and ensure the scientific and effective performance evaluation index system to the maximum extent still needs further research [27].

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Quantitative Influence Analysis of the Development Scale of Market Economy on the Level of Music Innovation

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Music art is a form of conveying cultural information and humanistic emotions. From ancient times to the present, the form of music has undergone great changes. The change of music form is closely related to the change in dynasties, the development of the market economy, and the change in humanistic spirit. Today, the development of music has reached a relatively prosperous stage, which is closely related to the rapid development of the market economy. At the heart of the quantitative analysis is the study of associations between data. However, it will be a difficult task to analyze the relationship between the development scale of the market economy and the form of music innovation only by artificial means. This research mainly uses a convolutional neural network and long and short-term memory neural network technology to quantitatively analyze the relationship between the development scale of the market economy and the form of music innovation, which is mainly a quantitative analysis of classical music, pop music, and rap music. The research results show that convolutional neural networks and long short-term memory neural networks have sufficient capabilities to quantitatively analyze the relationship between the market development scale and the form of music innovation. Neural networks with LSTM layers have lower errors in predicting market economic correlates than neural network methods without LSTM layers. The error is reduced by 0.27%. For the prediction of innovative forms of music, the largest prediction error is only 2.93%, which is closely related to the variability of popular music. The linear correlation indices for the predictions of the three forms of musical innovation also all exceed 0.955.

1. Introduction

Music is an art form that reflects national culture and the emotions of life. From ancient times to the present, the form of music has undergone many changes. However, the original intention of the music is to convey a cultural message and a way of life [1, 2]. Poetry, lyrics, and music are an ancient form of music, and ancient people endowed life emotions in this form of music art. In today's era, music is often in the form of pop songs or rap to show the charm of music. Ancient music often expresses the difficulties of life and the customs of the motherland, which will also be accompanied by the production of some musical instruments [3]. The music of today's era is often used to express one's own life emotions, life pressure, and the customs of the motherland. In general, the size of a market's development affects how people live and produce, which in turn affects how people influence music creation. Once people's way of life and production changes, it will lead to changes in the form of music that people create because the form of music is an art form that reflects people's voices and moods [4, 5]. After the rapid development of the market economy, people's life and production methods will undergo major changes, which will affect their mood and culture, which will lead to changes in the form of music innovation. For example, the economic development of the Tang Dynasty was relatively high, which resulted in a wide range of development scales and forms of music art. In the 21st century, China's economy has also developed rapidly, and the support of the economy has led to the rapid development of musical instruments [6]. This allows people to create more forms of music. For example, this has derived many forms of

popular music, folk music, classical music, and so on. It can be seen from the above that the development scale of the market economy will affect the development of music innovation. For the quantitative analysis between the form of music innovation and the development scale of the market economy, it is difficult to solve only by artificial means. This is because the music data and the data of the market economy development scale are huge, and there is a cumbersome relationship between these data. This study intends to use big data technology to quantitatively analyze the relationship between music innovation and market development scale.

Big data technology is a field that has developed rapidly in recent years, which also promotes the development of intelligent life and production [7, 8]. The core advantage of big data technology is the processing of cumbersome data. Regardless of the field, these research objects and developmental forms can be quantitatively analyzed. The form and the amount of data computation in each field are huge, which is difficult to handle only by manual or professional knowledge [9]. The development of big data technology also has an important relationship with the computing performance of computers. In recent years, the computing performance of computers and the development of hardware devices have also promoted the rapid development of big data technology [10, 11]. Today's computer has enough performance to support the operation of data in most fields. In the current life and production, the relationship between data is basically related to space, time, and environment. Big data technology has provided algorithms that can deal with spatial, temporal, and environmental correlations. In the quantitative analysis of the market development scale and the form of music innovation, it is mainly related to time and space, and the algorithms mainly include CNN and LSTM [12, 13]. The development of the market is closely related to time data, and there is a large spatial correlation between the elements of market development scale and the mapping of elements of musical innovation forms. The biggest advantage of big data technology is the processing of huge-scale data [14], and the quantitative analysis between the market size and the form of music innovation requires the support of data. Therefore, big data technology has obvious advantages in studying the relationship between market development scale and music innovation.

Quantitative analysis of innovative forms of music mainly includes classical music, pop music, and rap. There are large differences in the data of these musical forms. And with the rapid development of new media technology and Internet technology, the amount of music data is huge. The development of the market economy will also produce great changes with the development of time, which will generate a huge amount of data. The relationship between the data of the music innovation form and the data of the market economy development scale is complex, and it is a nonlinear relationship. The time correlation algorithm of big data technology can fully extract the relevant characteristics of the development scale of the market economy and the changes in the form of music innovation. The spatial correlation algorithm of big data technology can map the nonlinear relationship between music innovation form and market size.

This study uses a convolutional neural network (CNN) and long short-term memory (LSTM) neural network in big data technology to quantitatively analyze the relationship between market development scale and music innovation forms, which mainly include classical music, pop music, and rap music. This research mainly consists of 5 sections, and the research contents are as follows: Section 1 mainly introduces the research significance of music innovation and the research background of big data technology. The current state of development of innovative forms of music is presented in Section 2. Section 3 mainly shows the working principle of CNN and LSTM technology in big data technology and the scheme of quantitative analysis. Section 4 mainly analyzes the relationship between CNN and LSTM algorithms in a quantitative analysis of the market development scale and the form of music innovation. Section 5 summarizes the entire study.

2. Related Work

The development of innovative forms of music is rapid, and it is closely related to many factors. The changes in the form of music innovation are also closely related to the development of the market economy. A lot of research has been done on musical forms and other aspects by many researchers. May et al. [15] mainly used new concepts to study the aspects of popular music and music literacy. It first used popular music as a text resource to explore the accuracy and feasibility of music literacy. Then, he considered how to combine popular music with music education to promote the development of music education. It can also promote the development of music literacy. Elbir et al. [16] mainly study the music recommendation system of the music monitoring platform, which can complete the classification of music forms and genres according to people's preferences. It mainly uses deep learning neural network models to extract musical features based on acoustic properties. The research results show that this deep model can better perform the recommendation and classification of music genres and musical forms. Dobrota et al. [17] mainly studied the students' preference for classical music through questionnaires. The findings show that younger students have a higher degree of preference for classical music. Extracurricular activities in music courses had less effect on preference for classical music. This research will better guide the development of music teaching and the teaching of classical music. Andrea et al. [18] utilized deep learning and convolutional neural network methods to identify the positional and symbolic features of music in online music. This recognition task is mainly to identify musical positions based on musical notes, key signatures, staves, and other related features. The research results show that the CNN method can accurately identify the location of music with a recognition rate of over 80%. Fricke et al. [19] mainly study the accuracy of manual measurement and computer grade evaluation methods in the music preference evaluation system. The results show that the musical features extracted

by artificial means are in good agreement with those extracted by computer. He also used PCA and Procrustes methods for analysis, which showed that computer-extracted features can be used to assess people's preferences and preferred styles of music. Kertz-Welzel [20] believed that classical music is crucial in music education. It represents the essence of music. This study analyzes the educational perspectives of classical music from a philosophical and social perspective. It also explores the educational model of classical music dominated by British and American education. He believes that classical music is regarded as an essential music culture in music education all over the world. Kai [21] designed a music feature recognition system utilizing IoT technology. The sensors of the IoT system will be placed in different positions to obtain music information to further complete the analysis and processing of music signals. He uses a dynamic time regularization algorithm to analyze the maximum similarity of musical features. The research results show that the music recognition system is relatively stable, and it can capture high-quality music signals. It can also better assist people in completing the extraction and recognition of musical style and emotional features. Other researchers have also conducted more research on the related characteristics and identification of music using different methods. The innovation of this research is mainly to use the deep learning method to analyze the relationship between the development of the market economy and the form of music innovation, which is no longer limited to a single music feature. It also conducts a quantitative analysis of innovative forms of music.

3. Application of Big Data Technology in Quantitative Analysis of Music Form

3.1. The Significance of CNN and LSTM for Quantitative Analysis. This study mainly uses CNN and LSTM algorithms to achieve a quantitative analysis of the relationship between the scale of the market economy and the form of music innovation. Whether it is the scale of the market economy or the form of music innovation, both are closely related to time and space. The LSTM algorithm can be used to extract the temporal features of the scale factor of the market economy, which can form a mapping with a certain relationship to the musical innovation form. CNNs can map the complex nonlinear relationship between the size of the market economy and the form of musical innovation. The nonlinear relationship between the two is difficult to resolve by manual means. At the same time, there is a large amount of data in the factors of market economy scale and music innovation forms, which requires computers to process these complex data. In conclusion, CNN and LSTM methods can solve the cumbersome relationship between the factors of market economy development scale and the level of music innovation. This also enables quantitative analysis of data, which is not just a macro analysis.

3.2. The Quantitative Analysis Scheme Design and CNN Algorithm. This study mainly selects three forms of music for quantitative analysis, namely classical, pop, and rap music. Pop music and rap music are the two most popular forms of music in the current economic model. Classical music is also a relatively traditional music mode, which is closely related to the development of the market economy. Figure 1 shows the design of the quantitative analysis of market economic development factors and music innovation forms. In this study, the data related to the development of the market economy are processed in the form of time series and input into the LSTM layer, which is also the input data of CNN. The relevant data of the music innovation form is used as the label data and the output data of the CNN. First, this scheme takes the factor of market economy development scale as the input data of big data technology, which will be used to map the relationship between music innovation forms. The relevant data of the market factors are organized into the form of time series, which will be passed through the LSTM neural network method. The LSTM method will extract the time characteristics of the development scale of the market economy because the development scale of the market economy has a greater relationship with the changes in time. The data extracted by the LSTM neural network method will be used as the input data of the CNN method. At this time, it needs to use the data in the innovative form of music as the output data of CNN, which will form a one-to-one mapping relationship.

The CNN method has been applied in many fields, and it has also been shown to have high performance for feature extraction and nonlinear relation mapping. The development scale of the market economy and the innovative form of music are both difficult to quantify research objects in the form of data. Both need to be digitized, which can then be quantitatively analyzed using CNNs. Therefore, the advantage of CNN is to deal with the nonlinear relationship between data. Figure 2 shows the workflow of CNN. The work of CNN mainly relies on convolutional layers, pooling layers, and activation functions to complete. The convolutional layer is the core part of CNN, which will complete the feature extraction of the research object and reduce the amount of parameter computation. It can also be seen from Figure 2 that CNN can complete the nonlinear relationship mapping between the input data and the output data, which is also done through the feature extraction function of the convolution layer and the pooling layer. The pooling layer is mainly divided into a maximum pooling layer and an average pooling layer. The sampling method is divided into two methods: upsampling and downsampling. In this study, we sampled max-pooling layers and downsampling methods to extract relevant features.

In the operation and iteration process of CNN, the process of CNN is adjusted by many hyperparameters, such as the number of filters, step size, and other factors. However, there is a certain relationship between these hyperparameters. Equation (1) shows the relation satisfied by the CNN hyperparameters. Here, s represents the sliding step size of the window, and p represents the padding size of the window. k is the size of the receptive field of the convolutional layer. w is the size of the output weights.

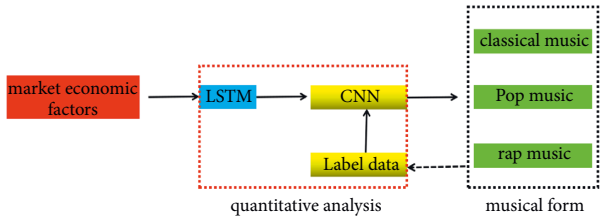

Figure 1: Scheme design of quantitative analysis of market economy scale and music innovation form.

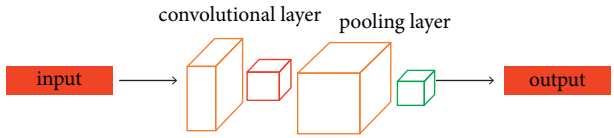

Figure 2: The workflow of the CNN method.

$$w' = \frac{(w + 2p - k)}{s} + 1. \tag{1}$$

In quantitative analysis, some data is required here to process. In this study, the scale of market economic development and the form of music innovation are digitized so that the data can be input and output in the form of a matrix. Equations (2) and (3) show the representation of test data and predict data. Among them, x represents the input data, which refers to the data of the development scale of the market economy. y is the output data, which here refers to the data in the form of music innovation.

$$\text{Test} = \{(x_1, y_1), (x_2, y_2), \ldots, (x_m, y_m), \ldots, (x_M, y_M)\}, \tag{2}$$

$$\hat{y} = \{\hat{y}_1, \hat{y}_2, \ldots, \hat{y}_m, \ldots, \hat{y}_M\}. \tag{3}$$

In the calculation process of CNN, it generally adopts the method of gradient descent. The gradient descent method is to find the direction of gradient descent through the derivation operation. This will involve many derivation operations during each layer of the CNN. Equation (4) shows how the derivation of the weights at each layer is calculated. In the actual iterative process, it will use the automatic differentiation (AD) technique. Equation (5) shows the derivation rule for weights, which is a weighted way of equation (4). ω and δ are the weight matrix and the bias parameter, respectively. d_k is the real value, y_j is the optimized value.

$$E = \frac{1}{2}\sum_{k=1}^{m}\left[d_k - f\left(\text{netw}_k\right)\right]^2 = \frac{1}{2}\sum_{k=1}^{m}\left[d_k - f\left(\sum_{j=0}^{n}\omega_{jk}y_j\right)\right]^2, \tag{4}$$

$$\frac{\partial E}{\partial k_{ij}^{\zeta}} = \sum_{u,v}\left(\delta_j^{\zeta}\right)_{uv}\left(p_i^{\zeta-1}\right)_{uv}. \tag{5}$$

3.3. The Market Economy Feature Extraction Based on Algorithm LSTM. In different periods, the scale of market economy development is different. The scale of market economy development is also an economic model that gradually accumulates over time. Therefore, before studying the quantitative analysis of the scale of market economy development and music innovation, it needs to extract the time characteristics of the scale of market economy development. Figure 3 shows the workflow of the LSTM method. It requires the input data to be in the form of a time series. Therefore, the data of the development scale of the market economy needs to be processed into the form of time series. The input of the LSTM algorithm will contain the current state data and part of the historical state information data, which is why the LSTM algorithm can achieve temporal feature extraction. The LSTM algorithm can also implement multiple network layers in order to extract deeper data features. The LSTM sampled in this study contains a 4-layer network structure. The last layer contains a fully connected layer, which contains 256 hidden operators.

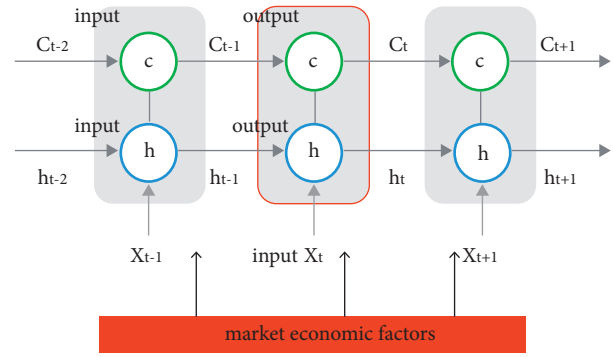

Figure 3: The workflow of LSTM method.

It can also be seen from Figure 3 that the LSTM method has more gate structures, which are realized by assigning different weights to the data. It can optionally filter the data by the size of the weights. Equation (6) shows how the input gate of the LSTM method is calculated. The input gate will selectively input current state information data and historical state information data according to the size of the weight, where h_{t-1} is historical state data. W and b are the weight matrix and the bias parameter, respectively.

$$f_t = \sigma\left(w_f \cdot \left[h_{t-1}, P_t\right] + b_f\right). \tag{6}$$

Equations (7) and (8) show the calculation method of the forget gate of LSTM. The forgetting gate will give different weights to the historical state information data, and it will input the historical state information with greater correlation. σ and tanh represent the activation function. tanh is the activation function.

$$i_t = \sigma\left(\omega_i \cdot \left[h_{i-1}, P_t\right] + b_i\right), \tag{7}$$

$$\widetilde{C}_t = \tanh\left(w_c \cdot \left[h_{t-1}, P_t\right] + b_c\right). \tag{8}$$

Equations (9) and (10) show how the output gate is calculated. The input gate will be connected to the forget gate of the next layer. It will selectively output data according to the weight. These data will be passed through an activation

function. This study chose the tanh function as the loss function, which is a hyperbolic tangent function.

$$O_t = \sigma\left(w_o \cdot \left[\overrightarrow{h}_{t-1}, P_t\right] + b_o\right), \tag{9}$$

$$\overrightarrow{h}_t = O_t \times \tanh\left(\overrightarrow{C}_t\right). \tag{10}$$

The refresh gate will refresh the weights. Equation (11) shows how the refresh gate is calculated. It will give different weights to current state information and historical state information. c_t is the state unit of the LSTM at time t. The tanh is the activation function.

$$\overrightarrow{C}_t = f_t \times \overrightarrow{C}_{t-1} + i_t \times \overrightarrow{C}_t. \tag{11}$$

4. Result Analysis and Discussion

4.1. Analysis of LSTM Algorithm in Extracting Market Economic Features. This study selects data from several music creation institutions in Beijing and the development scale of Beijing's market economy for quantitative analysis. Generally speaking, the development scale of the market economy in relatively large cities varies greatly, and the level of music innovation in this region is also relatively high. Moreover, the music innovation mode here is also changing rapidly. Therefore, this study selected the relevant data of Beijing as the research object of quantitative analysis. This research will process the data related to the development of the market economy and the form of music innovation into the data of uniform distribution and the same interval using the normalization method.

For the prediction of the development scale of the market economy, this study selects the neural network method with and without the LSTM method for relevant quantitative analysis. In this study, algorithms with LSTM layers refer to hybrid LSTM-CNN algorithms and algorithms without LSTM layers refer to CNN algorithms. Figure 4 shows the errors of the two methods in predicting factors related to the size of market economic development. From Figure 4, it can be seen that the neural network method with the LSTM layer has better accuracy than the method without the LSTM layer. For the method with LSTM layers, the maximum prediction error is only 2.85%. The largest prediction error is 3.08% for the method without LSTM layers. The forecast error of factors related to the development of the market economy decreased by 0.23%. This shows that the neural network method with the LSTM layer has higher performance in extracting factors related to the development of the market economy. At the same time, this also shows that the development of the market economy has a great correlation with time.

From the above description, it can be seen that the neural network method with the LSTM layer has higher performance in quantitative analysis of market economic development factors and music innovation forms, which is due to the fact that the prediction errors with LSTM are lower than those without LSTM layers. Therefore, in the quantitative

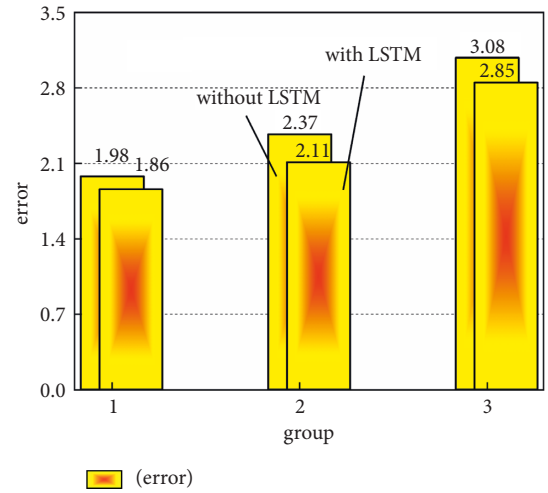

Figure 4: The prediction errors of factors related to market economic development using with and without the LSTM method.

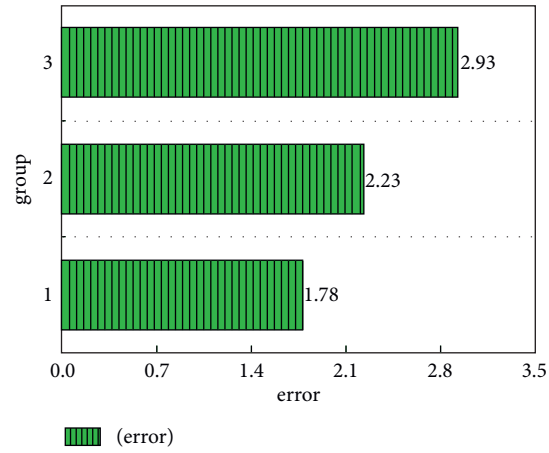

Figure 5: The prediction errors of musical innovative forms using LSTM methods.

analysis of the three forms of music innovation, this study chooses the neural network method with the LSTM layer to carry out the correlation analysis. Figure 5 shows the prediction errors for three forms of musical innovation, which refer to classical music, pop music, and rap music. Overall, CNN and LSTM methods have small errors in quantitative analysis of the market economy and music innovation forms, and all prediction errors are within 3%. This error is reliable enough to quantitatively analyze innovative forms of music. The largest prediction error is only 2.93%, and this part of the error comes from the prediction of popular music. Pop music is a more popular form of music in today's society. It has a greater relationship with the development scale of the market economy. When the market economy develops better, the creative mode of pop music will also change. The variability of the development scale of the market economy has led to the variability of popular music forms. This leads to a large error in predicting popular music. The creative mode of classical music is relatively stable, and it is less affected by the development scale of the

market economy. This resulted in a small error in predicting classical music, with a prediction error of just 1.78%. For the prediction of rap music features, this part of the error is only 2.23%. This is also a small and acceptable margin of error for a similar study of musical innovation. In conclusion, the CNN and LSTM methods have sufficient capabilities to quantitatively analyze the relationship between the size of market development and the form of music innovation.

4.2. Quantitative Analysis of Predictive Accuracy of Musical Innovation Patterns and Market Economy Development. For the three musical innovations, pop predictions are the hardest. This is mainly due to the close correlation between the creation of popular music and the development scale of the market economy. Figure 6 shows the distribution of predicted and actual values for popular music. The yellow area represents the prediction error between the predicted value of pop music and the actual value. It can also be seen from Figure 6 that the values of different groups of popular music fluctuate greatly, which is also related to the variability of popular music. However, CNN and LSTM methods can also better predict the trend and value of popular music. If there is a small correlation between the development scale of the market economy and popular music, this will lead to a large error in the prediction of popular music. This is because the data of the market economy development scale is the input data of CNN and LSTM. However, from the results in Figure 6, it can be found that although the development scale of the market economy is relatively large, it still has a relatively large correlation with popular music. Most pop music predictions are larger than they actually are. This may have a greater relationship with the ideal prediction environment of the algorithm. From the yellow prediction error area in Figure 6, it can also be seen that the CNN and LSTM methods have better accuracy in quantitatively analyzing the scale of market economic development and the form of music innovation.

Rap music is a music innovation model that has developed rapidly in recent years. This is also closely related to rapid economic development. Since rap music is a relatively new form of music, this leads to huge challenges in quantitative analysis of rap music. Figure 7 shows the prediction error for rap music. Generally speaking, the error of the error scatter plot does not exceed 5%, which indicates that the prediction accuracy has met the needs of the prediction. In this study, the input and output of the CNN and LSTM algorithms are the data related to the development of the market economy and the related data of rap music, respectively. If the model cannot well map the relationship between the market economy and rap music, it means that there is a small relationship between the development of the market economy and rap music. However, from the prediction error of rap music in Figure 7, it can be seen that the development scale of the market economy and rap music also have a greater correlation because this part of the error is relatively small. Overall, all forecast errors are within an acceptable range. Most forecast errors are within 3%. At the same time, it can also be seen from Figure 7 that there is a

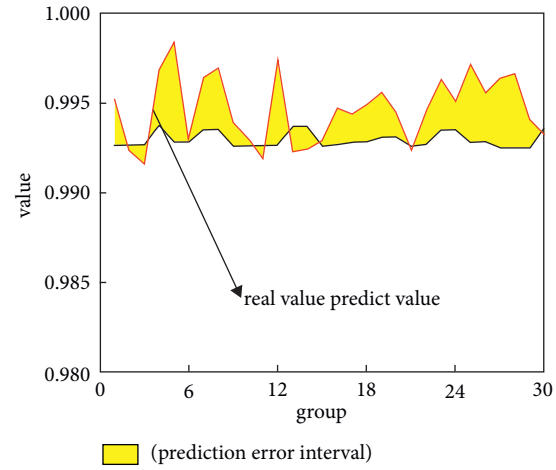

Figure 6: The distribution of predicted and actual values of popular music.

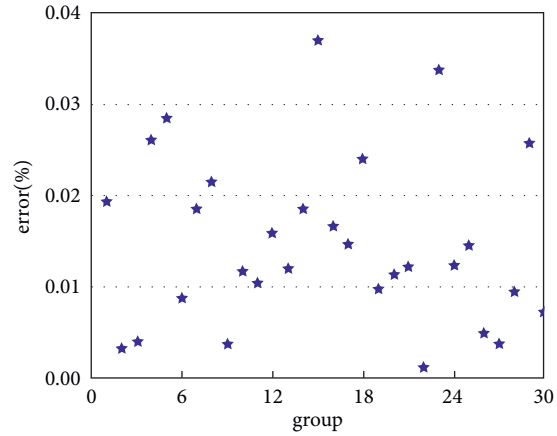

Figure 7: The prediction error distribution for rap music.

relatively large fluctuation in the prediction error of the rap music form, which also shows that rap music is greatly affected by the scale of market economic development. Only a small part of rap music has a prediction error of more than 3%, but this part of the error is also within 4%. This further illustrates that the CNN and LSTM methods have high confidence in predicting the form of rap music.

Classical music is a relatively stable musical art form, and it is less affected by the scale of market economic development. However, in today's rapid economic development, the development of classical music has been affected to a certain extent. In terms of quantitative analysis of the development scale of the market economy and the form of music innovation, it also analyzes the impact of traditional music forms. Figure 8 shows a box plot of the distribution of predicted and actual values for classical music forms. It can also be seen from Figure 8 that the change of classical music is relatively small with the change of the scale of market economy development. Overall, there is a small error between the predicted and actual values for classical music. CNN and LSTM methods can better perform quantitative analysis and prediction tasks on the changing forms and

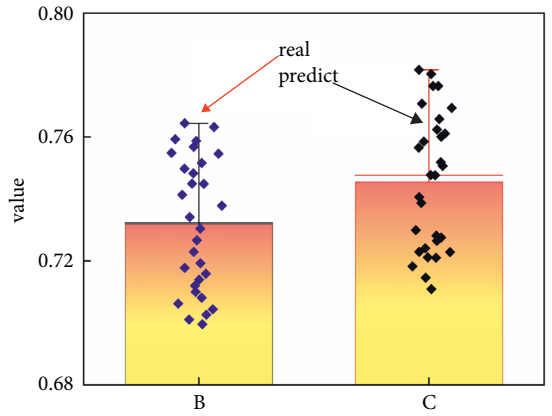

Figure 8: Predictive distribution box plot for classical music.

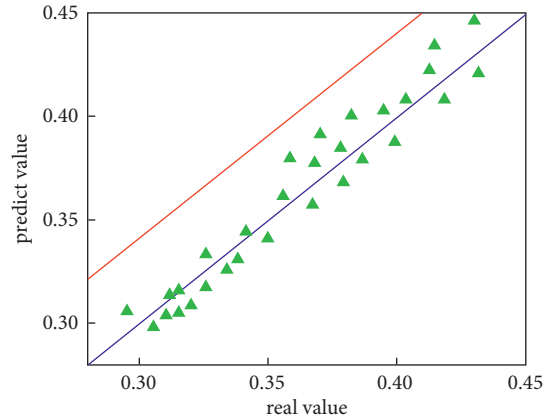

Figure 9: Linear correlation of predicted values for classical music.

numerical values of classical music. There is also a small difference in cabinet shape and size between the predicted and actual values for classical music. This shows that the CNN and LSTM methods can more accurately quantitatively analyze the relationship between the development scale of the market economy and classical music. Figure 9 shows the linear correlation of predicted values for classical music. In Figure 9, the red line represents the 95% confidence band, and the blue line represents the linear function $y = x$. It can also be seen from Figure 9 that classical music has a good linear correlation. The closer the linear correlation coefficient is to 1, the better the prediction efficiency is. Generally speaking, the linear correlation coefficient exceeds 0.95, which means that the prediction effect is better. The numerical values of classical music are distributed on both sides of the linear function, and the distance between these data values and the linear function is relatively close.

5. Conclusions

Music is an important part of people's life and production activities. The development of music art has a lot to do with the factors related to the development scale of the market economy. However, it is difficult to quantitatively analyze the relationship between the development scale of the market economy and the form of music innovation in an artificial way.

This study uses CNN and LSTM algorithms in big data technology to achieve a quantitative analysis of music innovation forms. LSTM can better extract the time characteristics of the development scale of the market economy, which is beneficial to the quantitative analysis of music innovation forms. This study mainly analyzes three types of music: classical music, pop music, and rap music. Overall, CNN and LSTM methods can quantitatively analyze the relationship between the scale of market economic development and the form of music innovation. The largest prediction error is only 2.93%, and this part of the error mainly comes from the prediction in the form of popular music. The smallest prediction error is only 1.78%, which mainly comes from the prediction of classical music. The linear correlations for classical music also all exceed 0.955. All prediction errors for the rap music form are within 3%. This shows that CNN and LSTM methods are sufficient to quantitatively analyze the relationship between the scale of market economic development and the form of music innovation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Teaching System Design of Art Design Major under the Background of Economic Management Mode Change

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With the development of digital technology, the curriculum design of art majors is also quite different from traditional courses. With the continuous development of information technology and the continuous maturity of campus network technology, teaching resources have become an important part of information resources. High-quality teaching resources play an important role in improving teaching quality and excavating educational development potential. However, traditional classroom teaching is difficult to meet people's needs. In the context of the current new normal, the way of social and economic management has changed. On the one hand, traditional course teaching resources store information in the forms of paper lesson plans, PPT courseware, discrete pictures, and video files. These forms of storage are not conducive to the distribution and sharing of resources. On the other hand, these teaching resources are scattered among the teaching teachers. As the curriculum develops, the courses taught by teachers change. Because schools lack effective means for unified management, these teaching resources are easily lost. The used method is not conducive to the accumulation of teaching resources or the continuation and development of courses. In order to present good results, these materials usually occupy a large amount of storage space. Therefore, some existing information-based teaching platforms cannot meet the demand. We use network and web technology to develop a teaching file management system, which is very necessary. This paper firstly compares the mature teaching resource management system on the market and some problems in its professional application. Secondly, the article analyzes the actual situation of teaching resource management of art design majors in China and generally describes the system development background and technology. Then, the paper analyzes the requirements of the system in detail by using the object-oriented method and gives the overall design and implementation method of the system. These methods include the use case diagram of the subsystem, the flow chart of the main module, the system architecture, and the design and application of UML. Finally, this paper designs a test case for the teaching resource management system.

1. Introduction

With the continuous development of information technology and the continuous maturity of campus network technology, teaching resources have become an important part of information resources. Effective management of teaching resources helps to improve the quality of teaching and tap the potential for educational development. This technology plays an important role in teaching work. However, traditional classroom teaching is difficult to meet people's needs [1–3]. On the one hand, traditional course teaching resources are stored in the form of paper lesson plans, PPT courseware, discrete pictures, and video files. This form of storage is not conducive to the distribution and sharing of resources. On the other hand, these teaching resources are scattered among the teaching teachers [4–6]. Students' homework results are also an important component of teaching resources. Many excellent teaching cases come from student work and have a lot of valuable content in student work. For students majoring in art design, a large number of animation and video assignments produced by students have great reference value for subsequent students' learning. As the curriculum develops, the curriculum taught by teachers changes. Schools lack effective means to manage this situation in a unified manner. These teaching resources are easily lost, which is not conducive to the accumulation of

teaching resources. This situation is also not conducive to the continued development of the curriculum. In order to deal with this situation, the school's repeated construction of the resource information system occurs from time to time. Compared with the traditional course teaching, the art design major has its own characteristics. Most of the teaching resources of this major are stored in CD-ROM and computer hard disks in the form of digital files. Such files are usually larger and occupy more storage space. Therefore, the management and sharing of teaching resources for art design majors also have great difficulties [7–10].

Over the years, since the establishment of the Chinese art design major, professional teachers have spent a lot of energy on the development of course teaching resources. This part of the development activities has also achieved good results. However, at present, China still adopts the method of archiving materials for different semesters to manage. This traditional file management method mainly relies on manual management, and the management method is relatively backward. This management method has many problems in the preservation, circulation, and sharing of teaching resources. The main problems are manifested in the following aspects. First, it is difficult for the system to store large-capacity files uniformly. Therefore, schools need to manage students' homework more scientifically. School materials management departments need to be able to identify outstanding student work. The school management also needs to archive these excellent results resources. These operations also constitute an important part of the construction of school teaching resources. The disk burning method used to save system information will cause files to be stored separately. This storage format will also bring an operational burden to the operator, and it is difficult to obtain the full support of teachers for this operation mode. For these reasons, some teachers cut down the content of resources that need to upload. The group of teachers coped with the burning of resources [11–13]. Second, after the teaching resources are archived, these resources are shelved. These resources are not regularly managed and used, and no one has carefully sorted out these resources. The main reason is that data analysis through traditional methods such as manual management will bring inconvenience to users in various aspects such as retrieval and query. This also causes the resource information to be cumbersome in the process of file adjustment, which is not conducive to the dissemination and use of resources. Third, teaching resources are mainly copied in the form of CD-ROM borrowing. These resources are generally only shared among individual teachers. These resources generally also communicated with each other when teachers need to communicate with each other. The school conducts scientific management of students' homework, which is very helpful for the accumulation and dissemination of teaching resources. However, students' homework data depends on the manual management of teachers. The teacher will effectively collect the topics and materials of the homework through the representative of the student class. In the whole system, there is no effective way to share teaching resources with student groups. Therefore, the value of these teaching resources is far from play [14–16]. Fourth, because teachers go out relatively frequently, there are certain difficulties in the location and maintenance of data. In addition, there are relatively more students going out, and it is difficult for schools to track and maintain some excellent teaching resources. This situation leads to the loss and duplication of teaching resources for some courses. This situation also wastes the school's human and material resources. In view of the above reasons, China's art design professional teaching and research departments need to develop a set of teaching systems that meet their own needs. This teaching resource management system can realize the scientific and unified management of professional teaching resources. This teaching system can also provide a platform for resource sharing and communication between teachers and students. This system can better serve teaching and research [17–19]. The overall design structure of the art design teaching system is shown in Figure 1.

At present, many Chinese universities still adopt the traditional manual management method for resource sorting. The same is true for Chinese art design majors. Manual management of teaching resources is relatively backward. The manual management method has serious deficiencies in the preservation, circulation, sharing, and interaction of teaching resources. Teaching resources are a collection of several course resources. The resources of the course are also divided into several resource fragments according to the knowledge points of the chapters. Different teachers share different teaching resources [17–20]. In the construction of teaching resources in schools, teachers divide labor and cooperate, and teachers undertake the responsibility of resource construction. The collection of teacher-created resources constitutes the teaching resources of the course. The teaching resources produced by the teacher group also rely on their own maintenance. On the one hand, the means of sharing resources is relatively backward, and it is difficult for teachers to effectively control the version of resources. Teacher groups cannot realize the timely updating and sharing of resources. Teachers use manual management methods to manage the teaching resources of art design [21–23].

In addition, the same courses will be repeated at different times and spaces. Typically, schools repeat similar courses. Teaching resources will also evolve and develop based on the original materials. The continuous updating of such data can effectively ensure the timeliness of the data. The school's curriculum management department needs to track such changes in a timely manner [24–27]. Schools need to actively accumulate curriculum resources and then organize the resources in a unified manner. By sorting out the data, the educational management organization makes the data organically integrated to form a unified curriculum resource. Manual management of teaching materials is difficult to achieve in-depth management of resources [28]. The school packs resources in a simple manual way. This management method is difficult to effectively improve the quality of teaching resources.

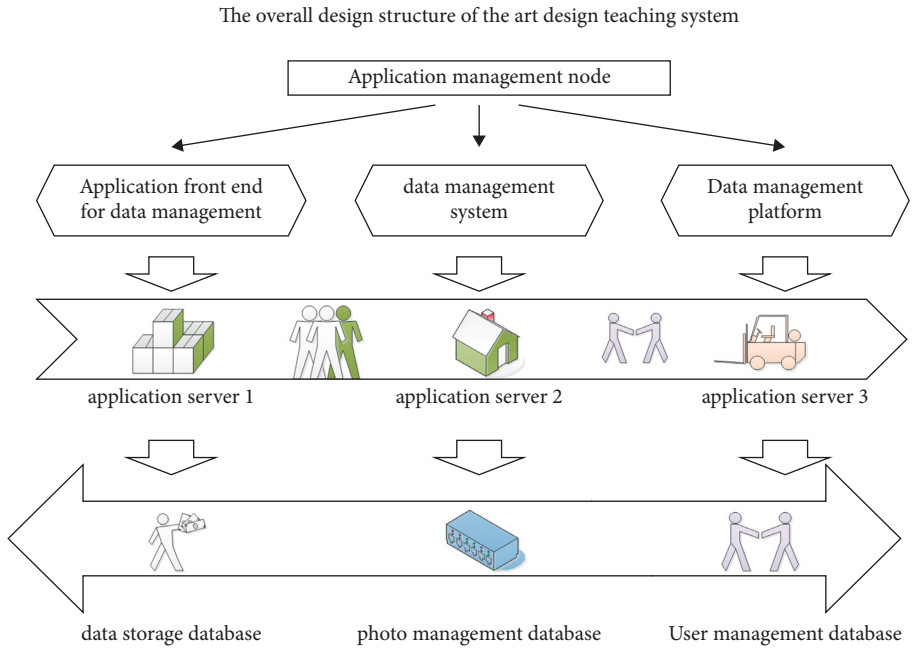

Figure 1: The overall structure of the art design teaching system.

2. The Current Situation of Teaching Resource Management System

This paper organizes and analyzes the existing research. There are many teaching platforms developed by China at present. In terms of functional design, these teaching platforms refer to the more popular open-source network teaching platforms abroad. From the research content, the existing art design-teaching platform mainly includes the following aspects. First, the platform uses the file management function to realize the sharing of course resources. Teachers can easily upload various teaching resources.

2.1. Main Features of the Chinese Art Design Teaching System. These resources include common Flash animations, audio and video multimedia materials, and teaching courseware. When learners are learning, they can use course resources to learn on demand according to their actual situation. Second is the auxiliary support for the interaction between teachers and students. The platform system provides smooth and synchronous text interaction. The system generally supports interaction in formats such as URL addresses, emoticons, and images. The system can provide teachers and students with timely discussion and exchange of course content. The system will record all discussion content, and you can set the degree of publicity of this content to the outside world. When students encounter difficulties in learning, teachers can implement one-to-one or one-to-many teaching guidance through the platform. These teaching guidance behaviors can realize real-time synchronization of teaching content. Third, the teaching system can effectively manage students' homework resources. The system allows students to upload assignments in various formats in file format. The system automatically records when students submit assignments. Teachers organize and file student data through class representatives. After the completion of the review, teachers will grade the students according to the quality of the results. Teachers can effectively archive and store some materials, which is conducive to the rational use of materials and the accumulation and construction of teaching resources. On this basis, the system provides targeted tutoring for those learners who cannot learn online in real time.

The system can provide students with autonomous learning according to the tasks assigned by teachers. The student group improves the circulation of homework resources by optimizing and sorting out homework resources. Student groups upload their learning results to the system for teachers to view and review. The schoolteachers will send the evaluation content of the homework to the students by mail or other forms. This teaching mode enables real-time communication between teachers and students. Fourth, the teaching system can provide the function of course discussion, which can help course groups collaborate and learn with each other. In learning activities, teachers can make differentiated groupings of students from the entire class. Students can create discussion boards for each group on the platform. Students can develop systematic discussions around related topics. Student groups can also upload valuable material to the discussion board. Fifth is the learning report function and learning monitoring function of the teaching system. Teacher groups can track students' learning process by viewing students' learning activity reports. This method of collecting and organizing resources is helpful for schools to effectively manage teaching materials and can help students and teachers better obtain excellent art and technology teaching resources. These reports can give a side view of students' attention to the course and their learning attitude. Teachers can organize students' learning according to the content recorded in the activity report.

Teachers can assess and give feedback on students' learning at different stages. In this way, students can see the gap between themselves and their classmates and adjust their learning strategies in time. The flow chart of the homework management system for students majoring in art design is shown in Figure 2.

2.2. The Problems Existing in the Chinese Art Design Teaching System. At present, there are many successful application cases of art design teaching platforms in the world. However, these platforms still have some deficiencies in the resource management of art design. These shortcomings are embodied in the following aspects. First, the existing research has too much emphasis on the network sharing and resource centralized control functions of the platform. The research ignores the topic of people's growth on the platform; in particular, the personal growth of teachers also needs to be paid attention to. Existing resource management platforms mostly focus on the integration of data but lack the management of individuals who use data. Secondly, the system platform lacks a unified curriculum resource construction. The classification of course resources relies too much on individual teachers, and this system organization model makes it difficult to integrate resources of similar courses between platforms. In addition, the platform has relatively little support for the growth of course resources. Course resources are just a collection of messy data. It is difficult for the platform to manage course resources systematically. The platform cannot systematically control the generation, processing, management, and use of resources. Finally, many existing platforms regard course content as the target of resource collection. The platform ignores the overall requirements of different majors for curriculum setting, and it is difficult to realize the coconstruction and sharing of curriculum information of different majors in the system. The calculation formula of the information entropy of each node is as follows.

The coverage index calculates the ratio of predicted items to all unscored items. It can measure the comprehensiveness of prediction. Assuming that h items are predicted, the calculation method of coverage is as follows:

$$Cov = \frac{h}{n}. \tag{1}$$

The calculation formula of single-sample statistics is as follows:

$$t = \frac{\bar{X} - \mu}{\left(\delta_x / \sqrt{n-1}\right)}. \tag{2}$$

The calculation principle of local consistency is relatively simple, mainly using the Kendal Concorde coefficient, and the specific calculation formula is as follows:

$$W = \frac{\sum \left(R_i\right)^2 - n\left(\bar{R}\right)^2}{(1/12)K^2\left(n^3 - n\right)}. \tag{3}$$

2.3. The Main Content of Art Design Teaching System. This paper studies the characteristics of curriculum resources for art design majors. This paper conducts research from many aspects, such as the accumulation of curriculum resources, the display of classroom teaching resources, and the exchange of resources between teachers and students. The problems solved in this paper include the following aspects. First, this paper realizes the scientific management of the teaching resources of design professional courses in an effective way, to ensure that the teaching resources are not lost or confused. The value of teaching resources lies in their use. Only when teaching resources are widely circulated and disseminated can they be maximized. The current Chinese art design teaching institutions generally adopt manual management methods. This article categorizes and archives resources, which is helpful for the accumulation of longitudinal resources in classroom teaching courses. Secondly, this paper provides sufficient resources to support the growth of classroom teachers themselves. The research of this paper provides help for the accumulation of teachers' experience, and the results of the research are helpful for the horizontal communication between teachers. Finally, this paper transmits information to students through a scientific resource display platform and collects students' classroom status information through the system's real-time interactive module. The system further provides assistance for the school's curriculum teaching by processing and analyzing this information. The art design management system proposed in this paper can solve the technical problem of large-scale file transmission on the network. The system can provide related algorithms for technical implementation and application abbreviated, effectively solving the resource transfer needs between students and teachers. The system can control the sharing timing of resources and the timing of information transmission and reception through effective rules. In order to ensure the accuracy of the results, this paper uses two evaluation indexes, mean absolute error and root mean square error, to evaluate the optimization effect of the model. The specific calculation formulas are as follows.

The adjustment interval for slack (S_n^x, S_p^y) is defined based on the calculation of the extreme differences $[\max(x_{nj}) - \min(x_{nj})]$ and $[\max(y_{pj}) - \min(y_{pi})]$ for each input-output in all evaluated provinces.

$$\begin{aligned} R_n^x &= \frac{1}{\left(N+P\right)\left[\mathrm{Max}\left(x_{nj}\right) - \mathrm{Min}\left(x_{nj}\right)\right)}, \\ R_p^y &= \frac{1}{\left(N+P\right)\left[\mathrm{Max}\left(y_{nj}\right) - \mathrm{Min}\left(y_{nj}\right)\right)}. \end{aligned} \tag{4}$$

From the definition of relaxation, it follows that (S_n^x, S_p^y) lies between zero and the extreme difference.

$$\begin{aligned} s_n^{x*} &= x_{nj} - \sum_{j=1}^{J} x_{nj}\varepsilon^*\mu, \\ s_p^{y*} &= y_{nj} - \sum_{j=1}^{J} y_{nj}\varepsilon^*\mu. \end{aligned} \tag{5}$$

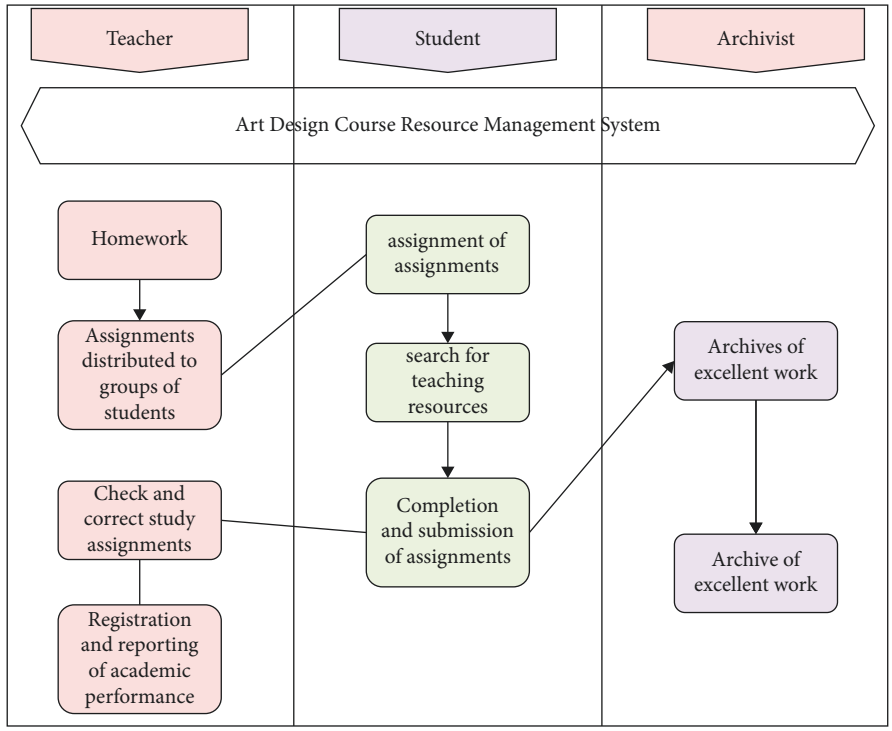

Figure 2: The flow chart of the homework management system for students majoring in art design.

The smaller the MAE value is, the higher the prediction quality is. Suppose there are n items in the system, the score set predicted by the algorithm is $\{p_1, p_2, \ldots, p_n\}$, and the corresponding actual score set is $\{r_1, r_2, \ldots, r_n\}$; MAE calculation formula is as follows:

$$\mathrm{MAE} = \frac{\sum_{i=1}^{N} |p_{ui} - q_{ui}|}{N}. \tag{6}$$

In this paper, the main contents of the system requirements analysis are combed in detail. First, the system sorts out the total according to the educational characteristics of art design majors. Then, this paper sorts out and analyzes the performance requirements, functional requirements, and nonfunctional requirements of the teaching system under the requirements of the transformation of economic management methods. Requirement analysis is a key step in system development. A good analysis activity helps avoid all kinds of errors that occur during system operation. A good data management system can effectively improve the development efficiency of the system. A good technical model can reduce the development cost of the system and effectively improve the software quality. The design of the system needs to meet the following three aspects.

First is the teaching needs of higher vocational art design majors. The art design is an aesthetic creative activity based on satisfying practicality. This data retrieval method is not convenient for resource preservation and management. Through single-point transmission and file copying, it is difficult for the teaching system to achieve a large-scale circulation of teaching resources. When students use teaching resources, users may have many questions. Under the background of modern industrialization, artistic design can organically combine the function of the product with a comfortable and beautiful appearance. Modern art design has gradually developed into a highly comprehensive subject area covering art, economy, society, culture, psychology, and many natural sciences and technologies. Art design is not only different from other liberal arts majors but also different from painting pure art majors. This major has the characteristics of nonreplicability and personalization of art, which also needs to meet the normative and common requirements of the design. Higher vocational education is neither a simple compression of ordinary undergraduate education nor a simple upgrade of secondary vocational education. This educational model is a higher education type that is parallel to ordinary undergraduate education and has distinct occupational characteristics. At the same time, higher vocational art design education is also a special type of vocational education. This educational model has different characteristics from general higher vocational education. The logical framework of art design course teaching and assignment submission system is shown in Figure 3.

2.4. Demand Analysis of Art Design Teaching System. The core requirements of talent training are as follows. At the current stage, the educational characteristics of art design majors in colleges and universities are mainly reflected in the training objectives of talents. The professional setting needs to adapt to the needs of socialist modernization. Art majors need to cultivate high-quality talents who master the basic knowledge, basic theories, and basic methods of design. These talents have aesthetic ability, modeling ability, creativity ability, engineering ability, and computer application

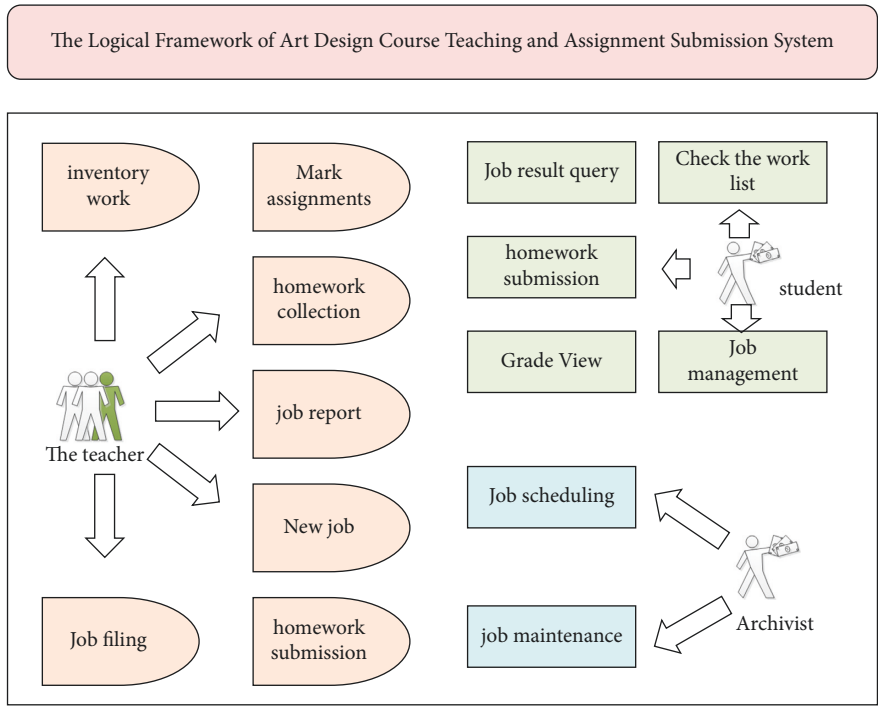

Figure 3: The logical framework of art design course teaching and assignment submission system.

ability. These talents can also make full use of modern means to design. These people are high-quality and high-skilled application-oriented design talents with good professional ethics, and their professional skills include comprehensive quality, professional skills, creativity, and sustainable development ability. These skills are embodied in the organic integration of the cultivation of artistic quality and the imparting of technical knowledge.

On this basis, the traditional manual expression ability training and the modern computer expression ability also need organically integrate. While teaching design methods, colleges and universities pay more attention to the cultivation of innovative consciousness. While paying attention to the cultivation of theoretical knowledge in the classroom, the school also emphasizes the cultivation of students' practical ability. In the design of art design professional courses, it is necessary to pay more attention to the cultivation of interdisciplinary subjects such as psychology, marketing, and ergonomics. Users are not familiar with the teaching materials, and it is difficult to understand the meaning of the teaching materials in a short period. The student group needs to have a special teaching management organization for guidance. The school pays attention to the communication and cooperation between majors and the discipline construction needs the cultivation of comprehensive qualities such as self-education adapted to social development. Finally are the requirements of personnel training and curriculum setting. The main way to achieve the goal of talent training lies in scientific and reasonable curriculum setting and implementation. The curriculum setting should be combined with professional characteristics and market demand. The college needs to carry out the teaching of industrial design professional courses with design ability as the main line according to the requirements of postability.

In order to verify the clustering effect of user attributes, the contour coefficient S is used to evaluate the clustering result, and the specific expression is

$$S(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}}. \tag{7}$$

It treats each of the monomials as m input models in the original structure of the modeling network:

$$v_1 = a_0, v_2 = a_1 x_1, v_3 = a_2 x_2, \ldots, v_6 = a_5 x_1 x_2. \tag{8}$$

The final information $i_t \times C_t'$ expressed as the value that can obtain C_t from the output information of the joint forgetting gate:

$$C_t = f_t {}^* C_{t-1} + i_t {}^* C_t{}^{'}. \tag{9}$$

The calculation method is

$$O_t = \sigma\left(W_o\left[h_{t-1}, x_t\right] + b_o\right). \tag{10}$$

The core objectives of the system construction include the following five aspects. First, the school's teaching management department realizes the scientific management of the teaching resources of art major courses through effective methods and ensures that the teaching resources are not lost, chaotic, and classified. The student group also needs specialized teachers to explain the teaching materials. Teaching modes such as traditional teaching seminars, Q&A, and after-school tutoring need to carry out within a fixed time and space. This scientific management mode is helpful for the rapid accumulation of longitudinal resources of the

course. Second, the setting of the management department is conducive to the growth and design of teachers and provides assistance for the accumulation of teachers' experience. This curriculum-setting mode is also conducive to horizontal communication between teachers. Third, the system provides a scientific resource display platform to transmit information to students and collects students' classroom status information in real time through the system platform to provide support for the evaluation of course teaching effects. Fourth, the system needs to address the technical requirements for large files to transmit over the network. Fifth, the system construction can effectively solve the problem of resource transmission between students and teachers. The system can control resource sharing timing and receiving transmission timing through effective rules.

3. The Goal and Specific Construction Content of Art Design Teaching System Design

This paper mainly develops systematic resource management software based on the characteristics of an art major. The software can provide a platform for the collection, sharing, and management of curriculum resources from the perspective of curriculum development and teacher growth. The system can also provide a suitable classroom resource platform to provide teaching assistance for teacher-student interaction. The system can facilitate the management and filing of students' homework and facilitate the exchange and dissemination of knowledge. The system mainly includes three parts: course resource management, coursework management, and FAQ management.

3.1. The Design Goal of Art Design Teaching System. At present, in professional art colleges, art design-related courses need to manage in a standardized way. Among them, the production, use, and archiving of teaching resources involve a series of processes. The specific content includes the following aspects. First, when a new course is proposed, the head of teaching assigns the teaching task to the relevant teaching group. The teaching group researches and formulates the teaching syllabus, selects the teaching materials, and prepares the teaching plan. Therefore, the scope and depth of knowledge covered by teaching resources are relatively limited, making it difficult to meet the requirements of students' course learning. The teaching group develops a schedule for the practical project. Teachers start preparing lessons according to the knowledge points of each chapter in the course. Teachers actively write lesson plans, collect teaching materials, and design teaching cases. Teachers further make multimedia courseware and carry out teaching activities for the outside world. Teachers will copy relevant teaching resources in the form of files. Teachers deliver these materials to students at a single point on the network. In the teaching process of the school, teachers need to submit relevant teaching resources to the teaching supervision and inspection. After viewing the teaching resources, the teaching supervisor will give an evaluation of the teaching level of the teachers. At the end of the semester, teachers provide all teaching resources to the departmental archivists. Administrators archive teaching resources. When the course content is repeated, teachers will further optimize and improve the original teaching resources. These resources are helpful to groups of teachers who are new to teaching. These new teachers obtain historical teaching resources from the original teachers by copying files and improve on this basis. At the end of the semester, the teacher will submit the teaching resources to the archivist for archiving. The comparison of advantages and disadvantages of art design teaching management platform is shown in Figure 4.

Teaching resources take the course as the basic unit, and the course system determines the skeleton of the course's teaching content, teaching materials, and teaching methods. The teacher is responsible for filling in the detailed teaching content and refining the teaching method. Teacher groups use curriculum resources as the medium to retain and transmit. Archivists are responsible for archiving instructional resource media. Teaching courses can exist simultaneously in different spaces at the same time. The courses taught can also coexist in different times and spaces. Only class groups and art teaching curriculum content are unique. Class curriculum resources are the core content of the entire resource system. Due to the different participants, the curriculum resources also want to be different. The formation of course resources depends on the division of labor and cooperation among the staff (mainly the teachers) involved in the production of the resources. The improvement of the quality of curriculum resources is helpful for summarizing the curriculum practice of each class. Therefore, the system should clarify the following aspects. First, the system should take courses as a unit to form and merge teaching resources. Secondly, the course teaching resources are the shared resource library of all class courses, which is maintained by the course group. In addition, class curriculum resources are instances of curriculum resources, formed by the interaction between teaching and students. Teachers can freely use course resources, and students can freely use teaching resources disclosed by teachers. Finally, the teaching courses of the class can have their own teaching resources, which are maintained by the classroom teachers.

3.2. Resource Archiving Process for Teacher Courses. In the setting of specific courses, the professional compulsory courses are mainly composed of three types: professional theory courses, combined theory and practice courses, and practical training courses. The main contents of these courses include professional theoretical teaching, design history, engineering knowledge, and interdisciplinary knowledge. The establishment of relevant professional courses provides professional designers with corresponding knowledge support in terms of culture, art, and engineering technology. Therefore, only by providing a convenient communication platform for resource users and producers can the limitation of time and space be broken. This platform can make the interaction of resources smoother. The resource-trading model of this platform can help people

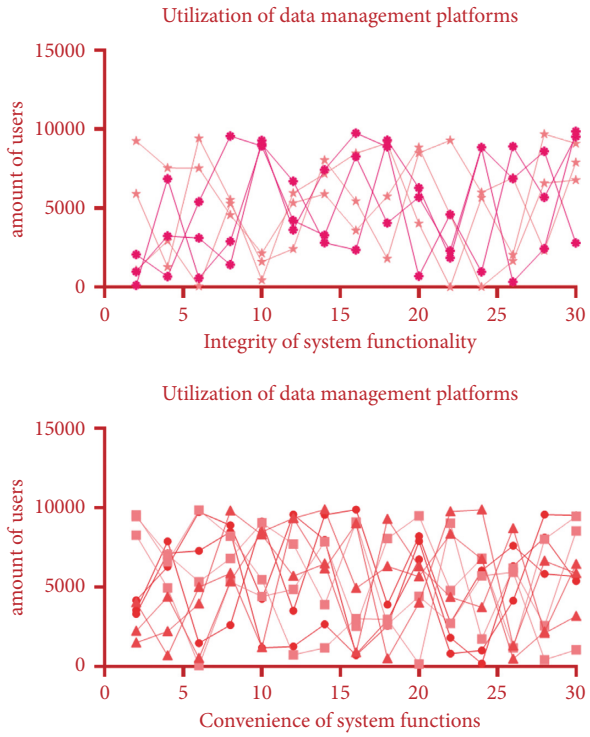

Figure 4: The comparison of advantages and disadvantages of art design teaching management platform.

conduct long-term and in-depth exchanges. The theory and practice compound courses are also called vocational skills courses. The class hours of the course are large, and the teaching time is concentrated. The course is mainly composed of three categories: modeling foundation, design foundation, and professional design. Modeling foundation and design foundation are the main courses of lower grade professional teaching in colleges and universities.

This teaching method can help students improve their internal strength through professional modeling and painting and computer-aided software training. Students majoring in art design need to meet the study of design procedures and methods and then cultivate students' hand-drawn expression ability and design software application ability. On this basis, the school needs further cultivate the thinking and innovation ability of the student group. This teaching mode can lay a good foundation for the future professional design of the student group. In addition, the school's professional design offers a comprehensive design curriculum for upperclassmen. This kind of course usually uses real projects or themes to help students develop comprehensive abilities such as mastery, understanding, application, and innovation of professional knowledge. On this basis, the transaction mode of resources can guide the system to develop in the direction of an autonomous and network learning platform. The platform revolves around the construction of the curriculum system, and teaching managers have discussed the content and details of teaching resources. The practical training courses mainly need each professional direction and each stage of learning to set the corresponding course content. As a pure practical course, the course teaching system can help students familiarize themselves with the operation of design and production enterprises and further improve students' practical ability. In addition, elective courses for design majors are also an important part of professional teaching. These courses are mainly in the form of students' self-selected reports. Specifically, teaching institutions offer courses in culture and art, professional knowledge expansion, etc., and further focus on the cultivation of students' overall quality. The user frequency before and after optimization of the art design teaching management system is shown in Figure 5.

3.3. Resource Management Process for Student Work. Student work is an important part of course teaching resources. It is the basic requirement of teaching management where the system archives a certain number of outstanding students' homework. This working mode is also an important measure to enrich the construction of teaching resources. The homework of art majors in the university is mainly electronic work, supplemented by paperwork. Pictures, statements, lessons, and videos dominate electronic assignments. This system mainly discusses e-learning resources, so paper assignment management is not within the scope of this paper. Teachers often assign homework after teaching. The teacher forwards the assignment requirements and resource materials to each student through the class representative. After the students understand the requirements of the homework, they further check the teaching materials and course teaching resources to complete the homework content. Students submit their homework to the class representative, who will count the homework, package it, and forward it to the class teacher. After receiving the homework, the teacher will mark the students' homework, register the grades, and give a grade report. The school archivist will keep excellent homework in the form of files, and other homework will be dealt with according to the situation. At the end of the semester, the task teacher will package the outstanding student work and send it to the file security administrator to keep the file. The evaluation of the use effect of the art design teaching management system is shown in Figure 6.

3.4. Requirement Analysis of Curriculum System Function. The main responsibility of the system management subsystem is to manage and maintain the operation of the system. The subsystem defines the relationship between roles and courses by setting the basic information of courses. The system is responsible for user authentication, management, and maintenance of the members of the research group. The system determines the participants of the subsystem through an object-oriented analysis method. These participants include archivists, course leaders, classroom teachers, and students. Based on this, teaching managers can build a knowledge base centered on resource knowledge points. Through this mechanism, teaching managers can promote the construction and development

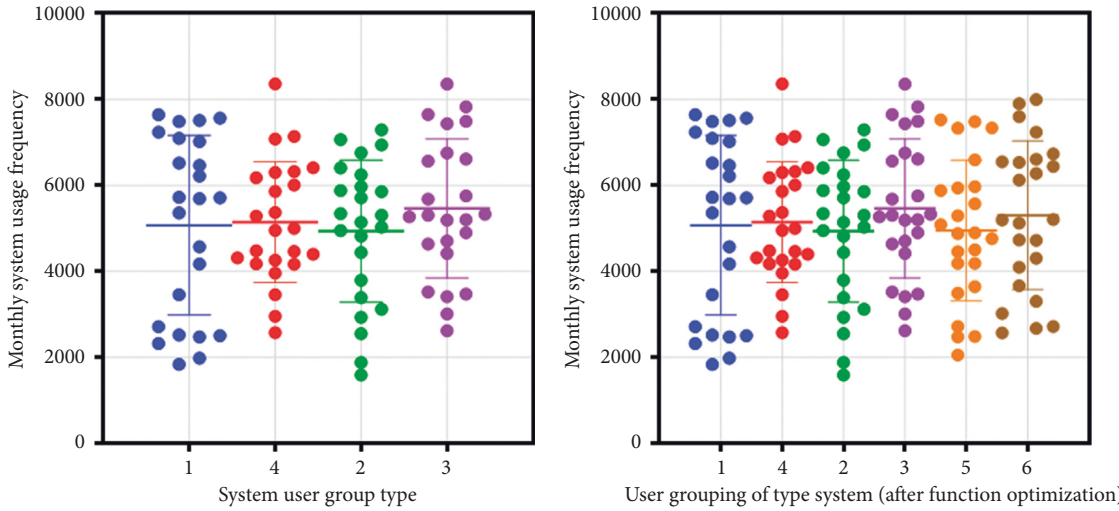

Figure 5: The user frequency before and after optimization of art design teaching management system.

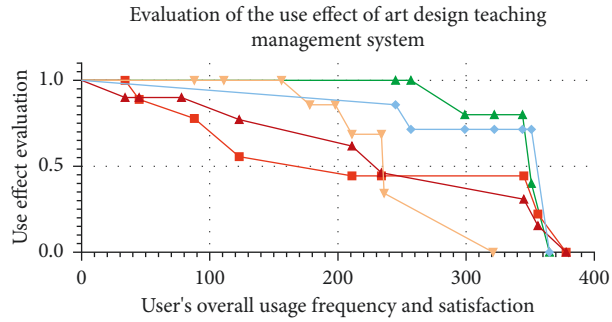

Figure 6: The evaluation of the use effect of the art design teaching management system.

of teaching resources. However, for the resource management method that used manual management in the past, it is necessary to adopt a new teaching management platform effectively manage resources. The system can manage the list of use cases through subsystems and draw use case diagrams. In addition, the system identifies the user through a specific account number. The student account represents the role of the student, and the account of the teacher represents the role of the teacher. Therefore, it can see from the previous analysis that the account of the course leader and the person in charge of the course are actually the same concept. A user account is a common name for all role accounts.

The research group is composed of the teacher and the leader of the course, so the members of the course group are the teachers. The main responsibility of the course management subsystem is to establish and maintain the relationship between teachers, courses, and students. Classes are created and maintained by the teacher, and the state of the class determines whether the class teacher and students can modify the data in the class course. Classes are made up of students, and curriculum resources are the medium of interaction between classroom teachers and class members. Course resources are categorized and presented in the form of a directory tree. Class teachers maintain the classification system of class curriculum resources. Class curriculum teaching resources belong to the class group, and the state of class activities is affected by many factors. Teachers and groups of students can optimize the system by rules as needed. The evaluation of the function use effect of the art design teaching management system is shown in Figure 7.

Students describe the content of the system from the role of the system, while the student account describes it from the perspective of system implementation. These two nouns are actually the same concept. Class members are made up of students, which is different from the concept of a natural administrative class. This concept is from the perspective of curriculum teaching, with a curriculum as an intermediary, a group collection maintained by the teachers. This teaching platform can ensure the effective collection and systematic storage of resources. This kind of platform can also ensure the effective circulation of resources among different groups. A course taught by a teacher can exist in multiple parallel classes at the same time. However, a course class belongs to only one course teacher. This system does not deal with the situation that multiple teachers teach a class at the same time. Each course class can have its own teaching resource system. The teachers themselves maintain this resource system.

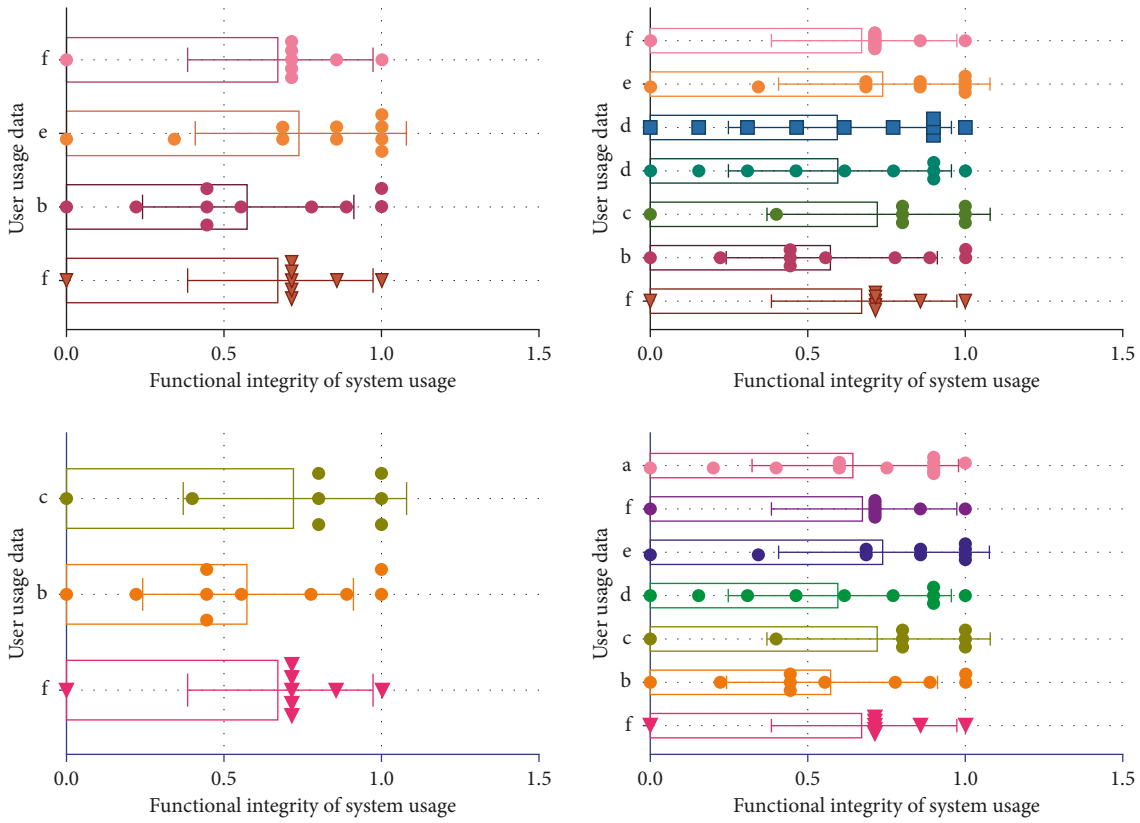

Figure 7: The evaluation of the function use effect of the art design teaching management system.

4. Conclusion

A teaching resource management system is a networked and distributed database application system. The system plays a very important role in the information of education management. After the system is implemented, it is very beneficial to the centralized management of professional teaching resources. The construction of the system can reduce the workload of resource maintenance and clarify the management process of each department. From the point of view of technological development, the realization of this system has some characteristics and difficulties. The system adopts the object-oriented programming method and follows the standard of software engineering to design and develop the system. This paper focuses on the following problems in terms of technology. This paper adopts the three-tier architecture of MVC to realize the system content, which greatly improves the performance of the system. The content studied in this paper helps the system structure to be more clear and more intuitive. When the number of clients or application requirements changes greatly, the system maintains the overall cost of the system by modifying related modules. The system adopts a modular design method, which further expands the system functions. On this basis, the system upgrades and develops functions. The system can develop modules independently and can increase or decrease the corresponding modules according to the specific needs of users. In addition, the system adopts the combined rights management mode of user authentication and system authorization, which improves the security level of the system. In the process of development, the system adopts the method of making relational data and configuring the data collection entrance, so that the system can be effectively applied. The theoretical course assessment of art design majors is mainly in the form of written examinations. Based on examining the relevant cognitive laws, this paper needs to pay attention to the understanding, application, and innovation of knowledge points. The design of the system needs to combine the form of answering questions such as scheme design, drawing, and commenting and strengthen the connection with the teaching of professional design courses.

4.1. The Design and Construction Points of Art Design Teaching Management System. Innovative works need to be creative, reflecting the designer's imagination and problem-solving ability. The technical application of artistic design needs to consider the application form of new materials and new technologies. The application of new technologies can generally reflect the role of aesthetic factors. The course resource management mainly studies three problems. How to organize and manage the teaching resources of a single course. How to organize and manage the course group of art majors. How course resources relate to course classes. How to set up the relationship between curriculum resources and longitudinal curriculum classes. The work should reflect the designer's understanding of the cultural background and aesthetic thinking. The system needs to express the content

of the artistic design, and the system needs fully express the designer's design intent. The art design teaching system further clarifies the performance requirements of the system through a detailed analysis of the art design teaching work. In addition, system development requires the purchase of a large number of software and hardware equipment and products, as well as follow-up work such as management and maintenance. However, the college's financial investment in this area is very limited. In teaching aid systems, the development cost is an important factor that system administrators need to consider. The system should improve the reuse rate of modules and codes as much as possible through reasonable design and reduce the development cost of the system.

With the continuous in-depth development of the art design profession in the college, the professional categories of art design will be further expanded. The number of teachers and students in art design will increase rapidly, and the curriculum system will be gradually refined and adjusted. In the face of this change, the system needs to be able to carry out corresponding function expansion. Specifically, it includes the expansion of the amount of information, the expansion of system functions, and the expansion of the number of people and professions using the system. For the traditional information management system, once the system configuration cannot meet the growing demand, the user can only update the function by continuously upgrading the software and hardware. However, various upgrade measures taken by the system cannot guarantee complete compatibility. At this time, the system needs to be revalidated, tested, and modified appropriately to adapt to the new environment. In addition, if the old system architecture cannot meet new performance or functional requirements, the entire system may need to redevelop. The operability of the system in practical teaching assistant work is very important. Only when the operability is strong enough does the system persist for a long time and then play a real role. Some traditional information management systems have complicated operation procedures. In this case, many functions of the system are not used in practice. This page is a waste of information resources. Therefore, the system needs to simplify the complex, make the difficult easy, and enhance the operability of the system. On this basis, it further guaranteed that the backbone of the system is clear, the procedures are simple, and the implementation is easy.

System development is a global and systematic project. System development usually needs to go through multiple processes, including infrastructure, requirements analysis, outline design, detailed design, testing, maintenance, and other links. The development of the system requires a lot of workers, material resources, and funds. The system should be aimed at realizing rapid development and saving resource utilization, effectively shortening the development cycle of the system, and enabling the system to be put into operation quickly. In addition, the security of the system is also a key content that needs to be considered in system development. Important information security in the system requires clear protection measures. Different people should have different permissions. Different personnel perform corresponding operations according to different permissions. In addition, the server needs to have certain defense functions against common network attacks and hacking methods.

4.2. The Main Features of the Art Design System Constructed in this Paper. The main features of the art design system constructed in this paper include three aspects. First, the system has advanced management ideas. This system manages all teaching resource data in a unified way and optimizes the traditional teaching management process. On the one hand, it simplifies teaching management, and on the other hand, it makes teaching resource management more scientific. Under this management mode, teaching resources cannot be lost, thus ensuring the continuous construction of the curriculum. Second is the powerful permission management function. The system provides a comprehensive security policy. The process of teaching resource management is relatively complex. This system can help each user who enters the system to set different permissions. Through centralized user rights, it can help different academic administrators to coordinate their work in the safest mode. Finally, the system conducts hierarchical management of teaching resources. This management mode makes the responsibilities of teachers and course leaders in the process of teaching implementation clearer. This model also enables continuous construction of curriculum resources, continuous growth of teacher resources, and real-time recording of class resources.

This system proceeds from the reality of professional teaching resource management, solves some practical problems of professional teaching resource management, and has certain practicability. Through the in-depth test of the system, it was found that the system meets the requirements of professional teaching resource management. The system can improve the work efficiency of professional teaching resource management. The system can achieve the intended design purpose. Of course, there are still many imperfections in the whole system due to the lack of management experience and the heavy coding work. These imperfections need to optimize in subsequent system updates.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

The Impact of the "Belt and Road" Initiative on Tourism Economic Development in Chinese Regions along the Route—An Empirical Analysis Based on DID Model

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As an important component of modern service industry, tourism is regarded as a "green" driver to regional economic growth and industrial upgrading. Applying the "quasi-natural experiment" advocated by the "The Belt and Road" initiative, this paper, based on the method of DID, assessed the influence of this initiative on regional tourism development by analyzing panel data collected from 286 prefecture-level cities in China over the period of 2007–2018. It is found that the "The Belt and Road" initiative has stimulated market dynamics and promoted tourism development in the regions along the route and has significantly improved indicators such as per capita domestic and inbound tourism revenue and per capita domestic and inbound tourist receipt. Also, the degree of contribution of domestic tourists to the tourism economy of the regions where the policy has been implemented is stronger than that of inbound tourists. In sum, the results of this paper not only confirm that the "The Belt and Road" initiative has significantly contributed to the high-quality tourism development of Chinese provinces along the routes but also provide important policy enlightenment for the upgrading of regional tourism industry and regional economic balance.

1. Introduction

In 2015, China released the "Vision and Action on Jointly Building Silk Road Economic Belt and the 21st Century Maritime Silk Road" (hereinafter referred to as the "Vision and Action"). The "the Belt and Road" initiative has not only driven the economic development of the regions along the belt and road, but also promoted the flow of people and derived the development of local trade, but also benefited the development of tourism. It is a programmatic policy document that maps out the blueprint for the development of the "The Belt and Road" and proposes to strengthen tourism cooperation. For the tourism industry, on the one hand, it enhances the domestic regional coordination and promotes the development of domestic tourism; on the other hand, it pushes forward the opening of tourism, attracts international tourists to visit Chinese attractions, and accelerates the pace of foreign tourism cooperation [1, 2]. Thus, it can help the development of the tourism economy along the route.

Based on this, this DID-based paper analyzes the panel data of 286 cities at the prefecture level and above from 2007 to the end of 2018 as a way to explore the impact of "The Belt and Road" initiative on regional tourism. The paper finds that it has boosted tourists' expenditure in the regions along the route, and the cities affected by the policy have significantly increased tourism revenue and the number of visitors. Both the number of domestic tourists and their relevant spending indicate the positive correlation to the initiative, but inbound tourists show less significant levels than domestic tourists. These results hold true after controlling for provinces. Further analysis of overnight travel reveals that the main path to growth in inbound travel is through an increase in average tourism spending from foreign visitors, rather than an increase in arrivals. The regression results pass the parallel trend test.

The contributions of this paper are that, first, it adds a perspective to the study of "The Belt and Road" by exploring the impact of "The Belt and Road" on regional tourism in terms of domestic and foreign tourist performance, which enriches the research elements of regional tourism and expands the scope of the research of this initiative. Second, the DID method analyzes the degree of influence of "The Belt and Road" on regional tourism, and the difference between the control group and the experimental one makes the results more credible. Third, this paper assessed the impact of "The Belt and Road" on tourism, which can positively influence the prosperity of regional tourism and can drive the development of regional tourism through the cities where the initiative is implemented.

2. Institutional Background and Theoretical Hypothesis

2.1. Institutional Background. In March 2015, the National Development and Reform Commission (NDRC), the Ministry of Foreign Affairs, and the Ministry of Commerce jointly released the "Vision and Action on Jointly Building Silk Road Economic Belt and the 21st Century Maritime Silk Road," announcing for the first time the overall top-level design and strategic plan of the "One Belt and One Road." Subsequently, this initiative was included in the main objectives of the thirteenth Five-Year Plan and was gradually put into in-depth implementation. So far, the "The Belt and Road" initiative has realized the evolution of "concept-strategy-planning-implementation." The vision of the initiative is to "jointly build an open, inclusive, balanced, and universally beneficial regional economic cooperation structure, and generally form a network of high-standard free trade zones." As the initiator of "The Belt and Road," China enjoys a long history, rich culture, and landscape resources, ideal geographic location, and huge throughput of tourists, all of which can promote high-quality tourism development from different dimensions. In addition, this initiative can promote sustainable tourism development in the countries along the route, improve the welfare of local communities, stimulate investment, protect the cultural and natural heritage, and provide tourists with an unforgettable experience of the Silk Road. The development of tourism of the Belt and Road will go through a process of integration from a loose alliance, and the future goal of this tourism is to establish a tourism free trade zone [3], thus promoting the future development of the tourism industry within the region.

2.2. Theoretical Hypothesis. In theory, the "The Belt and Road" initiative can form a multifaceted effect on the tourism economy of the domestic provinces along the route. First is policy incentive. The domestic provinces along the route will choose to respond the Belt and Road initiative to increase tourism investment in the region and promote local tourism supply, which is supposed to have a significant impact on enriching local tourism products and optimizing industrial structure [2]. The second is transportation improvement. Factors such as transportation infrastructure affect the agglomeration and diffusion of the regional tourism economy and are also the key concerns in the transformation and upgrading of the tourism industry and the improvement of quality and speed [4, 5]. The implementation of the "The Belt and Road" has further improved the transportation infrastructure in the provinces along the route, which has increased the spatial effect of tourism specialization. The third is the promotion of the flow of tourism production factors. "The Belt and Road" can strengthen tourism cooperation within the policy-implemented region, optimize the efficiency of the tourism industry, promote the use and flow of economic factors, improve the utilization efficiency of tourism resources, and coordinate the development of regional tourism [6]. In conclusion, the "The Belt and Road" initiative strengthens the interconnection of the tourism economies of the domestic cities where the policy is implemented [7], and through the interconnection of tourism resources between cities, a tourism circle is thus formed, which in turn promotes the growth of the local tourism economy. Accordingly, we propose the following hypotheses:

Hypothesis 1. "The Belt and Road" stimulates the market dynamics and drives tourism development and tourism economic growth in policy-influencing areas.

At the same time, the "The Belt and Road" policy will also attract foreign tourists to visit China in several ways, which can drive tourism development in the regions along the route. First is the policy interoperability. The countries involved in the "The Belt and Road" initiative will form a more practical cooperation, coordination, and effective policy support mechanism. The coordination of tourism-related policies can help connect tourists and tourist destinations to promote travel and mutual recognition, including visa-friendly policies to facilitate the arrival of tourists and mutual acceptance of industry standards, which will strongly support the development of high-quality tourism [1, 6, 8]. The second is unimpeded trade. The customs cooperation in information exchange, mutual recognition of supervision, and assistance in law enforcement in countries along the route widentrade scopes and optimizes trade structure; also, all of these increase the demand for materials, technologies, and resources in domestic areas along the "Belt and Road", further promoting the upgrading of regional industrial structure, provides a good industrial environment for tourism development and significantly increase business and tourism and other market sources. The third is the financial support. The convenient capital settlement of the countries along the route makes the trade including inbound tourism more convenient, and also, the elimination of investment and trade barriers diversify the investment and financing channels of the domestic regions along the route, promote the efficient flow of capital factors among industries, and provide factor support for the high-quality tourism development. Fourth is the cultural communication. The development of cultural projects and activities in countries along the route provides

a communication platform for tourism development, which can shorten the psychological distance of tourists. Tourism cooperation, sports activities, and other projects promote the development of domestic exhibition tourism, festival tourism, and other new industries; harmonious and friendly cultural ecology and public opinion environment is fundamental to the development of "The Belt and Road" tourism [3, 9]. In conclusion, one of the objectives of the "Belt and Road" is to promote the opening up of the region and to carry out deeper cooperation and exchange with the international communities, and the implementation of the strategy has contributed to the tourism cooperation of the countries along the route [2, 3, 10], allowing China's own unique historical and cultural and natural landscapes to attract tourists from all over the world. The "The Belt and Road" initiative helps the cities where the policy is implemented to be tourist-attracting while maintaining the stable development of domestic tourism, giving full play to the potential of regional tourism development.

Hypothesis 2. "The Belt and Road" attracts foreign tourists, increasing the number of tourist arrivals in China and boosting the development of regional tourism.

However, in reality, this initiative has had different impacts on domestic and international tourists. Firstly, visitors to China face higher costs of travel and information gathering; generally, only some very well-known scenic spots will be known by most people. Therefore, under the premise of information asymmetry and the pursuit of maximizing the utility of tourism experience, international tourists tend to choose those Chinese tourist destinations with high quality and reputation and thus have a limited effect on the tourism economy of cities without well-known tourist attractions, but domestic tourists are not likely to be affected by this above situation, whether it is a well-known scenic spot or not, domestic tourists are willing to visit it. Secondly, for traveling abroad, tourists face higher travel costs and also need to spend more time and energy to prepare for the trip, and inbound tourists will also need longer touring time to maximize the utility [11–13], In addition, other issues such as language and living habits, even customs, and legal issues should be taken into account; therefore, it will also form a certain obstacle to the number of tourists coming to China, and the increase of inbound tourists is lower than that of domestic tourists. Accordingly, we propose the following hypothesis.

Hypothesis 3. In the context of the "The Belt and Road" initiative, the contribution of domestic tourists to the tourism economy of the region where the policy is implemented is stronger than that of inbound tourists.

3. Identification Strategies, Data, and Variables

3.1. Identification Strategy. The "Belt and Road" initiative began in 2015, involving 140 prefecture-level cities, and this paper uses the DID method of time and region to analyze its impact on regional tourism. By the end of 2018, there were 298 prefecture-level cities, subprovincial cities, and municipalities directly under the Chinese central government, and from 2007 to 2018, the number of Chinese prefecture-level cities has changed, so to ensure consistency, the data of Bijie, Chaohu, Sansha, Haidong, Danzhou, Turpan, Hami, Rikaze, Changdu, Linzhi, Shannan, and Naqu are deleted, and finally, the data of 286 cities analyzed in the paper. Among them, there are 140 cities involved in "The Belt and Road" initiative, which are the experimental group; cities in other regions constitute the control group. Specifically, this paper implements the DID method through two-way fixed effects. The model is

$$\text{Tour}_{i,t} = \beta_0 + \beta_1 BR_{i,t} + \sum_j \beta_j \text{Control}_{i,t} + \gamma_t + \mu_i + \varepsilon_{i,t}, \quad (1)$$

where Tour represents tourism development, BR represents whether the city is the participant of "The Belt and Road" initiative; Control is the control variable; i represents the order of the respective city, and t represents the t-th year; γ_t represents the time fixed effect, and μ_i represents the regional fixed effect.

3.2. Data, Variables, and Descriptive Statistics. To study the impact of "The Belt and Road" initiative on the development of regional tourism, this paper introduces domestic tourism revenue, domestic tourist receipts, inbound tourism revenue, inbound tourist receipt, total domestic and inbound tourism revenue, and total domestic and inbound tourist receipt to indicate the level of regional tourism development and uses "The Belt and Road" to indicate the cities participating in this initiative. A series of control variables are also used, including the number of star hotels per 10,000 people, the number of taxis per 10,000 people, the per capita consumption of electricity, the level of medical care, the level of higher education, the per capita GDP, the percentage of the population in the tertiary sector, and the greening rate (Table 1).

In this paper, per capita domestic tourism revenue, per capita domestic tourist receipts, inbound tourism revenue per capita, inbound tourist receipts per capita, total domestic and inbound tourism revenue per capita, and total domestic and inbound tourist receipts per capita are selected to characterize the level of tour (tourism) development. The core explanatory variable Belt and Road (BP) is denoted by BR. The 140 provinces that participated in Belt and Road in 2015 were assigned the value of 1 from that year and 0 for the others.

In order to control the influence of other factors on the development of regional tourism, a series of variables were selected as control variables in this paper based on the literature findings and reality. In the process of local tourism development, per capita GDP, and per capita electricity consumption, which represent the level of economic development, play a very important role [14, 15]. The ability of tourist attractions to provide tourists with good services is also an important part of local tourism development. The variable number of star-rated hotels with 10,000 people reflects the local service and reception capacity [16–19]. Traffic directly affects the number of accessible tourist

Table 1: Introduction of variables and calculation methods.

Representation	Variable	Name of variable	Method of variable accounting	Average value
Level of tourism development	Domestic tourism revenue	pcinc_dom	Domestic tourism revenue	248707.5
	Inbound tourism revenue	pcinc _fore	Inbound tourism revenue	1814.44
	Domestic tourism receipts	pcpop_dom	Domestic tourism receipts	202774.3
	Inbound tourism receipts	Pcpop_fore	Inbound tourism receipts	3094.37
	Total tourism revenue home and abroad	pcinc	Total tourism revenue home and abroad	205868.6
	Total tourists receipts	pcpop	Total tourists receipts	250521.9
Ability of tourism service	Number of star hotels per 10 k	hotel	Number of star hotel/Total population of the region EOY	2.79
Level of traffic convenience	Number of taxi per 10 k	taxi	Number of taxi/Total population of the region EOY	177.66
Level of economic development	Per capita consumption of electricity	elec	Number of electricity consumption/Total population of the region EOY	154049.1
	Per capita GDP	gdp	GDP/Total population of the region EOY	418492.4
Level of higher education	Level of higher education	educ	Number of higher learning institutions/Total population of the region EOY	0.06
Level of medical care	Level of medical care	med	Number of doctors/Total population of the region EOY	33.61
Preference of landscape	Greening rate	green	Area of greening/Area of land	0.36
	Square of greening	green^2	(Area of greening/Area of Land)^2	0.156
	The Belt and Road	BR	BR city or not	

attractions [5, 20, 21]. Therefore, the number of taxis per 10,000 people is used to reflect the accessibility of local transportation. Higher education means that it is easier to attract foreign tourists because of more convenient cultural exchanges [17, 22, 23]. Therefore, the "number of higher education schools/total population at the end of the year" is used to reflect the local higher education penetration rate. In addition, travelers have a strong preference for mountainous and forested areas with high greenery rate and volcanoes and deserts with low greenery rate, so the quadratic term of greenery rate and greenery rate is used to reflect the attractiveness of the natural environment to travelers. This paper uses Chinese provincial data (with deletions) from 2007 to 2018 to analyze the impact of the Belt and Road on tourism. Data sources are China City Statistical Yearbook, China Tourism Statistical Yearbook, and provincial economic statistical yearbooks.

4. Empirical Results and Mechanism Testing

4.1. Basic Regression Results. This paper uses the software, stata12 for regression analysis of the data, and to prevent errors, time effects and individual effects are controlled. The regression results are shown in Tables 2–4.

Before controlling the regional economic development level, traffic accessibility, higher education level, medical care level, and landscape preference, the regression results show that the coefficients of different explanatory variables reflecting tourism development level, such as domestic tourism revenue and domestic tourist arrivals, are positive and significant, and the regression results thus support Hypothesis 1. The coefficients of inbound tourism revenue and inbound tourist arrivals are positive and significant, and the regression results thus support Hypothesis 2. Comparing inbound tourism and domestic tourism, the coefficients of inbound tourist arrivals and revenues are significantly smaller than those of domestic tourism, and the degree of significance is also lower, and therefore, the regression results thus support Hypothesis 3.

After adding controlled variables, the regression results still confirm the positive impact of Belt and Road on regional tourism development, as shown in Tables 2 and 3.

5. Robustness Test and Heterogeneity Test

5.1. Robustness Tests

5.1.1. Inclusion of Joint Geographic-Temporal Fixed Effect. As different tourism economic policies are adopted in different years in the central region (CR), eastern region (ER), and western region (WR), and their attention and investment in tourism vary, the characteristics of regional change over time can affect the development of tourism in each province. Considering that regional tourism development can be affected by overall tourism planning and policies at different geographic levels, this paper further considers joint geographic-temporal fixed effects in the robustness tests to capture the policy effects of each province over time. The impact of geographic differences for each province is examined.

The regression results are shown in Table 4. The coefficients of domestic tourism trips and domestic and inbound tourist arrival are significantly positive after adding the geographical control, and the other results are not significantly different from Tables 2 and 3; that is, the coefficients of inbound tourism and the degree of significance are smaller than domestic, which further supports Hypothesis 3.

5.1.2. Parallel Trend Test. The DID analysis assumes that the experimental and control groups have the same trend in the absence of event influence and that there is no ex ante error. The analysis in this paper assumes that tourism development in the control and experimental groups can maintain the same trend per se. If tourism development in policy-implementing and nonpolicy-implementing cities is systematically different, the premise of DID will not exist.

Parallel trend tests were conducted on the tourism development levels of the control and experimental groups in the first two and last four years of the Belt and Road, and the regression coefficients were plotted. The results are shown in Figures 1 to 6. In the year before 1, before 2, and the present year of current, the curves fluctuate above and below the value of 0, indicating that there is no systematic difference. In the year after 1, after 2, and after 3, the curves rise significantly, indicating that "one belt, one road" has brought a positive impact on regional tourism development, and the impact is gradually deepened in these three years. The curve declines sharply in the year of after 4, indicating that the positive impact declines in the fourth year after the implementation of this initiative. The impact of "one belt, one road" is generated after a one-year delay and deepens over the next three years, before declining in the fourth year. However, it should be noted that domestic tourism revenue, domestic tourist receipts, inbound tourism revenue, inbound tourist receipts, and total domestic and inbound tourism revenue all show the above trends and satisfy the requirements of the parallel trend test. But the total domestic and foreign tourist receipts did not pass the test, so this indicator should not be used as a variable for DID.

5.1.3. Exclusion of Extreme Values Test. In practical situations, there may be extreme cases affecting the regression results. For example, some cities have data that have a great positive impact on the regression results due to rich tourism resources, smooth transportation environment, and good policy conditions while some cities have the opposite. The occurrence of extremes can bring errors to the regression results. In order to exclude the influence of extreme values, this paper uses 1% and 5% winsorization to the data to exclude the extreme values above this degree in the variables, respectively, and then, the results are tested. The new regression results are similar to the above, and the effects of extreme values can be excluded from the data used in this paper.

5.2. Heterogeneity Analysis. The market operation mechanism is based on the existing tourism resources in the region, the degree of integration and utilization of tourism resources in the region is different, and the link between the richness of

Table 2: Impact of "one belt, one road" on the tourism economy of the regions along the route (a).

	Domestic tourism revenue		Inbound tourism revenue		Domestic tourist arrival	
	Control variables added	Without control variables added	Control variables added	Without control variables added	Control variables added	Without control variables added
BR-DID	84442.192*	102759.7***	1341.18*	1892.378*	3810.369*	16664.376*
	1.85 0.06	3.14 0.00	0.68 0.49	1.47 0.14	0.50 0.62	−0.13 0.89
hotel	−184.619	— —	66.607*	— —	3066.553*	— —
	0.06 0.96	— —	1.73 0.09	— —	1.05 0.29	— —
Taxi	144.942	— —	1.882	— —	92.82	— —
	1.34 0.18	— —	1.44 0.15	— —	0.89 0.37	— —
Elec	0.262 —	— —	−0.002	— —	−0.01	— —
	1.24 0.22	— —	−0.71 0.48	— —	−0.07 0.95	— —
educ	−126000**	— —	−157.216	— —	−116000**	— —
	2.15 0.03	— —	−0.27 0.79	— —	−2.02 0.04	— —
Med	−94.612	— —	−1.177*	— —	−111.74	— —
	−0.97 0.33	— —	−1.94 0.05	— —	−1.08 0.28	— —
Gdp	0.024	— —	0	— —	0.04	— —
	0.49 0.63	— —	−0.46 0.65	— —	0.75 0.46	— —
green	−37200***	— —	−70.761	— —	−40600***	— —
	−3.02 0.00	-	−0.78 0.44	— —	−3.15 0.00	— —
green2	−7695.159*	— —	−162.182***	— —	10313.894**	— —
	1.95 0.05	— —	−5.43 0.00	— —	1.99 0.05	— —
Whether to control time effects	Yes	Yes	Yes	Yes	Yes	Yes
Whether to control individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2_within	0.42	0.32	0.17	0.07	0.28	0.15

Table 3: Impact of "one belt, one road" on the tourism economy of the regions along the route (b).

	Inbound tourism revenue		Domestic and inbound tourism revenue		Domestic and inbound tourist arrival	
	Control variables added	Without control variables added	Control variables added	Without control variables added	Control variables added	Without control variables added
BR-DID	389.259*	1321.016*	84626.37**	102367.3***	17053.63	−5131.392
	0.75 0.45	−2.52 0.01	2.08 0.038	3.12 0.00	0.47 0.64	−0.18 0.86
hotel	365.182**	— —	−118.012	— —	3431.734	— —
	2.14 0.03	— —	−0.03 0.976	— —	0.98 0.33	— —
taxi	1.958	— —	146.8245	— —	94.772	— —
	1.09 0.28	— —	1.09 0.278	— —	0.79 0.43	— —
Elec	−0.003	— —	0.2599	— —	−0.0167	— —
	−0.61 0.54	— —	1.28 0.200	— —	−0.09 0.93	— —
educ	−1226.157	— —	−126376.3*	— —	−117577.9*	— —
	−0.89 0.376	— —	−1.77 0.077	— —	−1.86 0.064	— —
Med	−1.463	— —	−95.789	— —	−113.200	— —
	−0.63 0.532	— —	−1.01 0.312	— —	−1.35 0.178	— —
Gdp	0	— —	0.0236***	— —	0.0349	— —
	0.12 0.91	— —	0.57 0.000	— —	0.95 0.34	— —
green	−419.787**	— —	−37316.54***	— —	−41005.5	— —
	−2.37 0.018	— —	−3.54 0.000	— —	−4.39 0	— —
green2	185.368***	— —	−7857.342	— —	10499.26	— —
	3.98 0.00	— —	−0.98 0.33	— —	1.48 0.14	— —

Table 3: Continued.

	Inbound tourism revenue		Domestic and inbound tourism revenue		Domestic and inbound tourist arrival	
Whether to control time effects	Yes	Yes	Yes	Yes	Yes	Yes
Whether to control individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2_within	0.219	0.082	0.222	0.067	0.165	0.179

Table 4: Impact of the Belt and Road on tourism along the policy route after the inclusion of territorial control.

	Domestic tourism revenue		Inbound tourism revenue		Domestic tourist arrival	
BR-DID	85202.1**		38.22*		21592.54*	
	1.8	0.072	0.1	0.923	0.51	0.73
ER	10045.77		54.77		5351.84	
	0.31	0.757	0.2	0.839	0.19	0.91
Cross term of ER	−1925.76		48.31		−17214.37	
	−0.05	0.962	0.14	0.886	−0.48	−0.75
CR	19515.36		−156.64		−7430.056	118.099
	0.69	0.487	−0.67	0.503	−0.3	0.26
Cross term of CR	13034.25		318.78		−7071.35	−168.577
	0.32	0.751	0.93	0.352	−0.19	−0.26
Whether to control time effects	Yes		Yes		Yes	
Whether to control individual fixed effects	Yes		Yes		Yes	
R^2_within	0.412		0.168		0.28	0.224
	Inbound tourist arrival		Domestic and inbound tourism revenue		Domestic and inbound tourist arrival	
BR-DID	551.97*		85240.317**		22144.51	
	0.73	0.464	1.79	0.073	0.53	0.599
ER	470.189		10100.55		5822.02	
	0.91	0.363	0.31	0.756	0.2	0.84
Cross term of ER	−483.880		−1877.444		−17698.25	
	−0.75	0.455	−0.05	0.963	−0.49	0.625
CR	118.099		19358.72		−7311.96	
	0.26	0.792	0.69	0.492	−0.29	0.77
Cross term of CR	−168.577		13353.03		−7329.92	
	−0.26	0.797	0.32	0.746	−0.2	0.843
Whether to control time effects	Yes		Yes		Yes	
Whether to control individual fixed effects	Yes		Yes		Yes	
R^2_within	0.224		0.419		0.281	

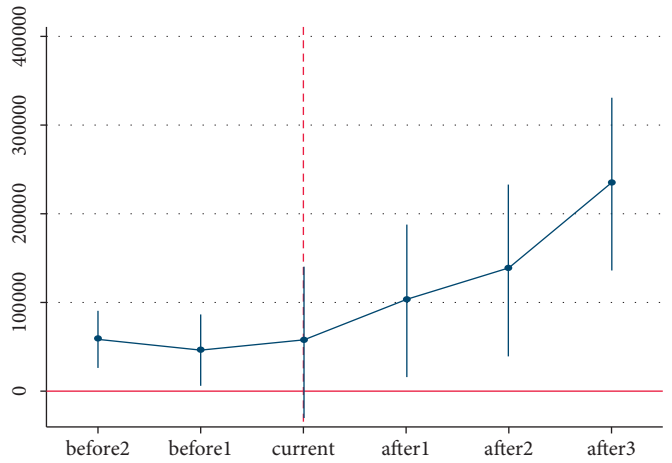

Figure 1: Parallel trends in domestic tourism revenue.

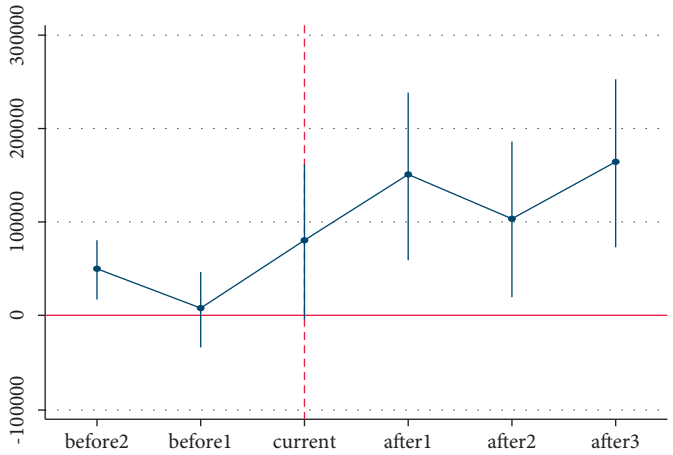

Figure 2: Parallel trends in domestic tourist arrival.

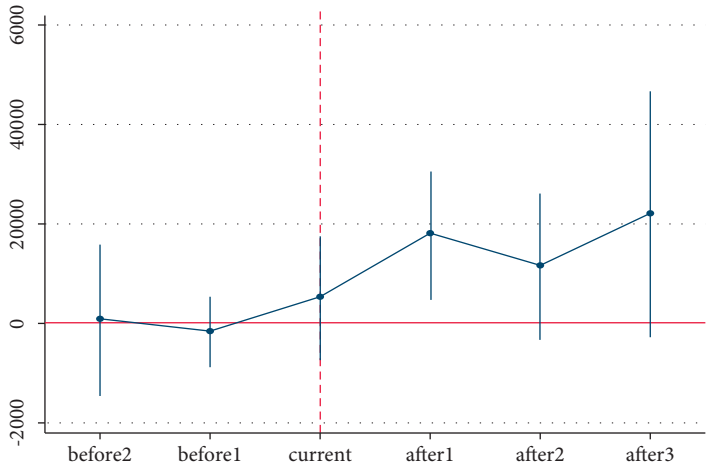

Figure 3: Parallel trends in inbound tourist arrival.

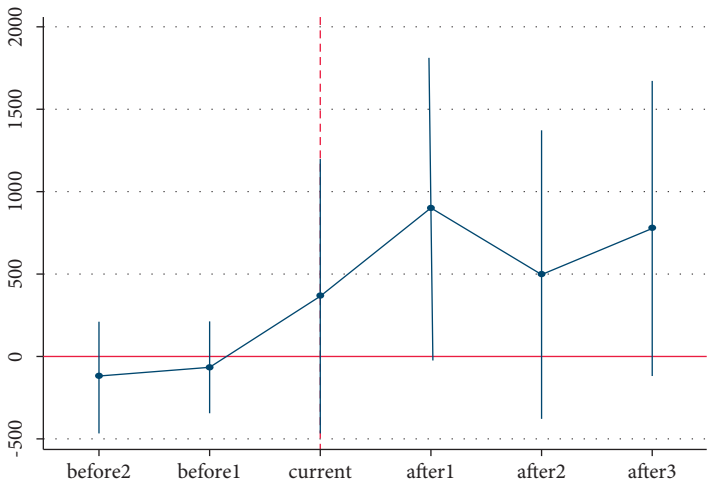

Figure 4: Parallel trends in inbound tourism revenue.

regional tourism resources and the impact of "one belt, one road" on the regional tourism economy is not consistent [24]. The impact of "Belt and Road" on the regional tourism economy should also be considered.

In this paper, the number of 5 A scenic spots is used to represent the richness of regional tourism resources. 5 A is the highest rating of scenic spots in China and represents the most authoritative distribution of tourism resources in

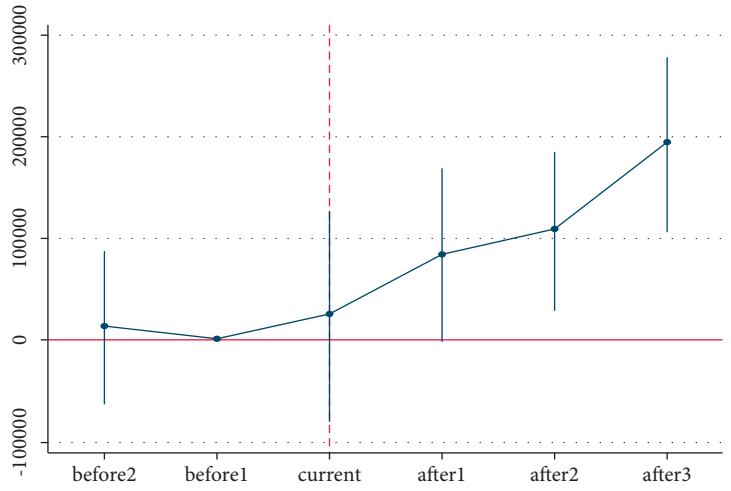

Figure 5: Parallel trends in domestic and inbound tourism revenue.

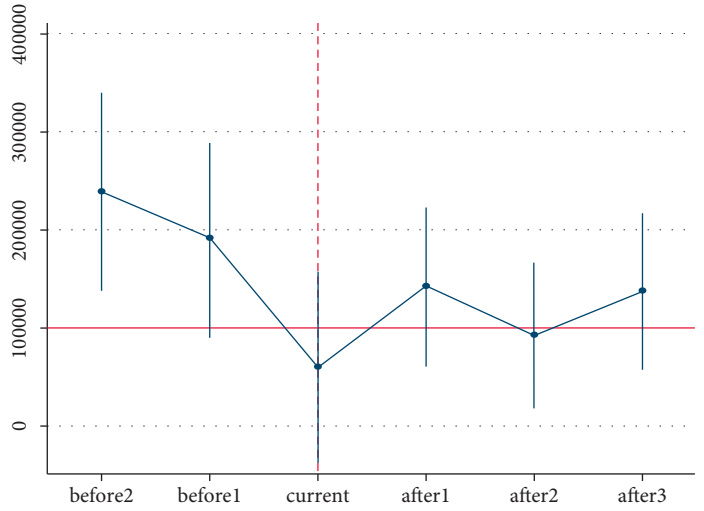

Figure 6: Parallel trends in domestic and inbound tourist arrival.

China. The data used are from the 5 A scenic spots list of 2020, because the formation of the landscape requires a long period of accumulation, even though some attractions are excluded in 201 for cross-regional scenic spots (some scenic spots are distributed across a wide area, making it difficult to identify the area to which their tourism revenue belongs) and scenic spots not under the jurisdiction of prefecture-level municipalities (tourism revenue of scenic spots not under the jurisdiction of prefecture-level municipalities is not within the scope of prefecture-level municipal tourism revenue and is thus not included in provincial statistics).

As shown in Table 5, the impact coefficients of the cross term on domestic tourism revenue, domestic tourist arrival, inbound tourist arrival, and domestic and per capita inbound tourism revenue are significant, but the impact coefficients on inbound tourist arrival are not significant; moreover, the coefficients of the six regressions are all negative. This indicates that the richer the resources of 5 A scenic spots, the smaller the positive impact of "one belt, one road" on the regional tourism economy. Because the 5 A scenic spot will attract a large number of domestic and foreign tourists, and the reception capacity of the scenic spot is limited, it is impossible to receive more tourists, so the overall income growth is limited. It can also be interpreted that the regions with abundant tourism resources are less dependent on the tourism economy promoted by the "Belt and Road," but the regions with insufficient tourism resources can gain the favor of domestic tourists through the "Belt and Road", and there are a large number of idle tourism resources in these areas, which have not been fully utilized and develop, including the increase in both of the number of domestic tourists and the spending of domestic tourists, which will bring new

Table 5: Regression results of cross-terms between 5 A scenic spots and "one belt, one road" nodes.

	Domestic tourism revenue		Inbound tourism revenue		Domestic tourist arrival	
BR-DID	84442.192**		184.18*		16664.37*	
	2.08	0.037	0.55	0.585	0.46	0.642
5A scenic spot	−8824.56		−541.95***		−17015.72	
	−0.98	0.326	−7.26	0	−2.14	0.032
Cross-terms	−43706.98***		−463.166		−23249.48***	
	−6.9	0	−8.81	0	−4.15	0
Whether to control time effects	Yes		Yes		Yes	
Whether to control individual fixed effects	Yes		Yes		Yes	
R^2_within	0.415		0.165		0.278	
	Inbound tourist arrival		Domestic and inbound tourism revenue		Domestic and inbound tourist arrival	
BR-DID	389.259*		84626.37**		17053.63	
	0.75	0.452	2.08	0.038	0.47	0.636
5 A scenic spot	−890.161***		−9366.51		−17905.89**	
	−6.23	0	−1.04	0.299	−2.24	0.025
Cross-terms	−263.736**		−44170.15***		−23513.22***	
	−2.62	0.009	−6.95	0	−4.18	0
Whether to control time effects	Yes		Yes		Yes	
Whether to control individual fixed effects	Yes		Yes		Yes	
R^2_within	0.22		0.414		0.279	

growth points for their tourism economies. This is in line with the above analysis that the impact of Belt and Road on domestic tourists is greater than that on inbound tourists. Meanwhile, this paper uses excellent tourism cities as representative variables of tourism resources included in the analysis, and its cross-term regression results are similar to those of the 5 A scenic spots and thus will not be repeated.

6. Conclusions and Policy Implications

6.1. Conclusion. The regression results of this paper support the hypothesis that "one belt, one road" has boosted the development of the tourism economy in the regions along the route. The "Belt and Road" has significantly increased domestic tourism revenue per capita, inbound tourism revenue per capita, domestic tourist receipt per capita, foreign tourist receipt per capita, and domestic and inbound tourism revenue per capita, while the contribution of domestic tourists to the tourism economy of the regions where the policy is implemented is stronger than that of inbound tourists. The "Belt and Road" initiative has promoted the development of tourism in the cities where the policy is implemented. Also, domestic and inbound tourists show a higher level of interest in tourism in the cities where the initiative is implemented, as evidenced by higher average spending. The stronger attraction of the Belt and Road initiative cities to domestic tourists may stem from their excellent performance in terms of tourism economic linkages, unique tourism resources, and tourism transportation conditions and advantages that accelerate the chances of tourism cooperation and integration of regional tourism effects. The increased interest of Chinese tourists in these cities is reflected in the increase in the average spending of the intrinsically interested groups, while they do not significantly increase the attractiveness of the originally uninterested groups. In short, compared with other studies, the panel data of prefecture-level cities show that the "Belt and Road" initiative has a good role in promoting the development of tourism.

6.2. Policy Implications. First, the analysis suggests that the Belt and Road has had a positive impact on tourism in the cities where the policy is implemented. In general, the impact of the Belt and Road on tourism is multifaceted. China's implementation of the Belt and Road has not only strengthened its ties with foreign countries and increased its openness to the rest of the world but has also greatly contributed to the development of tourism in the related cities. Therefore, Belt and Road cities should actively integrate and accelerate the implementation of specific rules and regulations to take advantage of the Belt and Road. As China's economy is facing the double pressure of eliminating backward production capacity and upgrading industries, the Belt and Road has strengthened domestic and international ties and contributed to breaking down regional barriers and releasing economic influence.

Second, the results of this paper show that the positive impact of Belt and Road on tourism development in policy-implementing cities exceeds that of nonpolicy-implementing cities which should actively integrate into

the Belt and Road development strategy, using policy-implementing cities as core circles to expand their tourism influence and seek to absorb the benefits brought by the Belt and Road. Many cities, especially nonpolicy implementation cities in central and western China, have rich natural landscapes and unique humanistic landscapes, but due to their geographical location, insufficient investment in tourism industry development, poor transportation infrastructure, and relatively backward service industries such as hotels and restaurants, they are unable to give full play to their tourism resources. Therefore, the policy should focus on narrowing the time distance between the "Belt and Road" to boost the potential of the local tourism industry, and thus, the utilization rate of tourism resources can be improved while satisfying the diversified tourism needs of people. The interaction of tourism elements between cities implementing the policy promotes closer tourism economic ties and achieves synergistic development between coastal and inland cities implementing the policy.

Third, the results of this paper show that the "one belt, one road" has had a significant impact on the average spending of visitors to China, but not on the number of tourist arrivals. In response to this feature, the cities implementing the policy should consider providing higher convenience to meet the spending needs of tourists coming to China. For example, provide greater convenience in tourist visas, train more bilingual tour guides, and provide private customized tourism services. By developing a more flexible foreign exchange conversion mechanism and more extensive promotion, the existing tourist attraction groups should be deepened, and their spending needs can be explored.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Disclosure

The article has been preprinted before, and the current manuscript has been improved on the basis of the preprint in https://www.preprints.org/manuscript/202112.0495/v1[25].

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Model Optimization Analysis of Customer Churn Prediction Using Machine Learning Algorithms with Focus on Feature Reductions

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Currently, Customers are struggling to retain their business in today's competitive markets. Thus, the issue of customer churn becomes a significant challenge for the industries. In order to achieve this, it is vital to have an efficient churn prediction system. In this paper, we discuss methods for reducing features using PCA, Autoencoders, LDA, T-SNE, and Xgboost. In this paper, a model for predicting light GBM churn is proposed. The model consists of five steps. The first step is to preprocess the data so that missing and corrupt values can be handled and the data can be scaled. Secondly, implementing a comprehensive feature reduction system based on popular algorithms reduces the features and selects the most suitable one. In the third step, light GBM's hyperparameter is tuned using Bayesian hyperparameter optimization and genetic optimization algorithms. Lastly, interpreting the model and evaluating the impact of the features on model outputs by using the SHAP method, and finally ranking the churners by customer lifetime value. Aside from evaluating and choosing the best feature reduction methods, the proposed method is also evaluated using four famous datasets. It outperforms other ensemble and ML algorithms like AdaBoost, SVM, and decision tree on over seven evaluation metrics: accuracy, area under the curve (AUC), Kappa, Mathews correlation coefficient (MCC), Brier score, F1 score, and EMPC. In light of the evaluation metrics, our model shows a significant improvement in handling imbalanced datasets in churn prediction. Finally, in this paper, interpretability and how the features affect the model's output are presented by the SHAP method. Then CLV ranking is suggested for better decision-making.

1. Introduction

Customer churn problem is a big challenge in industries, especially in the telecommunication industry. A churner quits the service provided by operators and yields no profit to any further extent. One of the most effective ways to deal with customer churn is to evaluate customer behavior to detect churn probability. Due to the development of centralized information systems, more information can be obtained about customers' behavior through customer data analysis. Customer retention is one of the primary goals of CRM (customer relationship management). Its significance has resulted in the creation of a number of tools that aid in several critical tasks in predictive modeling and categorization [1]. Employing many different analysis techniques can help evaluate customer behavior. Churn probability calculation can be the basis for calculating the risk of resource depletion, which is one of the most critical parameters affecting an industry's status. To effectively handle customers' churn in a company, it is essential to produce a valuable and accurate customer churn prediction [2]. Churn prediction methods are highly based on artificial intelligence (AI) classification algorithms. These kinds of classification methods face high dimensionality and imbalanced datasets impeding accurate churn prediction. The amount of data accessible for investigation, as well as the balanced or unbalanced nature of the dataset, has a considerable impact on the efficacy of certain data mining

approaches [3]. Churn datasets demonstrate the class imbalance problem, in which the churn class (minority class or class of interest) has fewer samples than the nonchurn class (majority class). This makes it harder for some machine learning approaches to identify the minority class [4]. So the ensemble methods demonstrate excellent results in handling imbalanced datasets in churn prediction.

Furthermore, ensemble methods are widely used in churn prediction models. They are accurate and straightforward to use for exploiting sophisticated models with low computational power. They are categorized into two groups based on their structures: parallel and sequential. The parallel ensemble is a set of different machine learning approaches that create an independent model in parallel. Sequential uses first algorithms to learn and generate a model. Then the second algorithm learns to modify the previous model, and thus, it will continue by its specific depths. Recent studies show that the boosting method outperforms the other ensemble methods in accuracy and imbalanced performances [5]. However, there is little focus on light GBM capabilities on churn prediction in literature. In some of the researches, it is utilized as a benchmark model. However, it shows a significant ability to improve models and win challenges in Kaggle.

Additionally, due to the light GBM algorithm's numerous hyperparameters, it is necessary to have an efficient and robust optimization algorithm to enhance the model's performance. The latest improvements in Bayesian optimization (BO) help us do faster hyperparameter tuning and avoid time-consuming computational calculations [6]. Thus, the BO enhances the model hyperparameter tuning efficiency and model performance metrics. Also, genetic optimization (GO) is a powerful optimization algorithm too. This paper uses the genetic algorithm for hyperparameter tuning. It compares it to the Bayesian optimization by their performance in churn prediction. In addition, the churn prediction systems calculate the probability of each customer's churn potentiality. In this procedure, the companies should determine the threshold of churn probability. The determined threshold is crucial for the analysis of customer churn prediction. Therefore, this paper uses threshold interval as a hyperparameter in the tuning algorithm for the first time.

Moreover, when performing complex data analysis, one of the major problems is the number of variables involved. Analysis with many variables generally requires a large amount of memory and computational power or classification algorithm that uses the instructional sample and generalizes to the new instances. There is a need to efficiently tackle the difficulties of high dimensional data analysis as the speed of current computers increases and parallel processing facilities become more affordable. Data mining and statistical approaches are utilized to deal with many feature sets for this purpose, and strategies such as feature reduction and subset selection methods may be employed to increase classification accuracy while requiring a low computing cost of the data mining process [7]. Feature reduction is a general term for constructing a combination of variables to solve high-precision problems [8]. Explicitly, feature reduction aims to select more representative features with more discriminative power over a particular dataset [9].

The following are the main objectives of dimensionality/feature reduction:

(i) The main goal is to select the best features for distinguishing classes.

(ii) Eliminate unnecessary data to reduce complex computations.

(iii) Improve data quality for data compression tasks such as pattern recognition and data mining.

(iv) Increase computational speed.

Therefore, in this paper, the comprehensive feature reduction methods such as Autoencoders, PCA, T-SNE, Xgboost feature importance selection, and LDA are discussed and compared. As a result, the best method has been chosen for the data feature engineering process and then in machine learning models analyses. Moreover, interpretability is necessary for customer churn prediction (CCP) models and helps decision-makers understand the model and features better. Feature or dimensionality reduction helps to understand more about crucial features. The rest of the paper is organized as follows: Section 2 reviews the churn literature and the process of churn prediction systems in the literature. Section 3 discusses the methodologies that are used in this paper. In Section 4, the proposed method has been discussed. Section 5 contributes to the results of experiments of the proposed method and benchmark models. Finally, Section 6 concludes the paper and suggests future research direction.

2. Literature Review of Churn Prediction Methods

Xiao et al. [10] presented a feature selection model of churn prediction using an ensemble algorithm with a dynamic environment. Their suggested model includes two main layers of the GMDH-type neural network and the classification layer. The resulted model has high performance regarding other methods of transfer learning. Idris and Khan [11] overcome the churn prediction imbalanced dataset and presented a classification method. The presented method is based on a filter wrapper and ensemble algorithm. In the first step, they used PSO-based methods for the extraction of the governing features. In the second step, GA was used for dimension reduction. The final phase consists of designing a new feature space and classification using an ensemble algorithm. Results show optimum dimension reduction for two datasets of orange and Cell2Cell. Saghir et al. [12] assessed the churn prediction using a method of neural network begging. The main goal is to increase the evaluation accuracy. Their results show that the presented method reaches 81% accuracy for several datasets. Amin et al. [7] used the feature of distance for churn prediction based on classification certainty. Their categorized dataset consists of two high and low certainty classifiers for churn prediction. The evaluation metrics include accuracy, precision,

sensitivity, and f-score. Results show that there is a direct relationship between distance and certainty of classification factors. If distance factors were high, therefore, the classifier obtains high accuracy. This finding was correct for low distance with low certainty. Mou et al. [13] presented the energy-efficient distributed permutation flow-shop inverse scheduling issue to reduce adjustment and energy consumption at the same time. In their work, Zenggang et al. [14] used the service quality of nodes and their own resources to design message pricing functions that restrict the capacity of nodes to make fraudulent offers by disclosing the resource status of both nodes. Höppner et al. [15] presented models of churn detection for achieving a high-profit model. The model was based on the expected optimum profit for the churn of customers. They presented a model of ProfTree for classification and designing decision trees. The model outperformed state-of-the-art based on the article's results. Maldonado et al. [16] provide a new churn prediction method that drives profit. The method is a developed version of the minimax probability machine algorithm for the classification of churns. The presented method consists of LASSO and Tikhonov algorithms for regularization. Results show that the presented method plays an essential role in increasing company profits. Calzada-Infante et al. [17] presented a churn prediction method based on customer behavior analysis. They used the social network to assess customer behavior using classification methods. They divide customers into churners and nonchurner. The results were illustrated on-time order and static temporal diagram with proximal metrics. Results show outperform of the presented method in comparison with other approaches. Taghizadeh and Ahmadi [18] purposed an innovative strategy to classify and analyze a long-run link and convergence among a variety of knowledge variations in the context of the knowledge-based economy (KBE). Zhu et al. [19] suggested a unique two-step reconstruction approach for enhancing the resolution of reconstructed temperature distribution pictures while maintaining a high degree of precision. According to Yang et al. [20], the aggregated vehicle fuel consumption data are protected against time-series-based differential attacks using a negative survey method. Khodadadi et al. [21] used deep learning methods for the prediction of customer churn. They used return time for the analysis, using recurrent neural networks. Their dependent variable is customer loyalty. Their ChOracle methods presented with high accuracy and performance for churn classification. Amin et al. [22] provide a method of churn prediction with the use of cross-company data. Mahmoudi [23] has developed an innovative strategy for mitigating the detrimental impact of coronavirus on the U.S. economy. Li et al. [24] introduced an innovative collaborative prediction unit (CoPU) that combines the predictions from many collaborative predictors based on a collaborative graph. Özmen et al. [25] developed ant colony optimization methods for optimization and genetic algorithm for feature extraction of data. They applied the model to 100 companies of Turkey to detect customer churn. The AUC of the model reached 99% that is competitive in comparison with other methods. Li et al. [26] developed a unique tutorial that uses the viewpoint of pre-coding design in a multiantenna wireless communication system to address interference exploitation strategies. Kostić et al. [27] used graph theory for churn analysis of telecom companies from the social network. Customer friendship and connection in social media are also effective in churn prediction in their model. They used graph theory to find effective nodes of customer connection in social media. The paper resulted in a useful model for churn prediction classified customers based on a telecom company's churn. Li et al. [28] have examined how symbol-level precoding may enhance the error-rate performance of large MIMO systems deploying 1-bit digital converters. Using logarithmic fuzzy preference programming, Ahmadi [29] has ranked and categorized the growth-affected knowledge-based economic indicators. Cai et al. [30] presented multiple relaxed control techniques for complex-valued memristive neural networks based on data quantization (CNNs). Ahmed et al. [31] presented an ensemble learner for achieving their aims. They used a hybrid method of boosted-stacked learners and bagged-stacked learners. They applied the method to the SATO company for performance analysis. Mahmoudi [23] investigated genetic algorithm evidence in determining the optimal point of purchase intention. The study has been used extensively by automotive activists. Liang et al. [32] suggested an agent-based model (ABM) to simulate the impact of policy initiatives on inhabitants' decisions on the usage of green space. The result shows that the method accuracy reaches 94.4% for the SATO database. Ahmadi and Qaisari Hasan Abadi [33] studied the object-oriented properties of C++ to design expert systems for strategic planning. Jain et al. [34] used logistic regression and logit boost method for churn analysis in the telecom industry. They first used the PCA method for feature selection of customer churn. Then the floating-searching approach is applied for churn analysis. The method outperforms other related approaches. Castanedo et al. [35] used different algorithms, including autoencoders, deep belief networks, and multilayer feedforwards networks for CCP by exploiting business intelligence dataset of millions of call records. They achieve higher AUC than traditional methods by using deep models. Nekah et al. [36] examined the relationship between brand personality, brand reputation, and self-image of Iran Khodro Company with the customers' purchasing intention. Spanoudes et al. [37] test abstract datasets for a company's software in churn prediction on many datasets attained by subscription and nonsubscription companies. They designed a deep learning pipeline that has a vast application on any subscription type business. However, their model does not show improvements in nonsubscription in comparison to subscription-type companies. They examine different layers and architecture and data reduction techniques over churn prediction problems. Their results show that data dimensionality reduction techniques like t-SNE are helpful in the preprocessing phase of deep models. Halibas et al. [38] consider different approaches and deep models in the telecommunication sector. The models are constructed on RapidMiner software. Their results compare the algorithms by various metrics by exploiting upsampling techniques. However,

their results show that GBT is better in comparison to the deep model. Saghir assessed the churn prediction using a method of neural network begging. The main goal is to increase the evaluation accuracy. Their results show that the presented method reaches 81% accuracy for several datasets. Table 1 shows the summary of research papers.

As the literature shows, the majority of papers emphasize one or two methods of feature reduction. Also, they did not consider both machine learning and deep learning methods on feature reductions. It is essential to have a comprehensive feature reduction algorithm evaluation because, in industrial applications, the bulk of features may cause high computational time and cost. Moreover, there is no way to understand, which feature reduction methods make a more reliable and good result according to the business goals. So, it is critical to evaluate all-powerful methods to choose the best feature reduction method. This paper discusses the most common feature reduction methods, including machine and deep learning algorithms.

Furthermore, the evaluation metrics are not sufficient to churn problems. In churn classification, methods should always compare models by their performance towards the imbalanced nature of datasets since the churn problem is highly imbalanced due to the lack of churners' data records. It is also essential to understand the model prediction outputs strength and their meaningfulness. Therefore, it is necessary to evaluate churn classification models with all related metrics to conclude the best method. Additionally, it is a priority to enhance model performance due to its vast hyperparameters. The ensemble methods lack concentration on the hyperparameter tuning algorithm, so the hyperparameter tuning-based light GBM method has been presented in this paper. Finally, a few papers focused on churn prediction interpretability as the main problem. Accordingly, in the industry, managers are also interested in knowing the model behavior and understanding how and why the model works correctly.

Furthermore, customer lifetime value is an essential key performance metric (KPI) for marketing efforts. This topic has received little attention in the literature. The customer lifetime value is presented as an essential component of the CCP model in this article. Thus, in this paper, one of the main focuses is model interpretability.

3. Churn Prediction

This section presents the stages of implementation of the churn prediction system in the literature. As illustrated in Figure 1, the process of churn prediction consists of five stages, including understanding business and customer features for analyzing churn problems, collecting customers' data, preprocessing the data, building the machine learning models, and finally, evaluation of prediction. Then researchers decide on conclusions and strategies towards churners.

3.1. Data Sources. Many datasets have been used in the existing solutions with different features of customers. Each of them is related to a specific industry. Some papers have been conducted on the finance sector, including banking, insurance, and funds [2, 48, 49], retail industry [50, 51], game [6], music [52], e-commerce [53], and telecommunication [15, 22, 25, 54–56]. It is worth noting that there are many datasets in the vertical of telecommunication due to the vast number of customers and available data.

3.2. Data Features. In business understanding and the customer features stage, the crucial attributes for measuring churn will be determined. Customer features, such as demographics, financial information, usage behavior, call detail records, tenure, and network structure of subscribers, have been used for more accurate customer churn prediction (CCP) models. Moreover, individual features such as recency, frequency, and monetary (RFM) [50], texts [57] and tweets [58], and log data [6] have been used in the churn prediction models. Table 2 shows some features of each financial, telecommunication, and e-commerce source.

3.3. Pre-Processing Methods. First, in the preprocessing section, most of the researchers exploit data cleaning techniques. Data cleaning is about detecting, correcting, or removing corrupt data. Furthermore, the next part is handling categorical features. The categorical features of customers like demographic data are usually vital in CCP models analyses. The critical part of data preprocessing is the imbalanced control of datasets. Churn datasets are highly imbalanced. Imbalanced data make a considerable impact on model evaluation metrics. There are several techniques for handling an imbalanced dataset. Under-sampling, upsampling, and algorithmic approaches are prevalent among imbalanced learning techniques. In this stage, some researchers also conduct descriptive data analysis (EDA) to understand the data better.

4. Methodology

In this section, the methods which are used in this paper have been discussed. It is essential to understand how these models work for more understanding of the results.

4.1. Feature Reduction Methods. Features are properties of objects whose values must be the same for objects in a particular class and objects in other classes (or backgrounds). Features may be continuous (such as numerical values) or deductions (such as tagged values). Length, area, and texture are examples of continuous variables, in contrast to the deductive or arranged features, such as where the ordering of labels has meaning (for example, class buildings, military grades, and degrees of satisfaction) or nominal, such as when there is no meaning (e.g., name, postal code, and department). Choosing the right features depends on the type of image and application that is desired. Feature reduction is used to simplify the features required to accurately describe a large set of data [8].

Table 1: Literature review summary.

References	Prediction method	Industry	Evaluation metrics
[35]	Feedforward network, deep belief network, and Autoencoder	Telecom	AUC
[39]	SMOTE, decision trees, random forest, AdaBoost, multilayer perceptron, K-means and Bayesian logistic regression	Telecom	*P*-value, accuracy, AUC, precision, recall, F1-Score
[40]	CCPBI-TAMO, CPIO-FS	Telecom	Precision, recall, accuracy, F-Score, ROC
[41]	Xgboost, AdaBoost, catboost, decision trees, SVM, KNN	Telecom	Accuracy, AUC, precision, recall, F-Measures
[37]	Deep feed-forward networks	Subscription companies	Accuracy
[38]	Deep ANN, machine learning algorithms	Telecom	Accuracy, precision, recall, F1-score, and AUC
[12]	Neural network with bagging	Telecom	Accuracy, precision, recall, F-score, kappa, absolute error, relative error, and classification error
[10]	Transfer learning of ensemble	Telecom	Area under curve of ROC (AUC) and complexity
[11]	Ensemble algorithm	Telecom	Area under curve of ROC (AUC)
[12]	Begging and neural network	Telecom	Accuracy and precision of classification
[42]	Artificial neural network (ANN) and self-organized map (SOM)	Telecom	Accuracy, recall, F-score, and precision
[15]	Profit tree	Telecom	Accuracy, cost, and profit
[16]	Minimax probability machines	Telecom	AUC and EMPC
[17]	similarity forests	Telecom	AUC, and tenlift AUPR
[21]	Temporal point processes (TPP) and recurrent neural networks (RNN)	Telecom	MAE and MRE
[22]	Cross-company just-in-time approach	Telecom	Accuracy, Kappa, and Recall
[25]	Multiobjective and colony optimization	Telecom	AUC
[27]	graph theory	Telecom	Top decile lift
[31]	Boosted-stacked learners and bagged-stacked learners	Telecom	G means and AUC
[34]	Logistic regression and Logit Boost	Telecom	Accuracy, Kappa, MAE, coverage case, and RMSE
[43]	Decision tree, artificial neural, networks, K-Nearest neighbors, and support vector machine	Telecom	Confusion matrix, precision, and recall
[44]	Logistic regression and random forest	Telecom, bank, and retail	AUC and cross-validation
[45]	Genetic algorithm, classification, and covering & LEM2 (rules generation algorithms)	Telecom	Accuracy, recall, mutual information, coverage, and F measure
[46]	Data transformations, DT, KNN, DNN, GBT, and SRI	Telecom	Probability of detection, probability of false alarm, area under the curve, and g-mean
[47]	Exhaustive, genetic, covering and LEM2	Telecom	TP, FP, FN, TN, COV, PRE REC, ER, ACC, and SPEFM

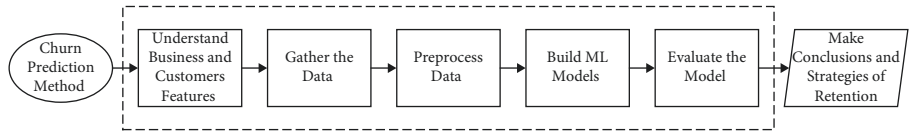

Figure 1: The process of churn prediction.

Table 2: Industries and their features.

Industry	Features
Financial	Credit score, balance, services, customer transactions
Telecommunication	Payment methods, monthly charges, internet services, number of lines, call details records
E-commerce	Frequency, recency, monetary, products, log data

4.2. Principal Component Analysis (PCA). The study of principal components is one of the outcomes of linear algebra mathematics because the nonparametric and straightforward method extracts relevant information from confusing sets. The transformation of the T can be obtained by minimizing the least-squares error, assuming that the

vector of properties is $X \in R^d$ (d-dimensional space), then the space of the reduced features [59]. $Y \in R^h$. If the vector of properties is $X \in R^d$ then, the least-squares error can be in the form of the following equation:

$$\mathrm{MSE} = E\left[\|x - \hat{x}\|^2\right]. \tag{1}$$

In PCA, we look for a conversion that obtains the least-squares error, which means the following equation is desired.

$$T_D = \arg\min_r \left\{E\left[\|x - \hat{x}\|^2\right]\right\}. \tag{2}$$

As stated, the PCA goes to find a linear transformation T that produces the least-squares error and maximizes this linear transformation $T^T \mathrm{cov}_{x-\hat{x}} T$ is maximized, in which $\mathrm{cov}_{x-\hat{x}}$ is the covariance matrix of data with an average of zero of X. Therefore, the PCA solves the special problem, and the vector of special features of the linear transformation columns forms the T-matrix. The data are shown in the lower dimension $Y = (x - \hat{x})$, namely Y. According to the above, MSE has at least $d - h$ value; that is, a special large vector corresponding to a large specific value should be taken to reduce the dimension or to the category objective for the minimum MSE. Here it is necessary to address some of the properties of the covariance matrix because in fact, the main problem is to find the special values of the covariance matrix. For example, in three dimensions, the covariance matrix is as follows [59]:

$$C = \begin{pmatrix} \mathrm{cov}(x,x) & \mathrm{cov}(x,y) & \mathrm{cov}(x,z) \\ \mathrm{cov}(y,x) & \mathrm{cov}(y,y) & \mathrm{cov}(y,z) \\ \mathrm{cov}(z,x) & \mathrm{cov}(z,y) & \mathrm{cov}(z,z) \end{pmatrix}. \tag{3}$$

The main goal of PCA is to obtain components that do not affect the external data layer, and a powerful covariance estimate matrix has replaced the covariance matrix. If the primary data of the problem is matrix $n \times p$ or $X = X_{n,p}$ N is the number of observations, and p specifies the number of variables.

4.3. t-distributed Stochastic Neighbor Embedding (t-SNE). One of the feature extraction algorithms is t-SNE, which defines a way to convert an extensive dataset into two or three dimensions. Randomly t-distributed neighborhood embedding can maintain a large part of the local structure of high-dimensional data, while also showing the overall structure, such as clusters at different scales. Randomly distributed neighborhood embedding is a nonlinear non-observational method used to explore and visualize data. Simply put, this method provides the user with an understanding of how data is organized in a high-dimensional space.

The built-in algorithm randomly estimates a similarity criterion between pairs of samples in high-dimensional data and low-dimensional space. It then optimizes these two similarity criteria using the cost function. The similarity between points in space dimensions is calculated in the first step. To better understand the subject, we can consider data points scattered in a two-dimensional space. The user around that point centers on the Gaussian distribution. Then the density of all points of the flat Gaussian distribution is calculated. Normalization is then performed for all data points. This provides a set of probabilities (P_{ij}) for all data points. These probabilities are comparable to the similarities and mean that their ratios and observations are identical if the data points x_1 and x_2 have the same values under the Gaussian circle. Then local similarities are given in the structure of the high-dimensional space and distribution or circle. The embedding similarity q_{ij} between the two points y_i and y_j is calculated as a normalized Student-t kernel with a single degree of freedom [60].

$$q_{ij} = \frac{\left(1 + \left\|y_i + y_j\right\|^2\right)^{-1}}{\sum_{k \neq 1}\left(1 + \left\|y_k - y_l\right\|^2\right)^{-1}}, \quad q_{ij} = 0. \tag{4}$$

The place of the y_i is computed by minimizing the Kullback Leibler divergence between the joint distributions P and Q as follows [60]:

$$C(\epsilon) = L(P\|Q) = \sum_{i \neq j} p_{ij} \log \frac{p_{ij}}{q_{ij}}. \tag{5}$$

The second step is identical to the first step. However, the Student T distribution is used with a degree of freedom rather than the Gaussian distribution. This gives the second collection of Q_{ij} probabilities in a low-dimensional space. The final step is for this set of probabilities from the lower Q_{ij} space to better match those in the higher P_{ij} Space. The nonconvex objective function is reduced by reducing along the gradient as follows [60]:

$$\frac{\partial C}{\partial y_i} = 4 \sum_{j \neq i} \left(p_{ij} - q_{ij}\right) q_{ij} Z\left(y_i - y_j\right). \tag{6}$$

4.4. Autoencoders. Autoencoders, of which several versions have been presented, are helpful tools in various fields such as data compression, extraction of features without supervision, reducing the size of data, and building productive models. Figure 2 shows the architecture of Autoencoder models.

The autoencoders are neural networks that try to copy their input to the network output. In general, they have a hidden layer h that creates a coded expression of the input data. These networks can be divided into two parts: an encoder function in the form of $h = E(x)$, which is the back of the neural network that maps the input to the hidden h. It also consists of a decoder function in the form of $r = D(h)$, like the encoder of a neural network, which is responsible for reconstructing the input data based on its encoded expression in the hidden layer. The following figure shows this architecture. It would not be helpful if the autoencoders only learned to map their input to output as $r = D(E(x))$. What matters about these networks is how they are designed [61]. These networks are designed in a way that they can not completely copy the input to their output. Restrictions are usually imposed on these networks that prevent them from

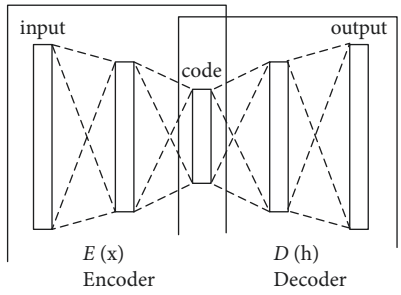

Figure 2: The Autoencoder architecture.

completely copying the input to the network's output and can only do so on an estimated basis. Due to limitations, the network is forced to learn, which aspects of the data are more prioritized for better data recovery at the output to maintain them. This allows the network to extract useful features from the data. One of the limitations is reducing the number of middle layer neurons relative to their encoder input dimensions. This example is shown in Figure 1, where the number of middle layer dimensions p and the number of input dimensions d are less. The MSE cost function or cross-entropy is usually used to train these networks. Also, like most networks, weights are updated using backward propagation algorithms. Equation (8) shows the definition of a network and equation (9) shows the cost function of a typical autoencoder network [61].

$$\begin{aligned} h_{W,b}(x) &= D_{W,b}\left(E_{W,b}(x)\right), \\ L(x;W,b) &= \left\|x - h_{W,b}(x)\right\|^2. \end{aligned} \tag{7}$$

4.5. Linea Discrimination Analysis (LDA). As the name implies, the goal is to find linear discrimination that separates data into known classes. This separator can be a line or, in higher dimensions, a surface. It is noteworthy that this method, in addition to data classification, also reduces the size of the data space. This classification model writes the data into a new space, which is one unit less than the classes defined for the data. These new dimensions are calculated under the components of the lines or surface, separating the data [62]. Suppose the input data are defined in two dimensions. In that case, the primary purpose of this supervised model is to find the direction by which the minimum in-class and out-of-class distance is maximized by looking at the data on it, i.e., in-class data have a minimum distance in the class and data in two different classes have a maximum distance from each other. In the LDA method, first, the model can be trained by training data, and the separating matrices inside the class make the classification model of appropriate directions S_w (total variance of members of each class) and outside class (S_B) and then the performance of the model by test data are benchmarked. The primary criterion of separation in LDA method calculations is the distance criterion [62]. In this method, a two-dimensional matrix with dimensions $a \times b$ is first converted into elemental $a \times b$ vectors. The two scattering matrices inside the class S_w and outside class S_b are defined as follows [62]:

$$S_w = \frac{1}{n}\sum_{j=1}^{c}\sum_{x\in c_j}\left(x - \overline{x}_j\right)\left(x - \overline{x}_j\right)^T, \tag{8}$$

$$S_b = \frac{1}{n}\sum_{j=1}^{c} n_j\left(\overline{x}_j - \overline{x}\right)\left(\overline{x_j} - \overline{x}\right)^T, \tag{9}$$

where c is the number of classes and $\overline{x_j}$ is the average class of j. One way to obtain the W_{LDA} conversion matrix is to use the Fisher criterion, which is obtained by maximizing the following equation:

$$J\left(W_{LDA}\right) = \frac{W_{LDA}^T S_b W_{LDA}}{W_{LDA}^T S_w W_{LDA}}, \tag{10}$$

where W_{LDA} is obtained by a set of particular vectors corresponding to the largest eigenvalues $S_W^{-1}S_b$.

4.6. Baseline Model. In this section, the explanation of light GBM is explained. It is included the main steps of performing these approaches.

4.6.1. Light GBM. Boosting is a sequential decision-tree-based ensemble machine learning algorithm. The algorithm uses a gradient boosting approach. The trees are built successively in order to minimize each previous tree loss function. Each tree learns from its predecessors in this procedure and then updates the residual errors until reaching specific depths. Later, the next tree that grows in the sequence will learn from an informed type of errors [63]. Light GBM is another boosting decision tree that uses a robust classifier with multiple weak classifiers [64]. It differs from Xgboost by its structure of one-side sampling to filter out the data splits. The model helps to enhance the training speed and efficiency.

4.7. Benchmark Models. The benchmark models that have been used in this paper for evaluating the results against the proposed method are explained in this section.

4.7.1. Support Vector Machines (SVM). Support vector machine is a supervised learning model that is structured based on risk minimization. The kernel function is used to improve performance. Research is taking place to find the best kernel or combination of them. The loss of prediction with SVM from the decision tree and sometimes ANN worked best. For example, the reference [43] has used the SVM method in predicting loss and has shown that SVM performs better than other methods.

4.7.2. Decision Tree (DT). The decision tree is a tree-type structure in which decisions are made that can create rules to classify specific datasets. In this tree structure, the leaves represent the class label. The branches represent the intersection of the attributes that lead to those labels. The decision tree does not perform well in complicated problems and nonlinear relations. While in the case of customer loss, the accuracy of the decision tree can be high, which depends on the data. This method has been used to predict loss in many

articles, including [43, 65, 66]. The high popularity of this method in the field of loss is due to recognizing the causes and characteristics of falls based on the division of branches. The random forest algorithm, which is a type of random tree learning, also has similar features.

4.7.3. Random Forest. The stochastic forest is an ensemble learning algorithm that consists of a set of primary regression trees (basic algorithm). A regression tree generates a partition of a data set using consecutive binary divisions based on covariance variables. In each obtained subset (called leaves), the observations belong to a homogeneous group. The key to forming a group is to choose a division criterion (e.g., least-squares) that aims to reduce heterogeneity at each stage [67].

4.7.4. Adaboost. Adaboost or adaptive boosting is a popular boosting technique that helps weak classifiers become a single robust classifier. Weak learners are classifiers that produce a prediction that is better than random guessing. The structure of AdaBoost works by sequentially applying a classification algorithm to reweighted forms of the training dataset. Lastly, the algorithm will take a weighted majority vote of all classifiers [68].

4.8. Optimization Algorithms. In this part, the optimization algorithm's structure will be discussed. Genetic and Bayesian algorithms will be used in hyperparameter tuning of boosting algorithms.

4.8.1. Genetic Optimization (GO). Inspired by nature, the evolutionary principle of "survival of fitness" is the genetic algorithm (GA). Although GA was proposed after the evolutionary strategy algorithm, it is the most popular evolutionary algorithm method. In a genetic algorithm, a population of individuals survives in the environment according to their best adoption in an environment based on a fitness function. A greater chance of marriage and childbirth would be for those with higher skills. Therefore, with improved skills and adoptability, children will be born to new generations. Each person in the population is inserted as a chromosome in the genetic algorithm. Over a few years, chromosomes have increasingly become complete.

Chromosomes are tested in each generation and allowed to survive and replicate by their fitness function value. Generation is discussed in the genetic algorithms with intersection and mutation operators [69]. A collection of search space points is randomly treated at each stage of implementing the genetic algorithm. Each point is assigned a character set in this process, and these sets are applied to genetic operators. For obtaining new points in the search space, the resulting sets are then decoded. Finally, the likelihood of their involvement in the next step is determined by evaluating each point's objective function. Genetic algorithms can be considered as a directional random optimization method that progressively moves towards the optimal point. Regarding the characteristics of the genetic algorithm compared with other optimization methods, it can be said that it is an algorithm that can be applied to any problem without any restrictions on the type of its variables and has a demonstrated efficiency of obtaining the global optimum. This method's ability to solve complex optimization problems is why this algorithm is so popular. Also, the classical methods are either not applicable or unreliable to find the general optimization is not reliable [69]. Figure 3 shows the diagram of genetic algorithms.

4.8.2. Bayesian Optimization (BO). In Bayesian optimization, the goal is to find a new solution y_{N+1} that maximizes the chance of refining the accuracy score of f_{N+1}, where the chance is often defined as a surrogate function $a(y_{N+1}|D_N)$. In Bayesian optimization $\{y_1, \ldots . yn\}$ is a set of solutions, $f = f(x, y)$ is assumed to be drawn from a probabilistic model $p(f|D_N|)\alpha p(D_N f)p(f)$, where $D_N = \{(y_j, f_j)\}_{j=1}^{N}$ and $f_j = f(x, y_j)$. Then, the algorithm proceeds by recursively generating a new solution y_{N+1} from $D_{N+(t-1)}$ and update the set $D_{N+t} = D_{N+(t-1)}U\{y_{N+t}\}$ to make a new sample set of solution $y_{N+(t+1)}$ with an informed, updated observation [70]. The whole process of Bayesian optimization is shown in Figure 4.

4.9. Model Explainability. The accuracy and interpretability of machine learning models are essential for data scientists, researchers, and practitioners to explain their models and comprehend the worth and accuracy of their findings. Meanwhile, explainability refers to how well the internal mechanics of a machine or deep learning system can be articulated in human words.

4.9.1. SHAP. SHAP (SHAPly Additive explanations) is mainly used in clarifying model outputs. SHAP is predominantly founded on game theory and neighboring clarifications. It suggests a way of assessing the dedication of each element. Assuming a boosting model where an output (N) is foreseen using a group N (with n features). Depending on their marginal commitment in SHAP, each variable (φ_i is the engagement or commitment value of feature i) on the model performance (N) is distributed [71].

$$\varnothing_t = \sum_{s \subseteq N_{\{i\}}} \frac{s!\,(n - |s| - 1)!}{n!}[v(s \cup \{i\}) - v(s)]. \tag{11}$$

Depending on the subsequent preservative element, the attribution method is considered to be a linear function of binary features t

$$t(z') = \phi_0 + \sum_{i=1}^{I} \phi_i z_i'. \tag{12}$$

4.10. Evaluation Measures. The evaluation measures are the most critical part of identifying the best model in our churn prediction methods. This paper use seven different measures, such as simple accuracy, imbalanced measures, AUC, kappa, Mathew's correlation coefficient, f1-score, and Brier score. Moreover, the EMPC metric is used to understand the model's performance towards profitability for the business.

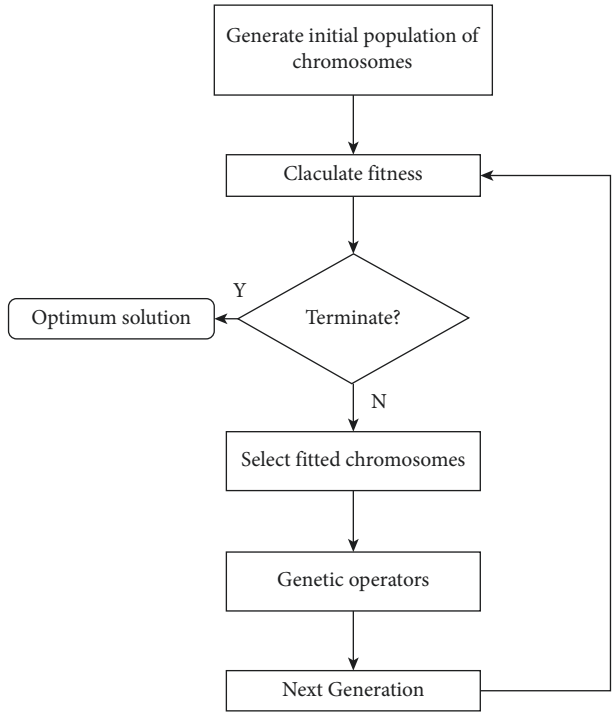

Figure 3: Genetic hyperparameter tuning flowchart.

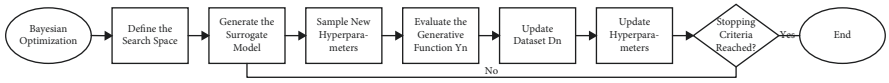

Figure 4: Bayesian optimization flowchart.

4.10.1. Accuracy. The accuracy informs the proximity of the model to the known values. There are four separate outputs in the binary classification, namely true-positive (TP), false-positive (FP), true-negative (TN), and false-negative (FN). The accuracy is simply calculated by the formula TP + FN/TP + TN + FP + FN. It is commonly used as a priority criterion for assessing the models in churn prediction systems.

4.10.2. Area Under the Curve (AUC). The receiver operating characteristic curve (AUC) indicates the model's power to separate groups. The receiver operating characteristic (ROC) curve is a central assessment of the classification model in the imbalanced data type distribution. In binary predictions, the ROC graph is a true-positive (TP/(TP + FN)×100%) or false-positive (FP/(FP + TN)×100%) graph. It is not easy to compare the ROC of different models, so it is better to use the AUC [72]. Table 3 shows the interpretability of AUC results.

Table 3: AUC value interpretation.

Interpretation	AUC
Weak	(0.5, 0.6)
Fair	(0.6, 0.7)
Good	(0.7, 0.8)
Very good	(0.8, 0.9)
Excellent	(0.9, 1.0)

4.10.3. F1-Score. F1-score is one of the critical measures to evaluate imbalanced classification models. It works based on false positive and false negative rates.

It is calculated by $2 * (\text{Precision} * \text{Recall})/(\text{Precision} + \text{Recall})$ formula. The higher score indicates better the model, especially toward imbalanced datasets.

4.10.4. Mathews Correlation Coefficient (MCC). MCC is a performance metric that is less influenced by imbalanced datasets by considering both accuracy and error rates in both classes [73]. MCC is obtained from (13). MCC results between −1 (worst) to 1 (best). So, a more positive rate will consider that classifier as a better classifier.

$$\text{MCC} = \frac{(\text{TP} \times \text{TN} - \text{FP} \times \text{FN})}{\sqrt{(\text{TP} + \text{FP})(\text{TP} + \text{FN})(\text{TN} + \text{FP})(\text{TN} + \text{FN})}}. \tag{13}$$

4.10.5. Cohen Kappa Score. Kappa score will tell about how much agreement between observed agreement and expected agreement. In simple words, it tells how much the model is

better than a random classifier [73]. Table 4 indicates the interpretation of the kappa score output.

4.10.6. Brier Score. Brier score is a score function that shows the accuracy of the probabilistic prediction of the classifier. Brier score ranges from 0 (perfect prediction) to 1 (poor prediction) [5]. Brier score is obtained from the following equation:

$$\frac{1}{N}\sum_{t=1}^{N}\left(F_t - O_t\right)\wedge 2. \tag{14}$$

N = the number of items, F_t is the forecast probability, and O_t is the outcome.

4.10.7. The Expected Maximum Profit of the Customer Churn (EMPC). The EMPC measures the profitability of the model in churn prediction systems. It was first suggested by [74]. The function measures the model's profitability by considering accuracy, cost of retention, cost of contacting, and customer lifetime value (CLV). The higher rates indicate the best good classifier in churn prediction. So, it is widely used to measure the performance of churn prediction systems due to its business functionality. In this paper, the constant CLV (200) and cost of retention (10), and the cost of contact (1) are being used.

5. Proposed Method

The proposed method flowchart is shown in Figure 5. The proposed method is conducted in three steps:

Step 1. The aim is to find the best feature reduction method for further model implementation. First, data are uploaded, and preprocessing methods like cleaning and scaling are executed. Then, the feature reduction methods by considering light GBM as a baseline model are evaluated on the datasets. Finally, the best feature reduction method is chosen for further analysis.

Step 2. The aim here is to use the reduced feature datasets to train and test on the benchmarks models. The code is prepared, and the reduced feature dataset is utilized for comparing the results with the optimization model.

Step 3. It is the foremost step in this method. It incorporates optimizing the light GBM hyperparameters by genetic and Bayesian, then training on reduced features dataset and evaluating the test dataset each iteration. Then, the best results will be published after the completion of tuning algorithms. Furthermore, evaluation results will be compared to benchmark models. After that, the model results and influences of each feature on outputs are going to be presented. Finally, churners by their CLV for other marketing campaigns will be ranked.

Table 4: Kappa score interpretation.

Agreement interpretability	Kappa
Minor agreement	(0.01,0.20)
Reasonable agreement	(0.21,0.40)
Moderate agreement	(0.41,0.60)
Considerable agreement	(0.61,0.80)
Perfect agreement	(0.81,0.99)

5.1. Feature Reduction. The preprocessed dataset is composed of numerous features. Handling such enormous features causes high computational costs and storage space [75]. It is necessary to avoid this volume of features by feature reduction methods. Feature reduction methods can be categorized into two groups: dimensionality reduction and feature selection methods. In this study, we examined different popular approaches on datasets. Light GBM as a base learner will choose the best model. PCA uses principal components to reduce the feature numbers and map them on two or three eigenvectors. However, LDA uses the best discrimination line to separate. Moreover, T-SNE uses T distribution to find the best feature reduction line. Autoencoder uses a neural network approach to encode the features into some blocks and decode them to make those features again. It will update the weight results after each epoch. Autoencoder's structure is built by one neuron, and the encoded blocks will be used in the baseline models. However, the feature importance by Xgboost is different from other approaches. It identifies the ten most important features used to find churners in the rules of a decision tree structure.

5.2. Hyperparameter Tuning of Light GBM. The algorithm has implemented the Bayesian optimization. It conducts by determined iteration, and it updates the hyperparameters by considering the surrogate function and the chances of getting better accuracy. The genetic algorithms, as discussed, will choose the best hyperparameters based on the best parents mating and their offsprings. Regarding having optimum and efficient hyperparameters, this paper uses Bayesian and genetic optimizations. On the other hand, there are some other methods.

In comparison, they are not as fast as algorithms like Bayesian optimization and genetic algorithm. The model optimized six hyperparameters of boosting algorithms that these hyperparameters by few minutes for full model training in IBM. Besides the long duration of training by grid search, it wastes many resources of storage and computational space. So, it is not applicable for efficient software to use this method as a hyperparameter tuning. Although it is possible to use random search for time-efficiency, this method does not update the hyperparameters as informed as Bayesian and genetics do. Thus, the model may get a local optimum than more general optimums of hyperparameters. Random search works with different subsets of hyperparameters that are chosen in randomness. Therefore, it does not always make good predictions. Then it could not be reliable to use the random search for tuning the algorithm.

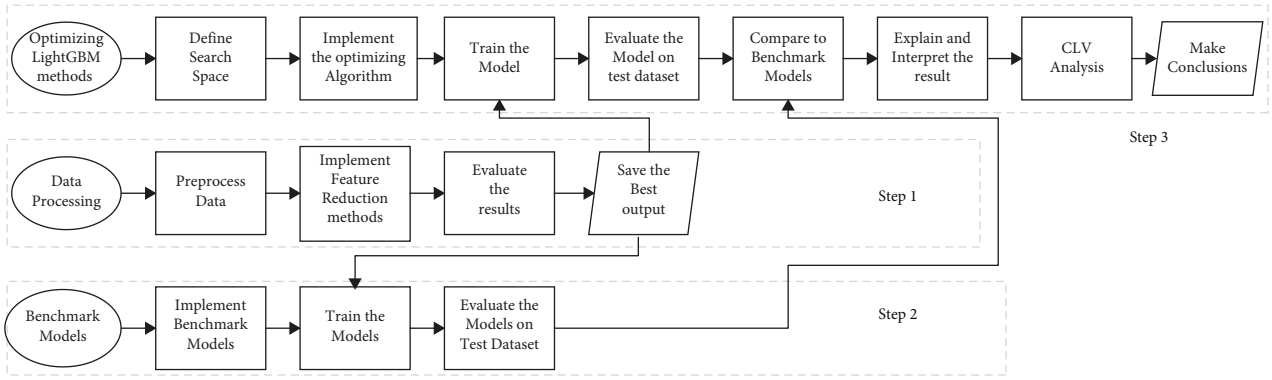

Figure 5: Flowchart of proposed method.

Also, it should be considered that grid search and random search are not optimization algorithms. They only use a subset of hyperparameters, but in genetic, it will update hyperparameters based on the merits of parents and their offspring in the genetic natural selection process. Bayesian optimization will update hyperparameters by their impact on the likelihood of better prediction by model training. As optimization and time-efficiency matter in churn prediction systems, the two optimization algorithms' Bayesian and genetic algorithms are conducted and compared together in this paper.

5.3. Benchmark Models. In order to evaluate the proposed model performance, it is compared to other ML models such as AdaBoost, support vector machine (SVM), decision tree (DT), light GBM, Xgboost, and random forest. These models are trained on the preprocessed and reduced features of the datasets and then evaluated on the testing dataset. Finally, the results of these methods are going to compare against the baseline model. The benchmark models are evaluated by 10-fold cross validation.

5.4. Model Explainability. According to the importance of churn prediction, it is essential to understand the model. There are so many features in datasets that are irrelevant or redundant. Therefore, many papers conduct feature importance analysis [74]. Also, SHAP is newly introduced for feature explanations. Shapely values are obtained by integrating concepts from game theory and local explanations. For each feature, the SHAP value explains the contribution to explain the difference between the average model prediction and the instance's actual prediction.

5.5. Customer Lifetime Value. In customer relationship management, customer lifetime value (CLV) is a critical measure. It may be used to enhance market segmentation and resource allocation, analyze competitors, personalize marketing communication, optimize product offering timing, and estimate a firm's market worth. The present value of all future cash flows from a client is the CLV [76].

5.6. Experiment. In this paper, the tuned light GBM churn prediction is considered as a baseline model. The model implementation can be divided into five main steps: collecting the dataset, data preprocessing, feature reduction conducted by evaluating five main approaches, and finally, hyperparameter tuning evaluation on baseline model and evaluating the model with other machine learning algorithms in churn prediction. Also, describing the model interpretation.

5.7. Datasets. The datasets used in this study are from 3 real datasets. They are utilized to verify the performance of the different approaches. IBM telecom (https://www.kaggle.com/blastchar/telco-customer-churn), bank customers (https://www.kaggle.com/santoshd3/bank-customers), and orange (https://www.kaggle.com/mnassrib/telecom-churn-datasets) datasets are downloaded from the Kaggle website. They have also been used in other papers. They have a different ratio of churners that show the highly imbalanced nature of the CCP problems. The summary of the datasets is presented in Table 5.

6. Results

6.1. Data Preprocessing. When dealing with real-world data, there is always the chance that it is imperfect, i.e., it may be noisy, have some missing values, or be inconsistent, and all these factors can lead to misleading results by the machine learning system. Therefore, improving the overall quality of the data will consequently improve the results. In order to do this, the categorical columns transfer into numerical using python libraries (LabelEncoder and get_dummies method of Pandas library). These libraries make the categorical columns into separate columns that each column is represented the individual category. Mathematically, this process could be represented as $1_A(x) = \begin{cases} 1; & \text{if } x \in A \\ 0; & \text{if } x \notin A \end{cases}$. For example, $A = \begin{bmatrix} A \\ B \\ C \end{bmatrix}$ will become $A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$. Thus, it only contains zero and one in each column that represents its category, for example, A, B, and C. So, the number of columns will be

Table 5: Data resources summary.

Dataset	Rows	Columns	Ratio of churners to whole dataset (%)
Bank Customer	10000	14	20.3
IBM Telecom	7043	21	26.5
Orange	3333	20	14.5

increased by two. Therefore, it makes the model training more time-consuming. So, more resources needed to compute these number of features. The amount of increase in features after preprocessing is shown in Table 6. Also, we conduct a standard scale for all columns and transfer them into a standard normal distribution. Therefore, the different scales of columns could not affect our datasets.

According to Table 7, there is an increase in the number of columns (dimensions) after using the processing method. It will be exacerbated by adding even one or two new categorical columns to this dataset. The data can be multiplied by the number of dimensions, so in actual use, it is necessary to create a reliable dimensional controlling channel that controls the number of features since only a small number of features are effective in the final result, and many features are extra [77]. Therefore, this number should be reduced automatically using known methods. In the next section, this issue will be discussed more. Also, dimensionality reduction makes it easier to visualize more significant features, which is advantageous for a better understanding of the data.

6.2. Feature Reduction Methods Evaluation. In order to find the best feature reduction method, the different algorithms have been adopted on the Light GBM classifier that shows the performance of each of them in Table 8. The results show feature selection based on Xgboost feature importance has higher achievement on all metrics. However, in the Bank dataset, it is a bit worse than LDA and Autoencoder. However, overall with considering two other datasets, the Xgboost has superiority. It enhances all the crucial metrics for accurately and meaningfully predicting the churners. As a result, the Xgboost feature selection will be selected in the following model implementation. At this stage, it is not necessary to compare methods based on their EMPC because the main reason for feature reduction is to enhance the model accuracy and computational speed.

One of the benefits of dimensional reduction, as mentioned, is the increase in computational speed. Table 8 illustrates this well before and after applying the dimension reduction by the method of feature importance of the Xgboost. Now suppose that a company's actual dataset will grow much more extensive over time, and as shown, as the data set grows larger in time or features are going to be added or changed, the need to increase speed and efficient use of resources and maintain the best accuracy increases. For example, the orange dataset has the highest speed improvement. Therefore, with time and also increasing the number of customers and features, there is an urgent need for methods to reduce and optimize features.

Table 6: Features amount before and after preprocessing.

Datasets	Features before preprocessing	Features after preprocessing	Ratio of increase (%)
Bank	14	20	142
IBM	21	33	157
Orange	20	71	355

6.3. Hyperparameter Tuning Implementation. Boosting algorithms are robust classifiers with many hyperparameters that require tuning. The model has been built for Bayesian and genetic tuning using the Google collab platform. The Hyperopt library has utilized the Bayesian optimization in python. It conducts by two hundred iterations. Because of the structure of TPE finding the local minimums, the minus value of accuracy calculates at each iteration. The genetic optimization uses eight parents. The number of parents mating is four, and also the generations will continue four times. The important boosting hyperparameters, such as learning rate and depth, and others have been considered in the model. Table 9 shows the different ranges of each hyperparameter of light GBM. In this paper, a range of 0.35 to 0.65 is considered as the threshold range. Usually, in the researches, it is placed on 0.5, but this paper took a more extensive scale.

6.4. Evaluation of the Result of Baselines and Benchmark Models. The evaluation metrics of customer chum prediction by different algorithms, including accuracy, AUC, MCC, Kappa score, Brier score, F1 score, and EMPC indicators, on the four datasets are shown in Tables 10–12. The results of all metrics are discussed below.

(1) Accuracy: In this metric in the bank dataset, the best accuracy belongs to Bayesian-based light. In the IBM dataset, the highest accuracy belongs to the Bayesian-based light GBM, with very little difference from the genetic-based light GBM. In orange, same as other experiments, Bayesian-based light GBM outperforms others. In all datasets, all the optimizer-based algorithms plus light GBM worked well together.

(2) AUC: The area under the curve is a good indication of an algorithm's power to identify all classes of a classification problem. In the orange and bank datasets, the genetics and Bayesian-based light GBM algorithms performed best, respectively. In the IBM dataset, genetic-based light GBM outperformed the Bayesian-based light GBM by a narrow margin of 0.0015. Also, Xgboost performed slightly better in this metric. According to Tables 10 to 12, all evaluations are in the sound and excellent range.

Table 7: Evaluation results of feature reduction methods.

Method	IBM Telecom	Bank Customer	Orange
PCA ($n = 3$)	Accuracy: 0.7923 AUC: 0.7026 MCC: 0.4481 Kappa_score: 0.4397 Brier_score: 0.2076 F1_score: 0.5730	Accuracy: 0.788 AUC: 0.5276 MCC: 0.1154 Kappa_score: 0.07888 Brier_score: 0.212 F1_score: 0.1396	Accuracy: 0.8110 AUC: 0.5036 MCC: 0.0101 Kappa_score: 0.0092 Brier_score: 0.1889 F1_score: 0.0999
PCA ($n = 4$)	Accuracy: 0.7889 AUC: 0.6971 MCC: 0.4377 Kappa_score: 0.4290 Brier_score: 0.2110 F1_score: 0.5640	Accuracy: 0.786 AUC: 0.5263 MCC: 0.1075 Kappa_score: 0.0749 Brier_score: 0.214 F1_score: 0.1384	Accuracy: 0.8080 AUC: 0.5018 MCC: 0.0051 Kappa_score: 0.0047 Brier_score: 0.1919 F1_score: 0.0985
PCA ($n = 5$)	Accuracy: 0.7889 AUC: 0.6990 MCC: 0.4392 Kappa_score: 0.4313 Brier_score: 0.2110 F1_score: 0.5670	Accuracy: 0.75 AUC: 0.5607 MCC: 0.1413 Kappa_score: 0.1375 Brier_score: 0.25 F1_score: 0.2824	Accuracy: 0.8035 AUC: 0.5168 MCC: 0.0417 Kappa_score: 0.0401 Brier_score: 0.1964 F1_score: 0.1437
LDA ($n = 2$)	Accuracy: 0.7906 AUC: 0.7046 MCC: 0.4466 Kappa_score: 0.4401 Brier_score: 0.2093 F1_score: 0.5760	Accuracy: 0.8604 AUC: 0.7237 MCC: 0.5297 Kappa_score: 0.5129 Brier_score: 0.1396 F1_score: 0.5927	Accuracy: 0.9505 AUC: 0.8438 MCC: 0.7842 Kappa_score: 0.7725 Brier_score: 0.0494 F1_score: 0.7999
t-SNE ($n = 3$)	Accuracy: 0.6387 AUC: 0.4684 MCC: −0.0842 Kappa_score: −0.0754 Brier_score: 0.3612 F1_score: 0.1143	Accuracy: 0.6944 AUC: 0.4864 MCC: −0.0305 Kappa_score: −0.0300 Brier_score: 0.3056 F1_score: 0.1511	Accuracy: 0.7361 AUC: 0.4862 MCC: −0.0261 Kappa_score: −0.0261 Brier_score: 0.2638 F1_score: 0.1287
Autoencoder	Accuracy: 0.7906 AUC: 0.7046 MCC: 0.4466 Kappa_score: 0.4401 Brier_score: 0.2093 F1_score: 0.5760	Accuracy: 0.8604 AUC: 0.7237 MCC: 0.5297 Kappa_score: 0.5129 Brier_score: 0.1396 F1_score: 0.5927	Accuracy: 0.9505 AUC: 0.8438 MCC: 0.7842 Kappa_score: 0.7725 Brier_score: 0.0494 F1_score: 0.7999
Feature Importances (features = 10)	Accuracy: 0.7969 AUC: 0.7152 MCC: 0.4658 Kappa_score: 0.4601 Brier_score: 0.2030 F1_score: 0.5929	Accuracy: 0.8548 AUC: 0.7223 MCC: 0.5139 Kappa_score: 0.5015 Brier_score: 0.1452 F1_score: 0.5860	Accuracy: 0.9505 AUC: 0.8614 MCC: 0.7861 Kappa_score: 0.7811 Brier_score: 0.0494 F1_score: 0.8092

Table 8: Computational speed before and after feature reduction.

Dataset	Computation speed before Feature reduction	Computation speed after Feature reduction	Improvement (%)
Bank	5 m 12 s	4 m 36 s	126
IBM	3 m 51 s	3 m 2 s	127
Orange	5 m 6 s	2 m 21 s	217

Table 9: Range and numbers of hyperparameters For Light GBM.

Hyperparameter	Range
Number of estimators	(150,300)
Max depth	(1,10)
Gamma	(0.01,9)
Cosample by tree	(0.01,1)
Subsample	(0.01,1)
Learning rate	(log(0.01),log(1))
Threshold	(0.35,0.65)

(3) MCC: Like AUC, it is a good indicator of the correct diagnosis of classification classes. In general, all algorithms based on genetics and Bayesian light GBM have achieved good results. However, in the bank dataset, light GBM did a bit better.

(4) Brier Score: This metric indicates that the prediction outputs strength, which Bayesian-based Light GBM performed the best in all datasets.

Table 10: Evaluation results in bank dataset.

Method	Accuracy	AUC	EMPC	MCC	Brier	Kappa	F1
BO-LightGBM	0.8688	0.7261	5.4771	0.5562	0.1312	0.5311	0.6038
GO-LightGBM	0.8624	0.6943	4.9208	0.5269	0.1376	0.4813	0.5509
Decision Tree	0.7936	0.6666	4.5939	0.3474	0.2064	0.3466	0.4745
Random forest	0.8412	0.7173	5.3804	0.479	0.1588	0.4734	0.5689
SVM	0.8548	0.6845	4.7804	0.496	0.1452	0.455	0.5291
Logistic regression	0.8332	0.6559	4.4109	0.4106	0.1668	0.3805	0.4674
Xgboost	0.8604	0.70733	5.1438	0.5224	0.1396	0.4938	0.5696
LightGBM	0.8604	0.7237	5.4526	0.5297	0.1396	0.5129	0.5927
Adaboost	0.8524	0.7044	5.1096	0.4966	0.1476	0.4764	0.5591

Table 11: Evaluation result of IBM dataset.

Method	Accuracy	AUC	EMPC	MCC	Brier	Kappa	F1
BO-LightGBM	0.8048	0.7132	8.5254	0.4793	0.1951	0.4677	0.5911
GO-LightGBM	0.8026	0.7147	8.5525	0.4758	0.1973	0.4666	0.5932
Decision tree	0.7645	0.6877	8.3582	0.3922	0.2354	0.3906	0.549
Random forest	0.765	0.6975	8.4663	0.4038	0.2349	0.4033	0.4033
SVM	0.7838	0.6729	8.1984	0.4101	0.2161	0.3915	0.3915
Logistic regression	0.7963	0.711	8.5276	0.4616	0.2036	0.4545	0.4545
Xgboost	0.8003	0.7182	8.6066	0.474	0.1996	0.4677	0.4677
LightGBM	0.7906	0.7046	8.4687	0.4466	0.2093	0.4401	0.4401
Adaboost	0.8026	0.7147	8.5525	0.4758	0.1973	0.4666	0.4666

Table 12: Evaluation result of orange dataset.

Method	Accuracy	AUC	EMPC	MCC	Kappa	Brier	F1
BO-LightGBM	0.958	0.8657	5.8275	0.8189	0.8097	0.0419	0.8333
GO-LightGBM	0.949	0.8649	5.7961	0.7809	0.7776	0.0509	0.8068
Decision tree	0.9265	0.8518	5.54872	0.7006	0.7005	0.0734	0.7434
Random forest	0.955	0.8596	5.7271	0.8052	0.7962	0.0449	0.8214
SVM	0.928	0.7649	4.2158	0.6732	0.6426	0.0719	0.68
Logistic regression	0.8575	0.5746	1.3099	0.2371	0.2037	0.1424	0.2635
Xgboost	0.949	0.8386	5.3913	0.7771	0.7644	0.0509	0.7926
LightGBM	0.9505	0.8438	5.4752	0.7842	0.7725	0.0494	0.7999
Adaboost	0.886	0.6746	2.7491	0.4512	0.4281	0.1139	0.4864

(5) Kappa Score: Kappa score means that the model is more meaningful than a random model. All algorithms based on optimizers have performed better. Bayesian-based Light GBM has better performance.

(6) F1-score: At the F1 score, similar to the results of the previous metric, the optimizers perform better overall.

(7) EMPC: The most important criterion for businesses is the estimator of the profitability of the created model. All optimizer-based algorithms have maximized profitability in boosting algorithms. This improvement reflects the excellent performance of optimizers with profitability. Bayesian-based light GBM achieved more in this metric except IBM that Xgboost achieved a slightly better result.

For better understanding of the best model, BO-light GBM Figures 6 to 8 show the ROC curve of each dataset. The AUC of the ROC curve is mentioned in the results tables.

The estimation of time complexities of the machine learning model is very difficult to consider. Especially, the proposed model is more complex by combining ML and optimization models. However, the execution time and parameters are mentioned to understand the model complexities better. All models incorporated 10 features due to

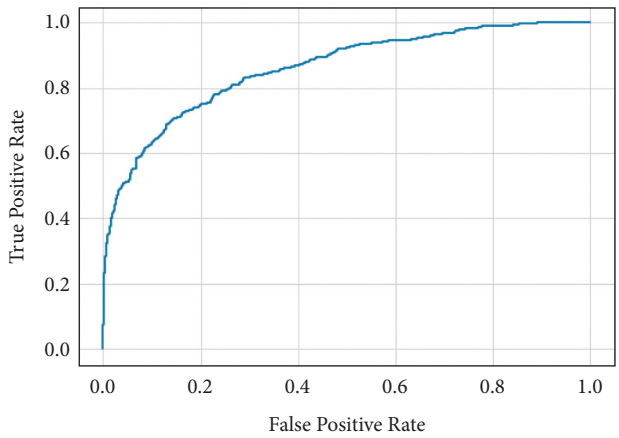

Figure 6: ROC curve IBM.

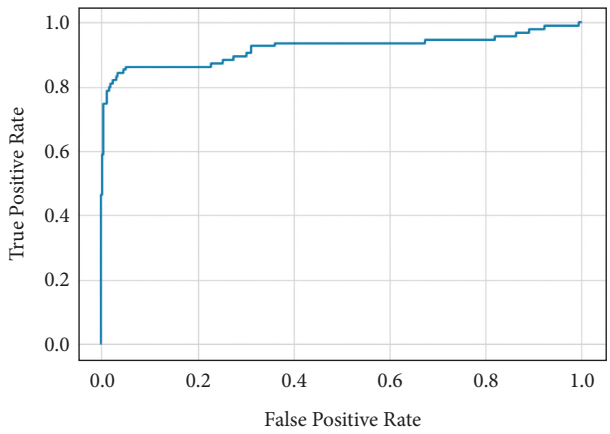

Figure 7: ROC curve orange.

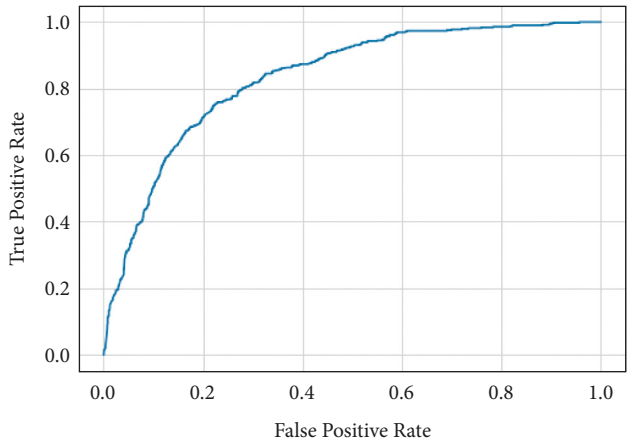

Figure 8: ROC curve bank.

the feature reduction methods that were implemented before this step (see Table 13).

6.5. Model Explainability. Light GBM constitutes regression trees. In Figure 9, the roles and branches of leaves of model implementation on bank datasets have been illustrated. It is split first by age and then uses the number of products count to split the churners. In the past, models were interpreted based on how features affected the machine learning models. Figure 9 shows how some features influence and play the most crucial role in separating tree branches, which can be a good indicator of the importance of features. For example, in the bank dataset, the number of products and user activity are essential features that can help decision-making. However, the SHAP model helps us take a more comprehensive look at the features and how they affect the model output. Model-independent SHAP is measured using embedded algorithms to analyze features' effect on the target variable (be churner or not). The horizontal line in Figure 10 shows the effect on the output, such as the probability of being a churner (target). Red and blue indicate the value of the desired feature, increase and decrease, respectively.

For example, for the IBM dataset (Figure 10), it can be interpreted that if one person has a month-to-month

Table 13: Samples and execution time.

Samples	Execution Time
10000	3 minutes and 21 seconds
7032	2 minutes and 51 seconds
2666	2 minutes and 23 seconds

contract value (value 1) is more likely to churn than other nonmonth to month contracts (value zero). The next item is the number of tenure years. The longer the contract, the less likely it is to churn, and vice versa, which logically dictates the same thing in mind. Therefore, this method enhances the interpretation of the boosting models well and makes more effective and accurate management decisions. Figure 11 also shows the SHAP summary of the orange dataset. Hence, there is much possibility for understanding the model, especially with boosting tree models light GBM. It helps managerial decisions be more productive and focused on customers by understanding their customer churn's underlying reasons.

6.6. CLV Analysis. After determining the fundamental causes of customer churn, marketing efforts should target those consumers with various offers such as discounts. Customer lifetime value, or CLV, is a valuable tool for estimating consumers' true values. CLV calculates the actual value of a company's customers [78]. According to Figure 12, the majority of customers have a low CLV. Targeting those clients raises marketing expenditures while providing little benefit to the firm. Targeting identified churners based on their real value to the organization improves performance and lowers the cost of marketing efforts.

In Figure 9, the CLV of churners is calculated by each customer's monthly charges multiplied by the company's gross margin. The company's gross margin is assumed to be 0.2. However, more data and company-specific metrics are required to compute true CLV.

7. Discussion

According to the result analysis, it is clear to distinguish that the Bayesian-based light GBM algorithm's prediction performance is best since it outperforms well in almost all metrics in all datasets, especially on imbalanced related metrics evaluation. The experimental results are concluded in four parts:

(1) All ensemble methods perform better in all metrics in all datasets. Bayesian-based light GBM outperforms mostly in all datasets.

(2) According to MCC and Brier scores, the BO and GO hyperparameter tuning makes the predictions more meaningful and better for imbalanced datasets.

(3) Other methods such as support vector machine, decision tree, random forest, and AdaBoost did not perform well. They were lower in all metrics than boosting algorithms, significantly light GBM optimized with optimizers.

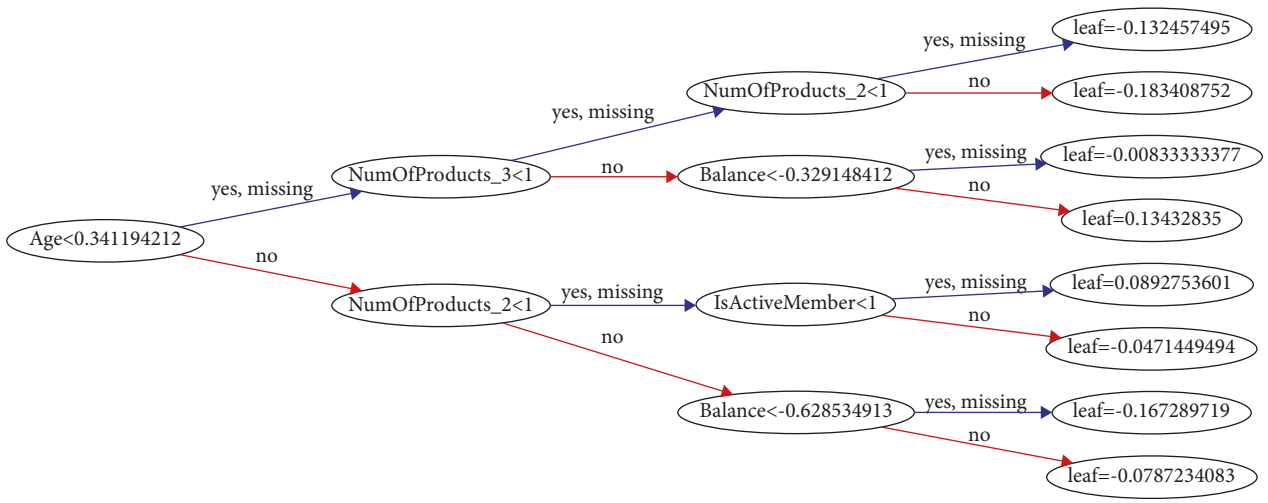

Figure 9: Tree chart of bank dataset.

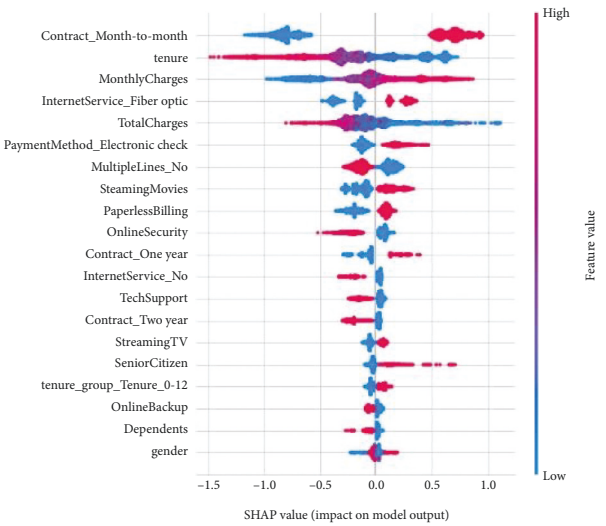

Figure 10: SHAP summary of IBM dataset.

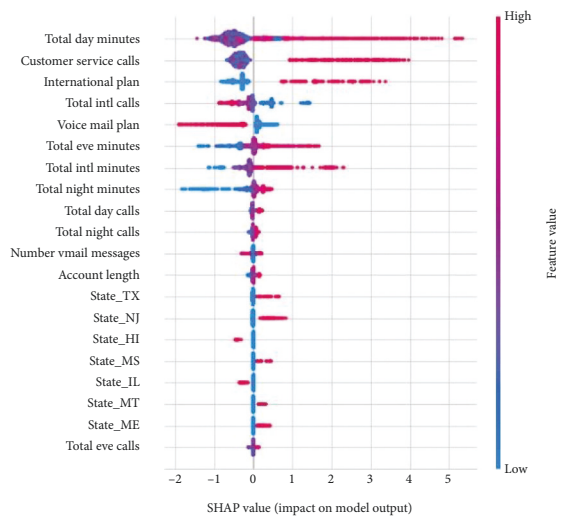

Figure 11: SHAP summary of orange dataset.

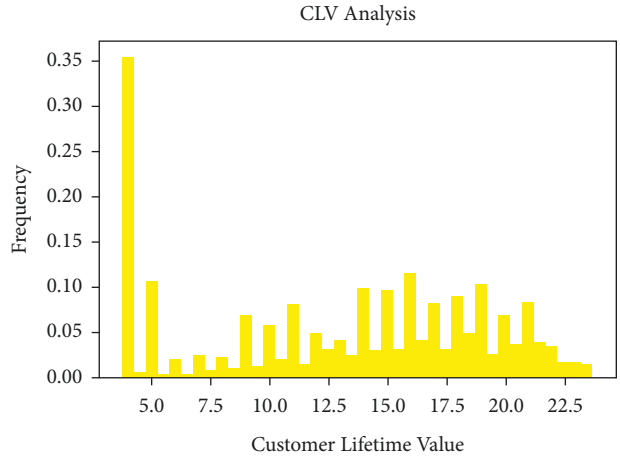

Figure 12: Ranking the IBM churners by CLV.

(4) Light GBM shows better results in imbalanced metrics and accuracy. Xgboost has slightly better AUC and EPMC in IBM datasets. However, the light GBM has better accuracy, brier score, and MCC in all datasets.

8. Conclusion

Given the importance of customer retention management in various businesses, including telecommunications, banking, insurance, and even online gaming, numerous studies have been conducted on predicting customer churn and the factors affecting it. This paper has implemented churn prediction systems, such as feature reduction and model selection, to compare various algorithms. However, there is a lack of concentration on ensemble methods implementation, especially the boosting methods like light GBM on CCP models. This paper focuses on enhancing the churn prediction models by the light GBM method and also hyperparameter tuning. The evaluation shows that the light GBM method obtains the best performances, especially when tuned by Bayesian optimization.

The results show that feature reduction effectively increases the speed and the important feature selection of the Xgboost algorithm has the best performance among feature reduction algorithms. Also, evaluating the algorithms on the datasets shows that the Bayesian-based light GBM is more successful and improves imbalanced evaluation metrics. Also, considering the computational speed, better prediction, and more profit in the business, the Bayesian-based light GBM method should be used over other ML and ensemble models. Furthermore, interpreting the results with SHAP helps the marketing team understand the underlying reasons for churn and helps them identify the customer's pain points better; also, targeting customers based on CLV and real value lowers marketing campaign costs and improves campaign performance. As a result, it leads to better-informed decision-making in client retention initiatives and tactics.

8.1. Limitations and Future Suggestions. For future studies, it is suggested studying the combination of more feature reduction methods like LDA and Autoencoder methods with ensemble learning. Other hyperparameter optimization algorithms can be implemented on light GBM in CCP models. One of the limitations of this study is the range of hyperparameters and the structure of hyperparameter tuning. It could be examined by other types, ranges, and structures to find the best-fitted model for the CCP problem. Also, the other limitation is the data structure. All datasets are comprised of structured inputs. It is highly recommended to use other unstructured data like text and images for future research, and therefore, the feature reduction methods will be more practical in this case. Also, it is worth measuring other marketing metrics and different methods in order to segment churners. It will be a broad research topic on how to handle churners after identifying them [78].

Data Availability

Data are available and can be provided over the emails querying directly to the author at the corresponding author (babakamiri@iust.ac.ir).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Three-Dimensional Teaching Method for Art Design Major from the Perspective of "Internet Economy"

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In view of the relevant teaching problems in the field of art and design, in order to study the teaching methods and contents of art design major from the perspective of the Internet economy, the evaluation indexes corresponding to the Internet are introduced into the partial least squares regression (PLS) path analysis model based on the relevant theoretical basis of the Internet. Through the method of model testing and relevant data analysis, the three-dimensional teaching method of art design is discussed, and the art design major is divided into five influencing factors, which are studied, respectively, according to the different influencing degrees. Finally, the model is verified by the experimental method, and the model is used to predict the three-dimensional teaching of art design from the perspective of Internet economy. The research shows that the overall proportion of economic strength remains between 70% and 90%, while the corresponding level of network design is relatively low. This study shows that the impact of economic strength research and related policies on the Internet economy is higher than the corresponding level of network design. Three-dimensional teaching occupies a dominant position in art design major. The proportion of network design and design frontier is relatively small, indicating that three-dimensional and information-based teaching can have a great impact on the art and design major from the perspective of the Internet. Different factors have different influences on art and design majors in Internet economy. The order of influence degree is innovation ability > design expression > design thinking. Based on the realization of Internet theory, this paper studies the three-dimensional teaching method of art design specialty, so as to provide a theoretical basis for the application and research of Internet in other fields.

1. Introduction

Internet economy has broad application prospects in different fields such as remote sensing data, ecological environment, social media, sharing economy and higher education: Halim Dareen and Samuel [1] proposed the Internet telemetry data center in view of the shortcomings of the Internet economy in the field of remote mapping. The data center can analyze the relevant data by using the algorithm of neural network model, so as to realize the application of the data in the field of Internet economy. The optimization model has the advantages of simplicity, high efficiency, and practicability. In order to further adjust and optimize the ecosystem, Jinil persis et al. [2] proposed a new optimization model based on the theory of Internet economy. The model adopts multidecision intelligent identification technology to find the optimal solution through intelligent analysis and evaluation of the obtained ecological environment data. To explore culture and social media in the context of the Internet vision, Maddox [3] proposed a social media operation model based on Internet economy. This mode adopts the computing method of Internet of Things cloud platform to achieve accurate push of social media. In this mode, users' browsing data are firstly summarized and imported into the cloud platform for analysis and calculation. Then, it can be divided into different types for output, and relevant content can be pushed through the analysis of Internet big data, so that relevant content can be analyzed and shared finally.

With the development of Internet economy, more and more fields have been integrated into the Internet economy. As a main content of Internet economy, sharing economy

has made a series of achievements in various fields, but it is worth explaining that sharing economy still has some problems under the effect of Internet. Akhmedova et al. [4] proposed a trust evaluation model based on the Internet economy to solve the problems existing in the sharing economy. The model converts problems existing in the sharing economy into signals of different sizes and determines the solution of corresponding problems by the strength of signals. In order to analyze the signals corresponding to the problem, related theories of sharing analysis are introduced on the basis of the original trust model, so as to obtain the corresponding trust optimization evaluation model under the effect of the Internet of Things. The coordinated development of higher education and Internet economy is global in a sense. Scientific understanding and accurate evaluation of the coordinated development of higher education and Internet economy is related to the macroscopic distribution of school education structure and the macroscopic guidance of industrial structure. In order to better evaluate the higher education under the Internet economy, Sun [5] proposed the evaluation model of the coordinated development of higher education based on the fuzzy neural network with the help of the Internet economy analysis platform. The model adopts the correlation calculation method of the fuzzy neural network to conduct quantitative analysis on the relevant influencing factors of higher education and obtains the influence degree under different indicators. It is defined as evaluation coefficient, and then the corresponding relationship between evaluation coefficient and Internet economy is studied. In this way, the evaluation system between Internet economy and higher education can be established. In order to study the application of Internet economy in the development of social group economy, Ridley Duff and Bull [6] provided a dichotomy model based on Internet economy theory. In order to maximize the role of social group economy in Internet economy, the model adopts resource allocation theory to divide social group economy twice. As a result, the solidarity economy will change to different degrees under the influence of the Internet economy.

There are a variety of teaching methods in the field of art design. The traditional teaching methods of art design are inconsistent with the reality and other related problems in talent training.

Jiang and Yang [7] proposed the new media interactive teaching concept and mode based on Internet economy in order to further solve the shortcomings and deficiencies in the field of art design. This concept is obtained by introducing the relevant theories of Internet economy into the art teaching model, which can more accurately describe and represent the problems existing in the field of art design. In the process of the development of art design, there often appear problems such as lack of professional personnel and weak theoretical foundation. Zhou [8] proposed that stylized teaching could be adopted in the classroom and practical activities of art design to further improve the application of Internet economy in the field of art design. This theory combines the contents of Internet economy and art design, which can well describe the art design under Internet economy. In view of the problems existing in the healthy development process of interdisciplinary art design, Atayero et al. [9] proposed an art-based model under the joint action of Internet economy and art and design profession. This model adopts the method of theoretical calculation to conduct quantitative analysis on the relevant factors of art design, which is introduced into the Internet economy, so as to find out the relevant models for optimizing art design.

In order to better study the development trend of the Internet economy, the development scale of the Internet in the past decade is summarized, as shown in Figure 1. The Internet shows rapid changes along with the timetable, because the development of high-tech industry promotes the development of the Internet to a certain extent.

The above studies mainly analyze the role of Internet economy in different fields, but there are relatively few studies on the art design under Internet economy. In order to study the application of Internet in art design major, based on the relevant theories of Internet economy, this paper adopts PLS path analysis model to conduct targeted analysis on the relevant content of art design. In addition, the three-dimensional teaching method is adopted to study and analyze the art design major from the perspective of the Internet economy. Finally, the optimization model is used to predict and analyze the relevant methods of art design major. This research can provide theoretical model and support for the application of Internet economy in other fields.

2. Basic Theory

2.1. Concepts Related to the Internet Economy. Internet economy is a general term for economic activities with Internet technology as the platform, network as the medium, and applied technological innovation as the core, and is the sum of economic activities generated based on the Internet [10–12]. Now, the Internet is very important to the economy, according to the Internet can control the direction of the economy. In addition to its significant impact on economic development, the Internet has fundamentally changed people's way of life. The Internet can solve the employment problem of countless people and increase the number of jobs. The Internet has changed the imbalance of the world's development. The birth of the Internet is an important milestone in the history of human development. The Internet will continue to have a profound impact on many aspects of human social life, as well as the economic development of the world. The overall distribution of Internet economy can be divided into three parts: network economy [13], e-commerce [14], and business model [15], which correspond to the three main components of the development of Internet economy. These three parts are realized by means of economic development, human resources, and economic structure, as shown in Figure 2.

It can be seen from the above research that the main influencing factors of Internet economy include the economic component of Internet, the policy orientation of Internet research, and the resource elements of Internet development. In order to more accurately explain the role of

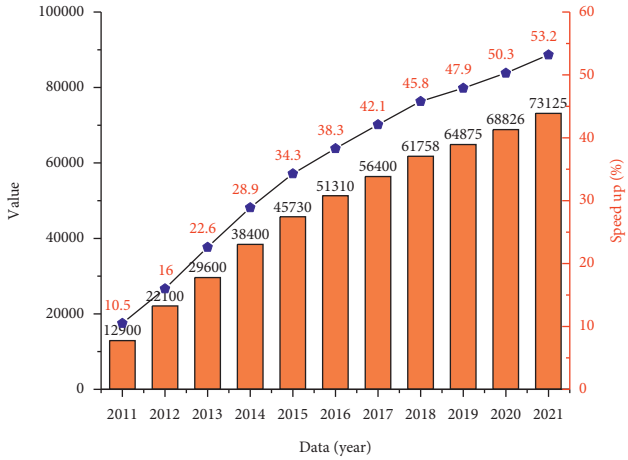

Figure 1: Internet scale map.

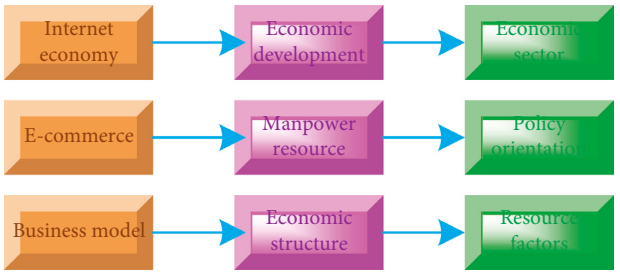

Figure 2: Internet economic distribution map.

Internet economy in life, the main types of Internet economy [16–18] are summarized, as shown in Table 1. E-commerce accounts for the largest proportion in the Internet economy, with e-commerce companies such as Tmall and JD Finance as the main part. Real-time communication accounts for 25%, including our commonly used QQ and Wechat. Internet finance and online games accounted for 17 percent and 16 percent, respectively, with products such as Alipay and League of Legends. Search engine accounts for the smallest, mainly including Baidu, Google, and other functions of the search software.

Internet economy has different forms of expression in different aspects of life, corresponding to different industrial structures [19, 20]. The main engines of integrated development of Internet come from three industries: the primary industry dominated by agriculture and animal husbandry; secondary industries, mainly including gas and electricity; the tertiary industry dominated by public services. The secondary industries also include water, construction, and manufacturing, which are closely related to people's lives. The corresponding tertiary industry includes market service, consumer service, and basic service, which are the supplement and foundation of public service (Figure 3).

2.2. Evaluation Model of Internet Economy. In order to better analyze the manifestations of Internet economy in different aspects, based on the previous analysis and evaluation of Internet economy, this paper uses principal component analysis [21] to build an empirical econometric model to measure the competitiveness of Internet economy, so as to evaluate the competitiveness of Internet economy in all aspects. According to different evaluation methods, Internet economy mainly includes economic strength evaluation, network facilities evaluation, human resources evaluation, e-commerce evaluation, and corresponding application evaluation, as shown in Figure 4. The evaluation of economic strength can be divided into economic environment, economic level, support of relevant policies, and corresponding policy level according to different relevant policies. Research on network facilities is the basis of Internet economy and the main research index of Internet economy, and the corresponding network facilities level includes information level, network level, and industry level. It is also worth explaining the human resources in the field of Internet economy. Relevant studies show [22, 23] that the development of Internet economy is closely related to the corresponding talent cultivation, indicating that the quality of talents, scientific and technological quality, teaching quality, and the level of human resources development are the main driving force of Internet economy.

In order to better analyze the evaluation indicators of Internet economy, the empirical econometric model is used to carry out relevant research. In general, if you have m samples, each sample has n indices $x_1, x_2, \ldots x_n$, they are integrated into Z comprehensive variables through principal component analysis:

$$\begin{cases} y_1 = a_{11}x_1 + a_{12}x_2 + \cdots a_{1n}x_n, \\ y_2 = a_{21}x_1 + a_{22}x_2 + \cdots a_{2n}x_n, \\ \cdots\cdots, \\ y_z = a_{z1}x_1 + a_{z2}x_2 + \cdots a_{zn}x_n, \end{cases} \tag{1}$$

where a_i is the model parameter. The variation relationship among parameters in formula (1) is as follows: $a_{k1}^2 + a_{k2}^2 + \cdots + a_{kn}^2 = 1$ $(k = 1, 2, \ldots, p)$. The number needs to satisfy three conditions: (1) y_i and y_j are independent; (2) find the corresponding correlation coefficient matrix; (3) work out the corresponding feature vectors.

The specific calculation steps are as follows:

(1) Standardized processing of original indicator data:

$$\begin{cases} X_{ij}' = \dfrac{x_{ij} - \overline{x}_j}{s_j}, \\ \overline{x}_j = \dfrac{1}{n}\displaystyle\sum_{i=1}^{m} x_{ij}, \qquad (i = 1, 2 \ldots; j = 1, 2 \ldots n), \\ s_j = \dfrac{1}{m-1}\displaystyle\sum_{i=1}^{m}\left(x_{ij} - \overline{x}_j\right). \end{cases} \tag{2}$$

Table 1: The type of Internet economy.

Serial number	Type	Ratio (%)	Illustrate
1	E-commerce	32	Tmall, JD.com, Amazon
2	Online finance	17	Alipay, JD Finance
3	Real-time communication	25	QQ, Wechat, Weibo
4	SE (search engine)	10	Baidu, Google, Bing
5	Online game	16	Honor of Kings, League of Legends

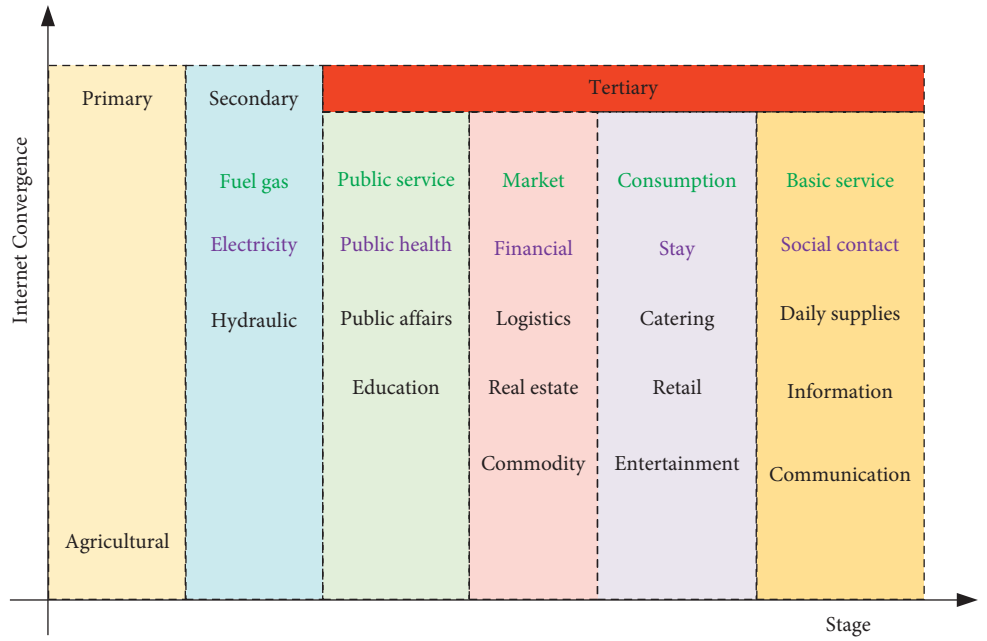

Figure 3: Internet convergence distribution map.

(2) The correlation coefficient matrix can be presented as

$$r = \begin{bmatrix} \beta_{11}\beta_{12}\cdots\beta_{1n} \\ \beta_{21}\beta_{22}\cdots\beta_{2n} \\ \vdots\ \vdots\ \vdots \\ \beta_{n1}\beta_{n2}\cdots\beta_{nn} \end{bmatrix}, \tag{3}$$

$$\beta_{ij} = \frac{\sum_{k=1}^{m} X'_{ki}X'_{kj}}{m-1}, \quad (i = 1, 2\ldots; j = 1, 2\ldots m).$$

(3) Z non-negative eigenvalues of the feature equation $c(i)$ are calculated by using the correlation coefficient matrix, and the corresponding eigenvectors of $c(i)$ are shown as follows:

$$c(i) = \left[c_1(i), c_2(i), {}_3(i)\ldots c_z(i)\right]. \tag{4}$$

(4) Major components of the Internet economy are selected, and define the proportion of the variance of the first v principal component to the total variance as η:

$$\eta = \frac{\sum_{i=1}^{v}\lambda_i}{\sum_{i=1}^{z}\lambda_i}. \tag{5}$$

It is generally believed that when $\eta \geq 0.85$, it is considered that the current v principal component basically retains the information of the original factor, so that the number of factors is reduced and a good screening effect is achieved. In order to make a detailed analysis of the variation trend of relevant industries in different Internet economies, the proportion chart of different economic indicators is drawn, as shown in Figure 5: relevant indicators include economic environment, economic level, economic policy, relevant policy level, corresponding information level, network level, and relevant industry level. Among them, the proportion of economic strength remains between 70% and 90%, while the corresponding level of network design is relatively low, about 40% to 60% as a whole. This study shows that economic strength and related policies have a greater impact on Internet economy than the corresponding level of network design.

3. PLS Path Analysis Model

In order to quantitatively analyze the proportion of Internet economy in related fields, partial least squares regression method is adopted to analyze the teaching methods of art design under Internet economy [24–26]. Partial least squares regression is a new multivariate statistical data analysis method, which mainly studies the regression modeling of

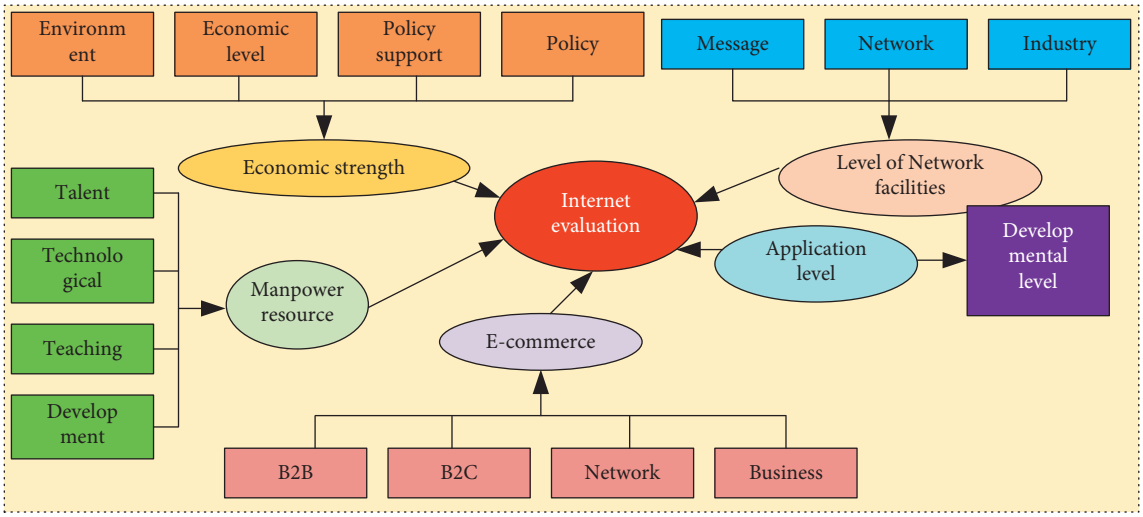

Figure 4: Evaluation chart of Internet economy.

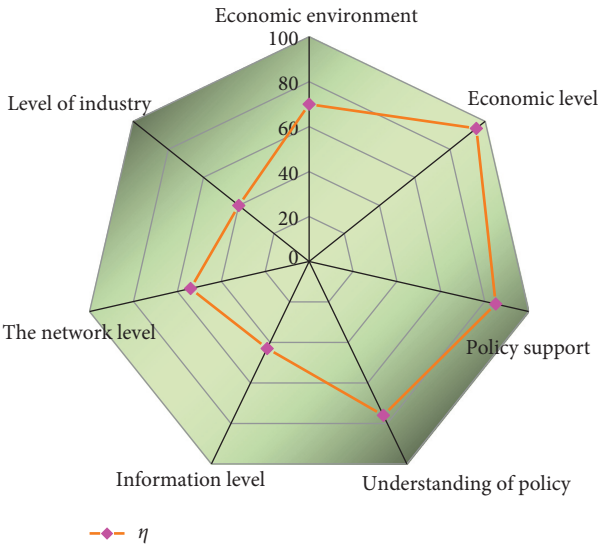

Figure 5: Proportion chart of different economic indicators.

multiple dependent variables to multiple independent variables. The partial least squares method is a combination of the advantages of principal component analysis, canonical correlation analysis, and multiple linear regression analysis [27, 28]. The path of the PLS model is shown in Figure 6. The relevant data collected by Internet economy are imported into the corresponding network society for corresponding data processing, and then the related content of data economy is fed back and studied through information economy. Then, the research content of information economy is checked through digital life, corresponding technical level and human resources. Finally, the calculation results of Internet economy in the PLS model are derived through relevant industrial structure.

3.1. Basic Theory of PLS Path Model. The main reasons for adopting the PLS analysis method in this paper are as follows: first, compared with other models, the assumptions of the PLS analysis method need not be so strict, and the requirements of sample data also obey the multivariate normal distribution. Second, PLS analysis can be used regardless of the size of the sample data. Third, the PSL analysis method can enlarge the original sample data by hundreds of times and then quickly converge, so that the same characteristics of the original sample data can be obtained in the new sample data. Fourthly, the PLS analysis method can not only measure the reflection indicator model but also measure the constituent indicator model. Before using the PLS path model to analyze the impact path for parameter estimation, model parameters need to be estimated and analyzed [29]. Before using the PLS path model to analyze the influence path and estimate parameters, it is necessary to assume that the information exchange between explicit variables is completed through latent variables, and the information transmission between latent variables is due to the adjacent relationship. PLS path model parameter estimation process is generally divided into two steps. First, the latent variables are estimated iteratively based on internal and external relations. Then, using the principal components of independent variables and dependent variables, PLS regression was performed. The PLS path model parameter estimation process is generally divided into following steps:

(1) Explicit variable centralization: assume that in k observation samples, each sample has n groups of measurable standardized explicit variables ξ. All latent variables and explicit variables are linear.

(2) External estimation: calculate the external estimation value of each potential variable, and calculate the potential variable γ_i. The corresponding formula is as follows:

$$\gamma_i^{t+1} = f_i^{t+1} \sum_{j=1}^{k} \pi_{ij}^t \xi_{ij}, \quad i = 1, 2, \ldots, n, \tag{6}$$

where π_{ij}^t is the external weight; f_i^{t+1} is the scalar weight. In formula (6), the latent variable γ_i is

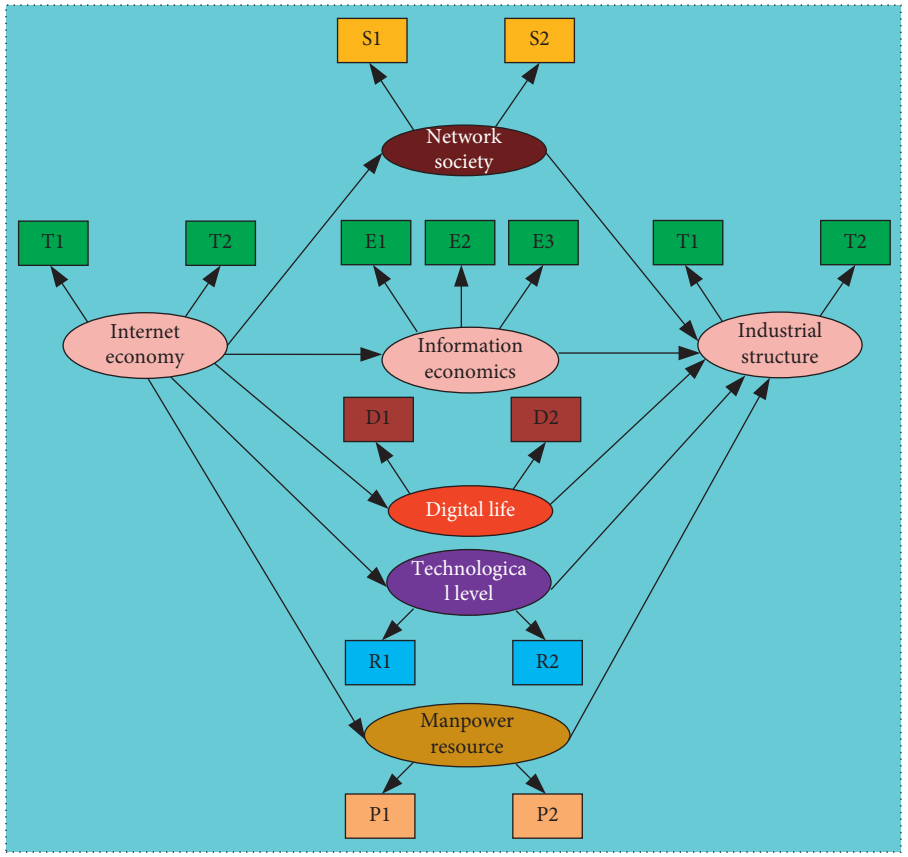

Figure 6: PLS model path diagram.

iterated t times to obtain its external estimate vector γ_i^{t+1}, whose variance is 1.

(3) Internal approximation: using relevant formulas to calculate the internal estimates of potential variables and calculate the internal weights,

$$\lambda_{k1k2} = \operatorname{sign}\left(r\left(\gamma_{k1}, \gamma_{k2}\right)\right) = \begin{cases} 1, & r\left(\gamma_{k1}, \gamma_{k2}\right) > 0, \\ 0, & r\left(\gamma_{k1}, \gamma_{k2}\right) = 0, \\ -1, & r\left(\gamma_{k1}, \gamma_{k2}\right) < 0, \end{cases} \tag{7}$$

where r is the matrix corresponding to the model.

Corresponding internal estimates

$$\overline{\gamma}_i^{t+1} = g_i^{t+1} \sum_a \lambda_{ia}^{t+1} \overline{X}_a^{t+1}, \tag{8}$$

where g_i^{t+1} is the internal weight of the scalar; λ_{ia}^{t+1} is the internal weight of the latent variable, $\overline{\gamma}_i^{t+1}$ is the vector of intrinsic estimates; $\overline{X}_a^{t+1}$ is the corresponding estimate vector.

(4) Weight estimation: the weight estimation equation of the measurement model corresponding to the reflection type is

$$\xi_{ij} = \pi^{t+1} \gamma_i^{t+1} + \varepsilon_{\zeta,ij}^{t+1}, \tag{9}$$

where ξ_{ij} is the weight estimation.

The weight estimation equation of the measurement model corresponding to the constitutive type is

$$\gamma_i = \sum_j \left(\pi_{ij}^{t+1} \zeta_{ij}\right) + \delta_{\gamma,i}^{t+1}, \tag{10}$$

where $\delta_{\gamma,i}^{t+1}$ is the parameter corresponding to the estimation function.

(5) The end condition is taken as the basis for judgment: after the end of each iteration, it is necessary to judge whether the iteration is over. The corresponding end condition of iteration is

$$\left|\pi_{ij}^t - \pi_{ij}^{t-1}\right| < 10^{-5}, \quad \text{or} \quad \left|\pi_{ij}^t - \pi_{ij}^{t-1}\right| < 10^{-5} \times \pi_{ij}^t, \tag{11}$$

where π_{ij}^t and π_{ij}^{t-1} are iterations.

(6) Calculate the value of latent variable, and the equation is as follows:

$$\gamma^T = \sum_{j=1}^{k} \left(\pi_{kj}^T \zeta_{ij}\right), \tag{12}$$

where T indicates the end of the iteration, and γ^T is the latent variable.

(7) Finally, load and path coefficients of variables are calculated, respectively.

The change relationship among weight, potential variable, and path coefficient calculated by using the above steps is shown in Figure 7. The weight coefficient shows a linear change with a slow increase in the number of iterations. When the number of iterations is 450, the coefficient rises rapidly, after which the curve still shows a linear change. The slope of the corresponding curve is higher than the linear change of the first stage, indicating that the increase of the number of iterations increases the growth rate of the weight coefficient. The potential variables show a typical two-step change: when the number of iterations is 450, it shows a linear increase, and when the number of iterations is 450, it shows a linear decrease. On the whole, the curve still shows increasing change. The corresponding curve was obtained by summarizing the relevant data of path coefficients. The curve showed a linear increase before the number of iterations was 450. When the number of iterations is 450, the curve rises rapidly. As the number of iterations continues to increase, the curve keeps an approximate constant trend. The research shows that the turning point of curve change is when the number of iterations is 450.

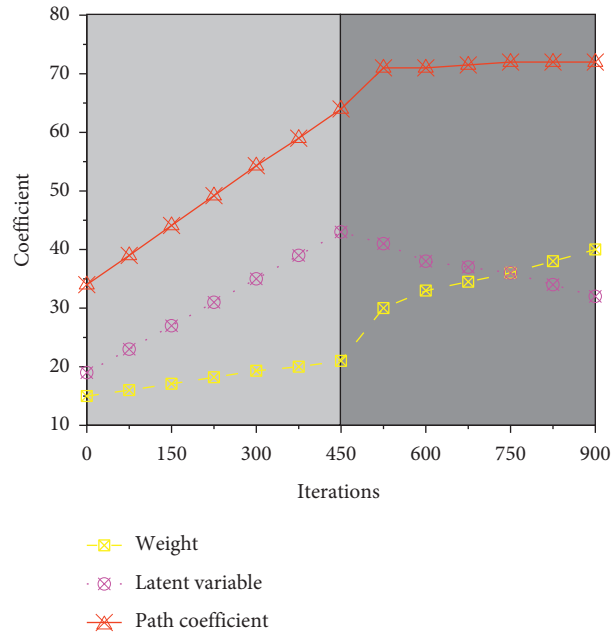

Figure 7: Diagram of variation of different coefficients.

3.2. Model Test. In order to verify the above models, reliability and validity tests were conducted.

(1) The so-called reliability test is to test the reliability or stability of index data in the measurement model, and judge whether the sample data are reliable from the test results. CR (compositereliability) and CA (Cronbach's Alpha) are two indexes of reliability test. The reliability test uses the sample data to make repeated measurements and observe whether the structure is consistent each time. The higher the test value, the more reliable the results.

The corresponding formula is as follows:

$$\mathrm{CR} = \frac{\left(\sum_k \lambda_i\right)^2}{\left[\left(\sum_k \lambda_i\right)^2 + \sum_k \left(1 - \lambda_i^2\right)\right]},$$
$$\mathrm{CA} = \frac{N}{N-1}\left[1 - \frac{\sum S_i^2}{S_t^2}\right], \tag{13}$$

where k represents the number of explicit variables in this latent variable, and λ_i represents the factor load of the i-th explicit variable in this latent variable. Generally, it is considered that if CR > 0.7, the model has high reliability. N represents the number of cross-sectional sample cities, S_i represents the variance of the i-th sample city data, and S_t represents the total variance of sample data. The main purpose of CA is to verify whether the sample is reliable at all times. Generally, it is considered that when CA > 0.7, the model has high reliability. When $0.5 < \mathrm{CA} < 0.7$, the reliability of the model is general and belongs to the acceptable range. When $0.4 < \mathrm{CA} < 0.5$, the model reliability is in the acceptable range. When CA < 0.4, the reliability of the model is poor and unacceptable.

(2) The validity test is to check the correlation degree of each obvious variable under the latent variable. The factor load value λ and AVE (average variance extracted) value in the result are the main indicators of validity test. λ_i is the factor load value of the i-th explicit variable in the latent variable. The judgment criterion is that when the factor load $\lambda_i > 0.5$, the relationship between the latent variable and its explicit variables meets linear equivalence, which is acceptable. If $\lambda_i < 0.5$, there is no linear equivalence relation between the latent variable and its explicit variables, which is unacceptable. For the AVE value, it is generally considered that AVE > 0.5:

$$\mathrm{AVE} = \frac{\sum_k \lambda_i^2}{\left[\sum_k \lambda_i^2 + \sum_k \left(1 - \lambda_i^2\right)\right]}. \tag{14}$$

The model testing method was adopted to calculate relevant indicators under the PLS path model, and relevant parameters of different indicators were obtained as shown in Table 2.

For more detailed analysis of the influence of the Internet economy, the Internet is divided into 15 secondary indexes and 7 first-level indicators, the first-level indicators include the following: the Internet economy, the development of network society, information economy, the numerical value of life, level of information technology, and the corresponding human resources investment and industrial structure adjustment and optimization. The corresponding

Table 2: Relevant parameters in the PLS path model.

Serial number	I	II	λ	CR	CA	AVE
1	Internet economy	Broadband Internet index	0.875	0.787	0.825	0.938
2		Mobile Internet index	0.894			
3	Network society	Affordability index	0.754	0.952	0.628	0.723
4		Social development index	0.943			
5	Information economics	Online government index	0.917	0.869	0.769	0.914
6		Development pattern index	0.736			
7		Economic development index	0.946			
8	Digital life	Mobile phone index	0.915	0.862	0.682	0.926
9		Computer index	0.836			
10	Technological level	Science input index	0.903	0.846	0.751	0.920
11		Investment index	0.846			
12	Human input	Education input index	0.612	0.706	0.615	0.864
13		Employment index	0.675			
14	Industrial structure	Proportion of tertiary industry	0.697	0.951	0.843	0.867
15		Ratio of tertiary industry to secondary industry	0.825			

inspection indicators are summarized and analyzed, as shown in Figure 8.

In Figure 8, the variation range of factor load value λ is 0.6–0.95, the corresponding variation range of CR is 0.70–0.96, the corresponding variation range of CA is 0.6–0.85, and the variation range of AVE is 0.7–0.94. The study shows that AVE and CR vary widely and the corresponding variation value is also high, indicating that the influence degree of these two parameters is obvious.

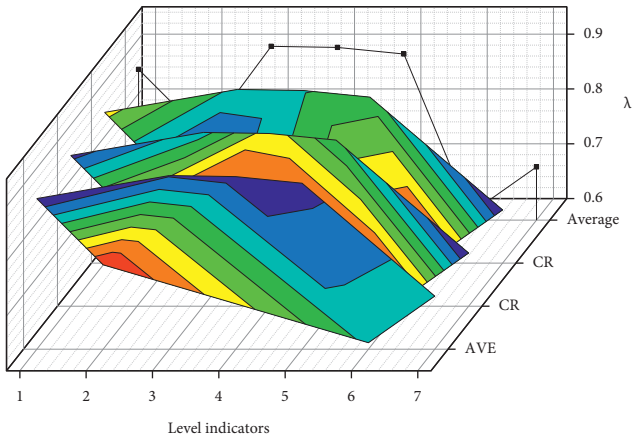

Figure 8: Analysis diagram of different parameters.

4. Teaching Methods of Internet in Art Design Majors

4.1. Major of Art Design. With the continuous development of technology, the Internet has become an indispensable part of people's daily life. In order to meet the needs of the society, art design majors need to carry out reforms. The reform of practical teaching in basic painting courses needs to be based on the application of network platform, design frontier dynamics, information teaching means, three-dimensional teaching and teaching plan, and other elements to make students develop the habit of collecting all kinds of knowledge through the network [30]. In order to better analyze the influence of different elements on art design majors from the perspective of Internet economy, the element analysis charts of different art design majors are summarized. It can be seen from Figure 9 that three-dimensional teaching occupies a dominant position in art design majors, accounting for about 40% of the overall proportion. Corresponding information teaching can also affect the development of art design major, accounting for about 28%. The proportion of network design and design front is relatively small, about 16% and 8%, respectively. Corresponding teaching programs accounted for the smallest proportion, only 6%. It shows that adopting three-dimensional and information-based teaching can have a great influence on the art design major from the perspective of Internet. At the same time, it also shows that the

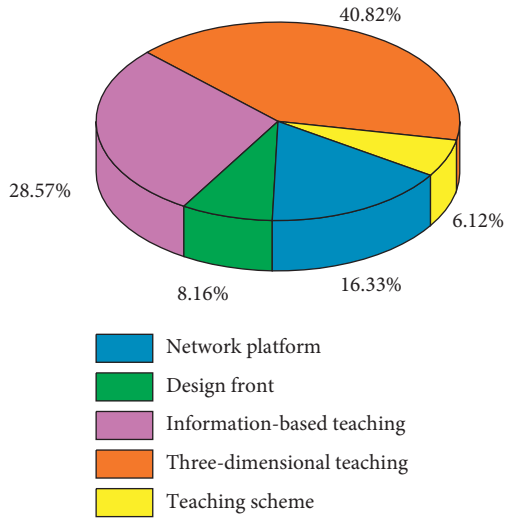

Figure 9: Different elements for art design majors.

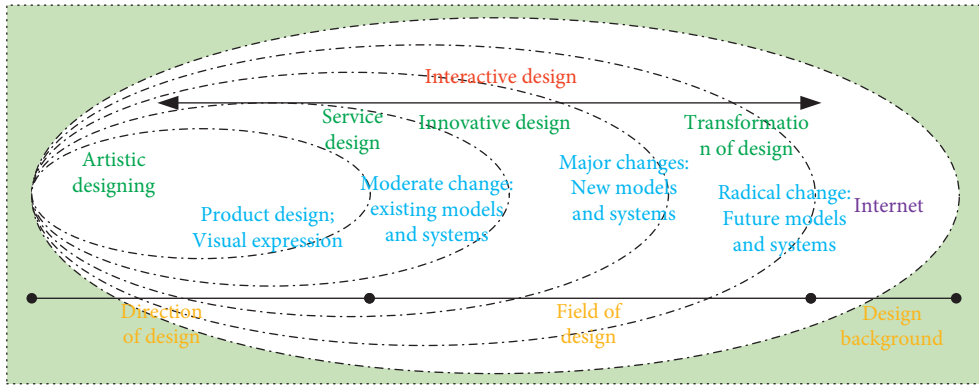

Figure 10: Art design teaching framework diagram.

description and analysis of art design can be better carried out from these two perspectives.

4.2. Improvement and Analysis of Teaching Methods. Based on the above analysis, the teaching framework of art design from the perspective of the Internet economy is obtained, as shown in Figure 10. The teaching framework of art design can be divided into four parts: art design, service design, innovative design, and transformation design, and different contents need to be carried out on the basis of the Internet. According to different design schemes, the obtained art design modes are also different, which can be expressed as follows. When there is no change, there will be visual expression of drinking. Moderate change will lead to the emergence of existing models and corresponding systems. Major Internet changes will make new models and systems replace the original models. Radical changes will make future models dominant in the field and profession of art design. Therefore, according to the different influence, the syllabus of art design can be divided into three parts: design direction, design field, and design background.

On the basis of the above research, aiming at the related problems of art design major from the perspective of Internet economy, the PLS model was adopted to carry out targeted research on three-dimensional teaching of art design. The summary of relevant research results is shown in Figure 11. Three-dimensional teaching of art design major can be divided into five aspects: research ability, innovation ability, design realization, design expression, and design thinking. The PLS model is used to carry out relevant calculation and inspection on the influence of different aspects of art design to obtain the corresponding calculation results. In order to express the relevant results vividly, the form of score and proportion is used to explain. 1–5 in the figure, respectively, represent the corresponding score. Among the different influencing factors, the overall score is 2, and the score of research ability is 5, which indicates that research ability has the lowest influence on art design major. The proportion of innovation ability, design expression, and design thinking are the same. It shows that innovation ability, design expression, and design thinking have great influence on art design major.

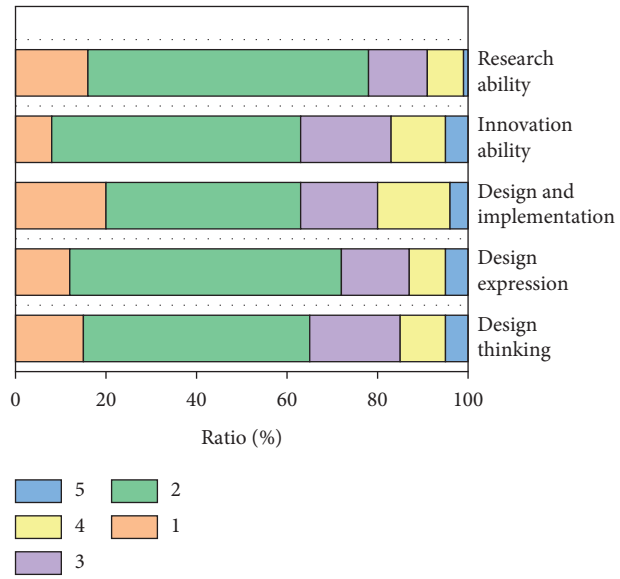

Figure 11: Art design professional ability score chart.

The above analysis shows that innovation ability, design expression, and design thinking are the influential factors of three-dimensional teaching in art design major under the background of Internet economy. In order to better analyze and predict the influence of these three factors, the PLS model is used to calculate and predict the three factors, and the results are shown in Figure 12.

It can be seen from the prediction chart of the influence degree of different factors on art design specialty that the changes of different factors are generally manifested as the change rule of quadratic function. It indicates that the relevant data of different factors conform to the change of quadratic function. As time goes on, the curve slowly rises to its maximum value and then slowly decreases, and eventually remains constant. The difference is that the maximum value and symmetry axis of the three factors are different, indicating that different factors have different impacts on the art design major in the Internet economy. The order of influence degree is innovation ability > design expression > design thinking.

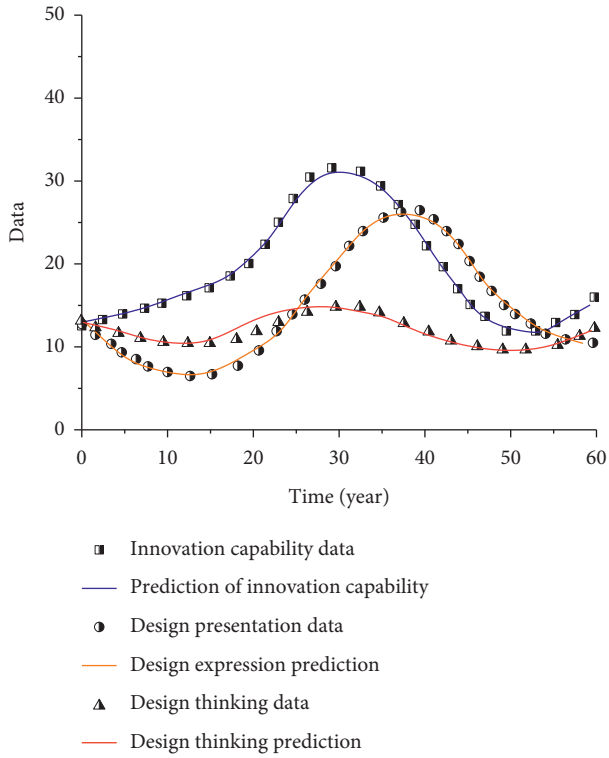

Figure 12: A predictive graph of the impact of different factors on the art design profession.

5. Conclusion

(1) With the increase of iteration times, the weight coefficient shows a trend of slow increase first, then rapid change, and finally linear increase. The potential variables show a typical two-stage change. The research shows that when the number of iterations is 450, it is the turning point of the curve change, so finding the optimal number of iterations of the path analysis model can further improve the accuracy of the model.

(2) The three-dimensional teaching of art design can be divided into five aspects: research ability, innovation ability, design realization, design expression, and design thinking. Among them, research ability has the lowest influence on art design major, while innovation ability, design expression, and design thinking have the greatest influence on art specialty.

(3) Through the calculation and analysis of different influencing factors by using the path analysis model, it is concluded that the corresponding influencing degree is innovation ability > design expression > design thinking, indicating that innovation ability has the greatest influence on artistic design.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Loosening of Access Threshold and Downturns in Listed Firms Performance: A Quasi-Natural Experiment from the "IPO Green Channel" for Poverty Alleviation

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The China Securities Regulatory Commission (CSRC) proposed the green channel policy for poverty alleviation Initial Public Offerings (IPOs), aiming to help poverty-stricken areas reduce poverty and increase income, but it has an impact on the business performance of the companies involved. This paper uses data from public annual reports of listed companies to construct a policy intervention group and a control group and comparatively analyzes the degree of annual performance downturn of newly listed companies in A-share from 2016 to 2017 through a counterfactual method, and the results show that the "IPO green channel" policy for poverty alleviation has an obvious negative effect on listed enterprises in poverty-stricken counties. The results show that enterprises listed via the green channel have more significant performance downturn than those listed normally during the same period. This paper suggests that the distortion of the market issuance system causes the declining of the quality of IPO firms. Finally, this paper suggests that regulators should cooperate with local governments actively to ensure the smooth implementation of the government's poverty alleviation efforts while balancing market equity and efficiency. The SFC should take more consideration of institutional compatibility for policy output in financial poverty alleviation to avoid institutional alienation and distortion of corporate behavior.

1. Introduction

Poverty is the primary problem faced by developing countries around the world, and China has made remarkable achievements and rich institutional innovations in the long-term process of benefiting and reducing poverty. In order to achieve the goal of comprehensive victory in the fight against poverty by 2020, the Chinese government has issued many policies to promote poverty alleviation. From early relief-type poverty alleviation to targeted poverty alleviation since 2013, the idea of poverty alleviation has been evolved; meanwhile, various government departments have actively adopted policies and measures within their own authority to help poverty-stricken areas develop. On September 9, 2016, the SFC issued the "*Opinions of the SFC on Playing the Role of Capital Market to Serve the National Strategy of Poverty Alleviation*" (hereinafter referred to as the "*Opinions*"), in which IPOs of enterprises in poverty-stricken areas enjoy special preferential treatment under the policy of "after reporting, the checking job will be immediately done and after checking, it will be immediately issued" (hereinafter referred to as the "IPO green channel" for poverty alleviation). According to the "*Opinions,*" in order to achieve the "IPO green channel" listing, if the enterprises under the jurisdiction of 832 impoverished counties across the country want to achieve the "IPO green channel" listing, they only need to meet any one of the following conditions in that year. (1) The place of registration or the place of main production and operation is classified as a poverty-stricken area, and it has local business and taxation records for three years. (2) In the last fiscal year, the local income tax is paid over 20 million yuan, and after listing, it promises not to

move out of poverty-stricken areas within three years. There is no doubt that the SFC's approach to speed up the pace of listing of enterprises in poverty-stricken counties by relaxing IOP regulation has raised high social concerns.

After the publication and implementation of the Opinions, 13 enterprises from poverty-stricken areas have been listed on the A-share main board market under the "IPO green channel" policy for poverty alleviation, and a total of 7.4 billion RMB has been raised in the capital market. In addition, 66 enterprises from poverty-stricken areas are further preparing for listing related work [1]. The "IPO green channel" policy for poverty alleviation has triggered dramatic social repercussions, and the theoretical circles also have different opinions. Listed enterprises in poverty-stricken areas are often scarce and are the backbone of local output and tax revenue. The original intention of the SFC to introduce this policy is to achieve the plan that listed enterprises in poverty-stricken areas can obtain better financial support through the capital market as soon as possible, improve their business performance, enhance their corporate governance, and develop and strengthen themselves so as to improve poverty alleviation and increase income in poverty-stricken counties. However, issuing and listing are still in the review and approval stage in China's securities market, and ordinary enterprises that plan to go public generally face a queuing period of 2-3 years after submitting their listing materials. The "IPO green channel" policy of SFC has faced fierce criticism, with many scholars questioning the quality of operations of companies listed in poverty-stricken areas and suggesting that there may be more problems for companies that are listed through the green channel unexpectedly. Policies can easily lead to adverse selection, which will make companies that can not succeed in the IPO queue turn to seek "IPO green channel" in poverty-stricken areas [2]. In addition, market fairness issues caused by the special treatment of IPOs have also been criticized widely.

It is because of the controversy that how about the late-stage business performance of companies, which go public quickly through the "IPO green channel," has become a hot issue in the society. From the perspective of the SFC's poverty alleviation policy implementer, this is related to the success or failure of the IPO policy for poverty alleviation; from the perspective of securities market supervision, this is related to the rigor and order fairness of the IPO system construction; from the perspective of listed companies, the distortion of institutional constraints will originate incentives of distort behavior; from the perspective of market participants, the special rule of "IPO green channel," which is closer to the registration system, will result in the adjustment of market valuation of the enterprises concerned. If the companies listed in the "IPO green channel" generally have serious performance changes, the emergence of the market for "lemons" will cause a phenomenon similar to the "Gresham," in which the bad money drives out the good money". And this phenomenon can lead to competition among listed firms and reduce the overall performance of the market.

Therefore, this paper attempts to adopt a potential outcome framework to assess the impact of the "IPO green channel" policy on the performance of enterprises listed through the "IPO green channel" in poverty-stricken counties. This paper demonstrated new proof of inefficiency performance, which was reduced by the finance market policy bias. In contrast, many present researches just focus on the exposure of inequity market standing of listed IPO firms. By examining the business indicators of the nine A-share main board-listed enterprises listed through the "IPO green channel" in 2016–2017 compared with those listed in the same period, it is found that the enterprises listed through the "IPO green channel" had a more obvious downturn than those listed through the normal IPO in the same period. Unlike previous studies, the marginal contributions of this paper are (1) differences-in-differences method, and a series of robustness tests are used in this paper to reveal the true characteristics of less performance of IPO companies in poverty-stricken counties, adding consolidation empirical evidence to the research in this aspect; (2) the study confirms that the loosened restriction arrangement of IPO policy has a stronger negative incentive mechanism, and the profits of companies listed through the "IPO green channel" for poverty alleviation have declined more than those of the listed firms in the same period.

2. Literature Review and Theoretical Discussion

2.1. Literature Review. There are lots of controversy of the theoretical analysis and research of the "IPO green channel" policy for poverty alleviation among domestic scholars. Some argue that the policy gives priority to supporting enterprises in poverty-stricken areas and encourages them to use capital market resources, that is, supporting capital to enter poverty-stricken areas [3]. IPO policy for poverty alleviation is conducive to accelerating the financing process of enterprises in poverty-stricken areas, absorbing their favorable resources to accommodate them; therefore, it can promote the economic development of poverty-stricken areas and coordinate the balanced development between regions [4]. Through the "IPO green channel" policy for poverty alleviation, enterprises in poverty-stricken areas have diversified their financing channels and expanded their financing scale in the capital market. In addition, the policy encourages high-quality enterprises to help enterprises in poverty-stricken areas and supports listed companies to purchase enterprises in these areas, so various resources will flow into the areas, which will promote local development [5]. Contrary to this view, some scholars think that this initiative may have an impact on the equity and efficiency of the securities market. The "IPO green channel" policy for poverty alleviation has prompted listed companies in poverty-stricken areas to enjoy the "super-national treatment" of the securities market issuance process, which actually constitutes eligibility discrimination for the group of enterprises in the long queue for IPO [6]. In the securities issuance market, there were as many as hundreds of companies queuing up for reviewing by the Issuance Examination Committee of the China Securities Regulatory Commission. A company has been queuing for a meeting since the IPO listing counseling period, which lasts for

several years, and the opportunity cost is huge [7]. Some companies even miss the opportunity of listing and withdraw from the IPO pending queuing sequence regretfully due to the high cost of IPO or fundamental changes in the market situation [8]. If the waiting period for IPO issuance approaches or even exceeds three years, some companies may eventually move to the fast track of relocating to poverty-stricken counties, which will lead to policy loopholes in the securities issuance market. Such policies can reduce market fairness and effectiveness when the cost of securities issuance fraud is low, the IPO registration system is not truly realized, and the chances of delisting of poorly listed companies are low [9].

Another study believes that "IPO green channel" policy is essentially an industrial guidance policy. The original intention of the SFC's policy is not only to help the stock of enterprises in poverty-stricken areas to go public, but also to open a policy window to guide some enterprises to relocate to poverty-stricken counties, so as to help the development of county economic and play a role in poverty alleviation. The formulation of these industrial policies is based on the view that as long as there are imperfections in the market mechanism and "market failures," it is necessary to give full play to the role of industrial policy [10]. The effectiveness of industrial policy is mainly reflected in whether the object of the policy can respond to the industrial policy. If the object of regulation does not respond to the industrial policy, it is difficult to say that the industrial policy is effective [11]. In emerging markets where government intervention is still prevalent, political capital does create value, and startups typically build political capital to facilitate their entry into the IPO market, but political capital does not bring further benefits to the post-IPO market [12]. Since the State Council promulgated the Outline of Industrial Policy and the Decision on the Main Points of Current Industrial Policy in 1989, a large number of industrial policies have been introduced and implemented in China over the years, but many of them have gradually been tested to be lack of effectiveness and even have negative effects on industrial development. Special IPO channels are a common tool for the SFC to favor policies for different regions, and before that, there were "IPO green channels" priority review for enterprises in Xinjiang and Tibet. The problem of relocating companies to list in poverty-stricken areas can, on the positive side, change the uneven distribution of listed companies and increase the number of listed companies in poverty-stricken areas, while on the negative side, it may have a negative impact on the future development of listed companies. For example, the company faces a new environment after relocation, and the infrastructure conditions in the poverty-stricken areas are relatively limited and unfriendly, which may affect the efficiency of the company. The "IPO green channel" can indeed save the time of queuing and reviewing compared with the normal listing of enterprises, but this phenomenon of "migration wave" should be considered rationally to avoid the phenomenon of "maladjustment" [13].

However, if the "IPO green channel" for poverty-stricken counties is regarded as an industrial policy, its own effectiveness is strongly questioned by academics. The new policy of industrial poverty alleviation is based on marketing means to promote poverty alleviation, which not only helps poverty-stricken counties form industrial chains and leading enterprises, but also helps establish a market mechanism to drive poverty-stricken areas out of poverty [14–15]. As the securities market environment keeps changing, and the relevant management system keeps improving, the effect of the "IPO green channel" policy for poverty alleviation may be weakened after its release [16]. The effect of industrial policy on equity and debt financing of listed companies proves that industrial policy is effective in the area of corporate finance, and the amount of equity and debt financing of listed companies supported by industrial policy is more than that of listed companies not supported by industrial policy [17]. By observing and sorting out industrial policies in different industries, it is found that for postindustrialized countries, although industrial policies can adequately promote leapfrog economic growth under specific conditions and at specific times, they gradually fail as markets to continue to mature as well as develop, and the role of market mechanisms in resource allocation is fully exploited [18, 19]. Additionally, for China, this change is more significant.

In summary, there are a lot of discussions on the "IPO green channel" policy for poverty alleviation. There are many academic disputes from the perspective of industrial poverty alleviation, regional development, market supervision, and corporate performance. However, most of the debates occur during the policy launch period, and the evaluation of the policy implementation effect is rare, and also empirical analysis is mainly used, while positive analysis rarely used. In addition, there is still a lack of comparative research on events at the listed company level regarding the impact of the "IPO green channel" policy for poverty alleviation in the securities market under the current domestic listing review system. The situation of profit management before listing and performance deterioration after listing has occurred in both China's and international securities markets. There is no convincing empirical evidence on whether the performance downturn after listing is different from that of IPO companies in the same period as companies listed through the "green channel" lack effective withdraw mechanisms under the environment of loosened listing supervision. Will such performance changes be exacerbated under the attempts of China's securities market regulatory authorities to alleviate poverty through IPOs? This paper attempts to answer this question through empirical quantitative analysis of the same history period.

2.2. Mechanism Exploration. The law of securities market for many years shows that a large number of companies have deteriorated performance before IPO issuance and during a financial period after IPO listing, which is manifested as a precipitous decline in ROA and ROE [20–22]. And this phenomenon is called "performance change" by secondary market participants. Studies at abroad have generally focused on the management of profits during the IPO counseling period of companies listed in the industry and

the question that leads to "performance changes" [22–25]. Satta et al. found that the long-term aftermarket performance of IPOs was poor through conducting an OLS regression analysis by using the long-term performance of IPOs in the seaport industry [26]. Falconieri et al. even noted that the impact of poor post-IPO performance is pervasive, which could lead to higher underpricing and lower valuation of newly listed companies in the market [27].

China's A-share market listing resources have become scarce due to the approval system, and the delisting companies are quite rare, which invisibly increases the responsibility of the market supervision department and also aggravates the "performance change" of listed companies. Under the approval system, all companies that are going to be listed must line up to pass the review of all the reviewed companies by the Issuance Examination Committee of the China Securities Regulatory Commission. And qualified companies obtain the endorsement of listing qualifications, forming the so-called "paternal love" [28]. Since listed companies are considered to have the invisible guarantee of the government because of the prelisting information quality and performance endorsement by the government regulator, there is a phenomenon of manipulating the performance of the listing counseling period through profit management to win "paternal love" for the company [29]. The direct consequence of this practice is that firms lose the incentive to manage their surplus after listing, which directly leads to performance collapse.

The limited market response to postregulation is a problem that the A-share market has been facing for a long time [30]. Therefore, under the strong supervision, the SFC has extended the queuing process of companies before listing, which has increased the cost of companies manipulating their earnings to obtain listing qualifications in terms of time span. Conventional research suggests that the waiting time for IPOs is longer under the approval system than under the registration system, and the "performance change" of that firm is more severe [31]. Because high profit levels are conducive to a high premium for IPO valuation, firms are generally eager to improve their pre-IPO valuation through profit management [32]. However, that firms hire issue counseling agencies to maintain a high profit manipulation for a longer period of time directly pushes up the indirect cost of the issue [33], and after the listing, it will inevitably lead to a compensatory downturn in the level of corporate profits. Also, the company's total assets will expand due to the expansion of the listing, while its net earnings per share performance decline significantly.

It is doubtful that the mechanism of "performance change" of listed companies in poverty-stricken counties skips the queuing process and goes directly through the "IPO green channel" for listing. One possibility is that companies listed through "IPO green channel" in poverty-stricken counties are expected to reduce profit manipulation and lower the degree of "performance changes." Because of the short time of profit management in the early stage of the through train listing, the indirect issuance cost of IPO companies is reduced, and theoretically, it is not easy to have a compensatory fall in profit after listing.

Accordingly, this paper proposes hypothesis 1a: the "IPO green channel" mitigates the performance downturn of listed firms in poverty-stricken areas.

At the same time, there is another possibility that the "IPO green channel" listing becomes an attempt to deregulate [34], which will attract a group of "secondary" companies that do not have average performance and have difficulty in the traditional IPO queue to choose to go public, thus triggering more serious "performance changes".

In summary, this paper proposes hypothesis 1b: the "IPO green channel" exacerbates the performance downturn of listed firms in poverty-stricken areas.

3. Research Design

3.1. Variable Descriptions and Data Sources. The study is done based on the specific approach of Zhang, Wang and Zhou [35], takes the A-share main board enterprises listed in 2016–2017 as the overall sample, and selects 9 enterprises listed through the "IPO green channel" as the treatment group, including 3 listed in 2016 and 6 listed in 2017. The other 596 enterprises were selected as the control group, of which 166 were listed after September 9, 2016, and 430 were listed in 2017. After excluding the samples with incomplete data, the firm-level unbalanced panel data for the period 2017–2020 for 556 samples are constituted. The data are mainly from the CMARS database, with some supplementary data from individual companies' public annual reports and the Straight Flush Finance Database. ROA, ROE, fixed assets ratio, quick ratio, current ratio, net value of inventory, total asset, and operating receipt are taken as observed variables. And for the sake of data stability, the variables using price as the unit are all adjusted with the constant value of RMB in 2016 to perform CPI reduction and logarithmic processing.

3.1.1. Policy Variables. This paper sets whether to go public through the "IPO green channel" for poverty alleviation as the policy variable, for example, if the enterprise that is listed through the "IPO green channel" is set as 1, while other listed enterprises of the same batch are set as 0.

3.1.2. Control Variables. Fixed assets ratio, quick ratio, current ratio, net value of inventory, total assets, and operating income are used as control variables in this paper. These indicators are all financial indicators, among which fixed assets ratio is used to examine whether the company has idle funds. According to the aspect of the company's operating capacity, the higher the fixed assets ratio is, the weaker the operating capacity is. The quick ratio and current ratio indicate the company's solvency, and if they are lower, the company's short-term solvency is weaker. The net value of inventory indicates the net realizable value of the company's inventory, which also reflects the company's profitability. Total assets represent the total assets of the company. Operating income indicates the income from main business and other businesses of the company. These financial indicators are used to indicate the operating ability of

enterprises, so they are selected to measure the operating ability of enterprises listed through the "IPO green channel" and normal listed enterprises.

3.1.3. Outcome Variables. In this paper, the return on assets and return on net assets are used as outcome variables. The return on assets is an important indicator of the profitability of an enterprise, and if the return on assets is higher, it indicates that the profitability of the enterprise is higher. The return on net assets indicates the efficiency of capital use and is generally used to analyze the profitability of an enterprise. Using the return on assets and the return on net assets as the outcome variables in this paper, the impact of IPO green channel policy on enterprise performance and the effectiveness of pro-poor "IPO green channel" policy can be analyzed more accurately.

3.2. Research Ideas. For the sake of completeness and validity of the sample data, this paper tries to compare the business indicators of enterprises listed through the IPO green channel on the A-share main board from 2016 to 2017 with those of other enterprises listed in the same batch, because the policy requirement of "IPO green channel" in poverty-stricken counties may lead enterprises to relocate to poverty-stricken counties for three years to seek green channel listing. From 2016 to 2017, a total of nine enterprises from poverty-stricken areas were listed on the A-share main board through the "IPO green channel." This paper takes "IPO green channel" policy for poverty alleviation as a quasi-natural experiment and will use the differences-in-differences (differences-in-differences) method to examine the impact of the IPO green channel policy on corporate performance and the effectiveness of "IPO green channel" policy for poverty alleviation. The study uses a multiphase differences-in-differences method to conduct a counterfactual study by selecting nine A-share main board firms listed through the "IPO green channel" as the treatment group and other A-share main board firms listed in the same batch as the control group. The reliability of the results is then further verified by replacing the outcome variable, replacing the estimation method, and replacing the counterfactual method with a series of robustness tests.

3.3. Measurement Model Setting. According to the model setting of differences-in-differences method, the econometric model of this paper is as follows:

$$Y_{it} = \beta_0 + \beta_1 P_i + \beta_2 T_t + \beta_3 \left(P_i \times T_t\right) + \theta X_{it} + \mu_t + \lambda_i + \varepsilon_{it}. \tag{1}$$

In this formula, Y_{it} represents the effectiveness of the explained variable "IPO green channel" policy, i denotes the sample firms, and t refers to time. P_i represents the treatment group dummy variable representing whether the sample enterprises participate in the "IPO green channel" for poverty alleviation. If the company is listed through the "IPO green channel," it is set to 1, and other companies in the same batch are set to 0. T_t denotes the time dummy variable, and since the "IPO green channel" policy for poverty alleviation was proposed in 2016, T_t is set to 0 for the year 2016 and before, and 1 for the year after 2016. $P_i \times T_t$ is the interaction term between the variables in the treatment group and the time dummy variable after the implementation of the "IPO green channel" policy. X_{it} represents the vector set of control variables, and the control variables in this paper include fixed asset ratio, quick ratio, current ratio, net value of inventory, total assets, and operating income. θ is the coefficient of control variables. μ_t refers to time fixed effects, λ_i represents individual fixed effects, and ε_{it} is the random disturbance term.

4. Empirical Analysis

4.1. Baseline Regression. This paper uses differences-in-differences method to estimate the impact of "IPO green channel" policy for poverty alleviation on firm performance. Table 1 shows the benchmark regression results, in which model 1 and model 2, respectively, represent the effect of policy intervention on return on assets without control variables and with control variables; model 3 and model 4, respectively, show that the return on net assets without control variables and the return on net assets with control variables are affected by policy intervention. The results show that, under the four models, ROA and ROE are significantly negative in response to "IPO green channel" policy, and the average processing effect coefficients of corporate performance are −6.216, −3.690, −12.558 and −8.756. That these results are all significant at the 1% level indicates that the implementation of the "IPO green channel" obviously reduces the business performance of enterprises, which explained that the enterprises listed through the "IPO green channel" have a more significant downturn in performance than the normal IPO enterprises during the same period. From the regression results, the return on net assets in model 3 and model 4 is more likely to be influenced by the "IPO green channel" policy for poverty alleviation. ROE is considered as the ratio of net profit to net assets. A decrease in ROE indicates a decrease in net profit or an increase in net assets. This means that the company's performance declines after going public through the "IPO green channel," and the net profit decreases or the net assets increases, resulting in a change in the company's performance. Therefore, hypothesis 1a is falsified, and hypothesis 1b holds that the pro-poor "IPO green channel" increases the performance collapse effect of enterprises listed through this opportunity.

As shown in Table 1, the effects of fixed assets ratio, quick ratio, net value of inventory, and total assets are all obviously negative. It can be seen that, in order to enjoy the policy bonus of "IPO green channel," the enterprise in question has a stronger incentive to whitewash its previous performance statements to meet the criteria for listing and meet the purpose of listing. In fact, the "IPO green channel" policy is used to reduce the listing queuing time and raise capital, while that whether the enterprise can help poverty-stricken areas out of poverty is unknown, which is contrary to the original intention of the "IPO green channel" for poverty

Table 1: Baseline regression results.

Variables	Model 1 *ROA*	Model 2 *ROA*	Model 3 *ROE*	Model 4 *ROE*
$P_i \times T_t$	−6.216***	−3.690***	−12.558***	−8.756***
	(1.362)	(1.219)	(2.662)	(2.508)
Fixed assets ratio		−0.103***		−0.168***
		(0.014)		(0.029)
Current ratio		0.015***		0.003
		(0.003)		(0.006)
Quick ratio		−0.020***		−0.011
		(0.004)		(0.007)
Net value of inventory		−1.529***		−1.903*
		(0.498)		(1.025)
Total assets		−11.968***		−19.639***
		(0.653)		(1.344)
Operating revenue		11.175***		18.379***
		(0.866)		(1.783)
Constant	7.511***	27.357***	12.184***	40.961***
	(0.185)	(3.510)	(0.361)	(7.223)
Sample fixed	Fixed	Fixed	Fixed	Fixed
Time fixed	Fixed	Fixed	Fixed	Fixed
Observations	3, 451	3, 261	3, 451	3, 261
R-squared	0.198	0.355	0.247	0.342
Number of id	556	534	556	534

Note. ***, **, and * indicate, respectively, significance at the 1%, 5%, and 10% levels. The t-values are in parentheses.

alleviation. From the postlisting performance, the business performance and operational strength of these enterprises are far below the listing standards. After controlling for the reduction of fixed assets ratio, quick ratio, net value of inventory, and total assets, the performance of enterprises in the intervention group declines significantly. To sum up, the initial intention of the SFC is good, but it is necessary to strictly follow the listing standards to avoid policy speculation in the "IPO green channel" for poverty alleviation.

4.2. Robustness Test

4.2.1. Replacement of Result Variables. Taking robustness into consideration, two result variables are selected in this paper, namely, the return on assets and return on net assets, and these two variables are replaced to avoid the contingency of empirical results. As shown in Table 1, when the return on net assets is used as a result variable, policy intervention has a significant negative effect, which verifies the robustness of the benchmark regression results.

4.2.2. Replacement of the Model Estimation Method. The differences-in-differences method is based on the premise that the trends of the treatment group and control groups share the same trend before the implementation of the policy; namely, if there is no "IPO green channel" policy for poverty alleviation, there is no significant difference in the trends of listed enterprises in poverty-stricken areas and those in other areas over time. At this point, the differences-in-differences method may not be able to fully prove it, and the above benchmark regression results are not reliable if the performance of the "IPO green channel" companies is lower than that of other companies in the same period before the implementation of the policy. Therefore, in order to eliminate the sample active selection bias of the listed enterprises through "IPO green channel," improve the comparability of the two groups, and avoid the error of the treatment and control groups in the trend of changes before the implementation of the policy, this paper uses the PSM-DID to replace the benchmark differences-in-differences for robustness test. Based on matching estimators, the basic idea of PSM-DID is to find neighboring enterprises with similar characteristic variables among other enterprises listed in the same batch, so that the observable variables of the enterprise and those listed through "IPO green channel" policy for poverty alleviation can be matched, and thus the two can be compared with each other.

The results from PSM-differences-in-differences estimation are presented in Table 2. The PSM-differences-in-differences coefficients of models 5 to 8 are significantly negative, which are consistent with the results of benchmark differences-in-differences. The only difference is that the return on equity estimated by PSM-differences-in-differences model is more affected by policy. The above regression results test that the "IPO green channel" policy for poverty alleviation has a significant negative effect on the performance of the enterprises involved, which is listed through "IPO green channel" policy for poverty alleviation.

4.2.3. Replacement of Counterfactual Method—SCM. To further verify the robustness of the empirical results and to avoid the performance of individual samples affecting the significance of the whole intervention group, this paper replaces the counterfactual estimation method with synthetic control method to estimate the test for a single enterprise sample. Two enterprises listed through the "IPO green channel" in 2016, namely, Gaozheng Explosive and Emin Pharma, and two enterprises listed through the "IPO

Table 2: Regression results based on PSM-DID.

Variables	Model 5 *ROA*	Model 6 *ROA*	Model 7 *ROE*	Model 8 *ROE*
$P_i \times T_t$	−4.353**	−2.465*	−10.717***	−7.758**
	(1.791)	(1.471)	(3.374)	(3.067)
Fixed assets ratio		−0.033		−0.087
		(0.026)		(0.054)
Current ratio		0.085***		0.057
		(0.030)		(0.062)
Quick ratio		−0.090***		−0.065
		(0.031)		(0.064)
Net value of inventory		0.348		0.691
		(0.778)		(1.622)
Total assets		−9.852***		−17.788***
		(1.443)		(3.009)
Operating revenue		5.084**		8.986**
		(1.974)		(4.115)
Constant	8.364***	38.128***	13.417***	70.286***
	(0.393)	(8.457)	(0.740)	(17.635)
Observations	907	822	907	822
R-squared	0.165	0.287	0.231	0.307
Number of id	233	223	233	223

Note. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The t-values are in parentheses.

green channel" in 2017, namely, Xinjiang Torch and Huabao Oil and Gas, are selected for the study. Among them, Gaozheng Explosive and Xinjiang Torch belong to heavy industry enterprises, and Emin Pharma and Huabao Oil and Gas belong to light industry enterprises. The enterprises in different years are selected to avoid time and other instabilities; different industries are selected to avoid the particularity of the same industry, which would influence the experimental results. Therefore, the selection of these four enterprises can better reflect the effectiveness of the "IPO green channel" policy.

In this paper, the control group enterprises, which are not listed through the "IPO green channel" policy, are regarded as the counterfactual substitution of the treatment group enterprises through the "IPO green channel" policy in the synthetic control method with ROA as the outcome variable. The results of the study are shown below. Figures 1–3 all reflect that the trends of the treatment group and the control group basically share the same trends before the enterprises are listed through the "IPO green channel," but after the implementation of the policy, the curve of the treatment group drops sharply, and there is a significant gap with the control group, and the policy has a negative effect. This indicates that the performance of enterprises listed through the "IPO green channel" is far inferior to that of enterprises listed through the normal channel and that these enterprises have changed their performance after being listed through the policy, which further questions the effectiveness of the "IPO green channel." Contrary to the results of the previous three figures, the performance of Huabao Oil and Gas has improved after being listed through the "IPO green channel" (Figure 4). In the figure, the solid line shows the actual ROA of the "IPO green channel" listed firms, and the dash line shows the counterfactual targets. The SCM results show the differences between synthesis control term and actual term.

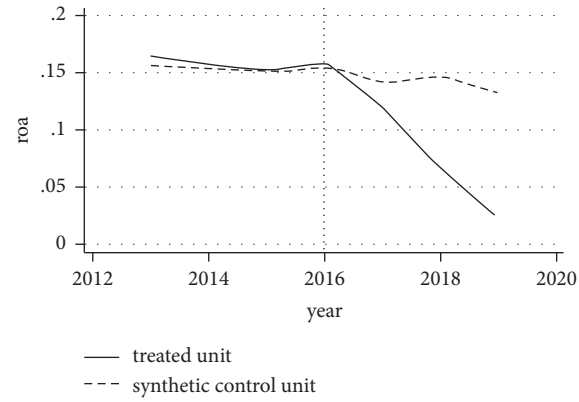

Figure 1: ROA figure of Gaozheng explosive. Note: Gaozheng explosive was listed through the "IPO green channel" for poverty alleviation in 2016, and the development trends of the treatment group and control groups were basically the same before the IPO policy for poverty alleviation was proposed in 2016, and there was a change by the time the policy occurred in 2016, with a sharp decline trend in the treatment group fold and a flattening trend in the control group fold. There is a large difference between the two (the figure is directly exported by Stata software).

Although there are exceptions, most of the results indicate that the "IPO green channel" has led to a decline in performance, which is consistent with the above empirical regression results and further verifies the robustness of the empirical results.

4.3. Mechanism Analysis. The previous paper can adequately verify that "IPO green channel" policy for poverty alleviation has a negative effect on the listed enterprises in poverty-stricken areas through the benchmark regression and further robustness tests. However, the specific mechanism of "IPO green channel" policy for poverty alleviation that leads to the

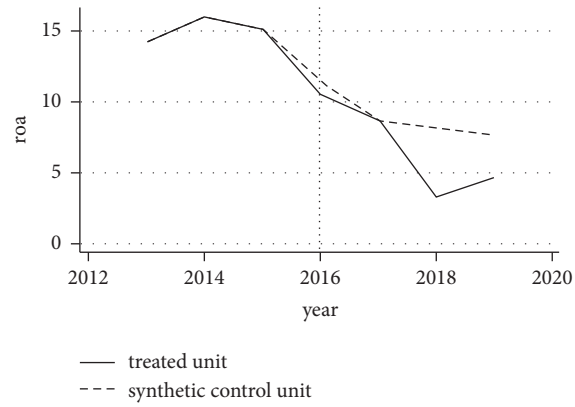

Figure 2: ROA figure of Yiming pharma. Note: Yiming pharma was successfully listed in Tibet through this policy in 2016. The trend of treatment group and control groups was basically the same before the occurrence of the policy in 2016. After 2016, both treatment group and control group showed a significant downward trend, but the decline of treatment group was more drastic and the gap between them was getting bigger (the figure is directly exported by Stata software).

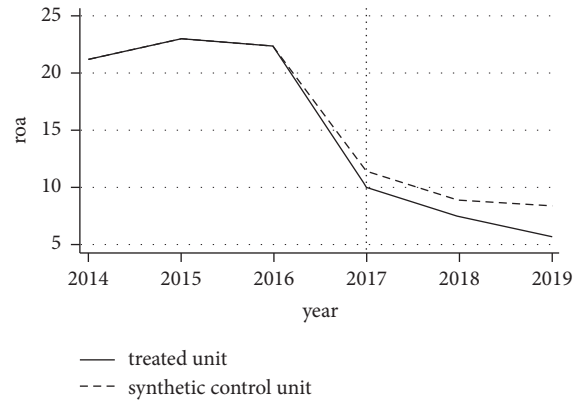

Figure 3: ROA figure of Xinjiang torch. Note: Xinjiang torch was listed through the IPO green channel in 2017. And before its being listed, the treatment group and control group fold share the same trend. After 2017, both experienced a decline, but the decline in the treatment group was more severe, which indicates that Xinjiang Torch has experienced a change in performance after being listed through this policy (the figure is directly exported by Stata software).

change of enterprises' performance after being listed still needs further discussion. This paper explores the effectiveness of the "IPO green channel" from two perspectives, net profit and total profit, which are the main indexes to measure the operating efficiency of enterprises. The higher the net profit and total profit, the better the operating efficiency of the company. The higher the net profit and total profit, the better the company's operating efficiency. Starting from these two indicators, respectively, the performance change factors of the enterprises can be reflected more effectively. And it reflects that the "IPO green channel" policy of deregulate a significant deterioration of the profit of listed companies in the average treatment effect value. The regression coefficients of model 9 and model 10 are −4.353 and

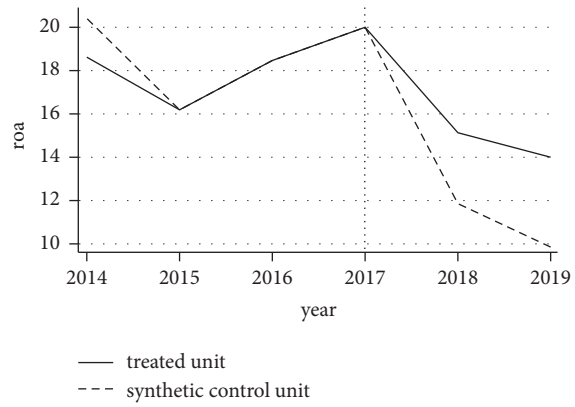

Figure 4: ROA chart of Huabao oil and gas. Note: Huabao oil and gas was listed through the "IPO green channel" in 2017. Before the occurrence of the policy, the trend of the treatment group and the control group are roughly the same. However, after the policy occurred, the control group declined more severely than the treatment group with observable differences from the first three figures (the figure is directly exported by Stata software).

−7.758, both of which are negative and significant at the level of 10%, indicating that the policy intervention reduces corporate profitability by more than 10%. After the implementation of "IPO green channel" policy for poverty alleviation, there is a significant decline in net profit and total profit, indicating a direct causal relationship between the "IPO green channel" policy and the change of corporate performance. The outcome variable in the baseline regression is return on assets, which represents the ratio of net profit after tax to total assets. A decrease in return on assets means a decrease in net profit or an increase in total assets. After being listed, enterprises can use the securities market to raise funds and absorb more capital, so the asset size of enterprises listed through the "IPO green channel" is increased. The result of Table 3 shows that the net profit of the enterprises decreases after being listed, which leads to a rapid decrease in ROA due to the combination effect of increasing asset size and decreasing net profit. The analysis of the mechanism shows that the net profit of enterprises listed through the "IPO green channel" decreases instead of increasing, the return on assets decreases, and the level of performance declining is much faster than that of other enterprises listed in the same batch.

4.4. Discussion. Although CSRC plays a crucial role of the stock market equilibrium, it was difficult to balance efficiency and justice when the regulation policy distorted to eliminating the poverty. We demonstrated the main results of DID estimation that the "IPO green channel" policy not only reduced market justice, but also damaged market efficiency in the operation performance indicators including ROA and ROE. The robustness tests verified our main results solidly. There were nine enterprises listed from the "IPO green channel" as a poverty-aid tool. Unfortunately, all these listed companies showed their less profit ability after IPO. Compared with the other new listed companies in the same period from Sep 2016 to Dec 2017, the listed companies

Table 3: Mechanistic analysis of net profit and total profit.

Variables	Model 9 *ln_netprofit*	Model 10 *ln_totalprofit*
$P_{it} \times T_{it}$	−0.1060*	−0.1182*
	(0.0549)	(0.0629)
Fixed assets ratio	−0.0042***	−0.0040***
	(0.0006)	(0.0007)
Current ratio	−0.0002	−0.0002
	(0.0001)	(0.0002)
Quick ratio	0.0003*	0.0004**
	(0.0002)	(0.0002)
Net value of inventory	−0.1802***	−0.1936***
	(0.0225)	(0.0257)
Total assets	−0.3194***	−0.3564***
	(0.0298)	(0.0342)
Operating revenue	1.3114***	1.3529***
	(0.0400)	(0.0458)
Constant	0.7386***	0.8310***
	(0.1600)	(0.1832)
Observations	3, 231	3, 227
R-squared	0.3873	0.3242
Number of id	534	534

Note. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The t-values are in parentheses.

coming from poverty areas exhibited the lower ROA and ROE performance. Our mechanism analysis revealed that great loss of net profit and total profit contribute the big strike to these "bad" companies. The IPO rules of more than two years waiting prevent the risk of listed companies by lasting the IPO applying period. The "IPO green channel" policy broke out the rules. The implementation of policy gathered the risk of listed companies.

The public should not be surprised by performance drop pattern of new listed companies in China. But they could not endure the faster speed and deeper collapse of these upstarts, which were released from "IPO green channel" by the name of poverty alleviation. China have already claimed the goal of poverty elimination that has already been gained comprehensively. The benefits of local economic are not clarified, though, of course, the listed companies received more money from the stock market and have more economic power to improve the local situation of poverty. The cost of loosening restriction leaved the big problem of performance degradation.

5. Conclusions and Recommendations

5.1. Research Conclusions. In this paper, through differences-in-differences, nine enterprises listed on the main board through the "IPO green channel" in the A-share market from September 2016 to December 2017 are used as the experimental group, and other enterprises listed in the same batch are used as the control group to analyze of the effectiveness of "IPO green channel" policy for poverty alleviation. The article further verifies the repetitiveness of the results by replacing the outcome variables, replacing the estimation method, and replacing the counterfactual method to conduct robustness tests. This paper analyzes the mechanism of the "IPO green channel" policy through the perspective of net profit and total profit and concludes that the specific mechanism of the "IPO green channel" policy for poverty alleviation leads to the change in the performance of enterprises after being listed. The results of the study include the following:

First, the negative impact of the key indicators such as the return on assets is common among the enterprises that are listed through the "IPO green channel" for poverty alleviation. The empirical results show that the implementation of the "IPO green channel" policy for poverty alleviation significantly reduces the business performance of related listed enterprises and that, on the basis of the general performance deterioration of newly listed enterprises in domestic A-share listed enterprises, enterprises that are listed through the "IPO green channel" have a more significant performance decline than other enterprises listed in the same period. There are two reasons: on the one hand, most enterprises choose to be listed through "IPO green channel" in poverty-stricken areas, and the driving factor is not in response to the National Poverty Alleviation policy, but to obtain the relaxed preferential treatment of the entry threshold of listing and shorten the time cost and compliance approval cost of listing. After being listed, various defects and deficiencies of enterprises have been exposed, and their performance is far inferior to that of normally listed enterprises. On the other hand, there are also some enterprises that meet the criteria for listing in the "IPO green channel" for poverty alleviation, but there is a gap between the actual situation of the enterprise and the development capacity of the region to which the enterprise has moved, and there is a possibility that the business performance of the enterprises will fluctuate significantly after moving to the poverty-stricken areas.

Secondly, through the mechanism analysis from the perspective of net assets and total assets, this paper finds that the net profit of enterprises decreases after they are listed through the "IPO green channel" for poverty alleviation. After being listed, enterprises can raise funds and absorb more capital, so the asset size keeps increasing. On the other hand, in order to carry out continuous surplus management, enterprises have the impulse to actively reduce profits after being listed, resulting in a significant decrease in ROA. This may be that the mechanism of "IPO green channel" policy for poverty alleviation has a mitigating effect on enterprises' performance. However, enterprises listed through "IPO green channel" for poverty alleviation generally show a stronger impulse to change their performance, which is beyond social expectations.

5.2. Policy Implications. As a major industrial policy for poverty alleviation, the implementation of the "IPO green channel" policy for poverty alleviation has tried to make some enterprises move to poverty-stricken areas to stimulate the vitality of local industrial development, promote the employment of local residents, and increase the total economic scale of poverty-stricken counties. However, in practice, the listed enterprises themselves do not improve

their performance because of being listed, but rather show performance changes, and compared with other enterprises listed in the same batch, this part of the enterprises show serious shortcomings and weak points in performance and operating ability.

In order to better implement the "IPO green channel" policy for poverty alleviation and effectively promote industrial poverty alleviation, this paper suggests that regulatory departments should actively cooperate with local governments to ensure the smooth implementation of the government's poverty alleviation efforts while taking market equity and efficiency into account.

First of all, the regulatory departments should strictly review and verify the listing standards of enterprises, and the standard of enterprises listing can not be lowered. The original purpose of the SEC's "IPO green channel" policy for poverty alleviation is to help the industry alleviate poverty and change "blood transfusion" to "blood creation." In order to attract enterprises to move to poverty-stricken areas, the requirements for enterprises listing may be relaxed. However, this will lead to some enterprises failing to meet the listing standards and low quality enterprises being listed, which is not beneficial to the long-term development of enterprises and poverty-stricken areas. Therefore, the regulatory departments should strictly review the listing capacity of enterprises. The regulatory departments should control the total number of enterprises listed through the "IPO green channel" policy for poverty alleviation. The work of poverty alleviation lies in the quality rather than in the number, and controlling the total number of listed enterprises is not only conducive to improving the quality of listed enterprises, but also conducive to easing the pressure of new share issuance and building a healthy and harmonious stock market environment. Regulatory departments also need to do a good job of information disclosure and to accept the supervision of all aspects of society.

Secondly, the local government should make differentiated choices according to the actual local situation. The local government should take local conditions into account and encourage enterprises that can promote local economic development to move into the area based on a comprehensive consideration of factors such as industrial structure and various resources. Many enterprises move their empty shells into poverty-stricken areas in order to be listed, but their main business does not move on. This has no practical effect on the development of poverty-stricken areas but provides a channel for enterprises to speculate. The local government is required to strengthen supervision and strictly make differentiated choices according to the actual local situation. After enterprises are listed, the local government should not relax its supervision on the listed enterprise but strengthen the supervision.

Third, enterprises should enhance their sense of integrity, combine their actual development needs, and apply for listing in strict accordance with the requirements of the "IPO green channel" policy for poverty alleviation. Enterprise managers should continue to implement the sense of honesty and integrity and shoulder social responsibility without falsifying data and whitewashing performance statements for the sake of listing under the guise of responding to government policies, which is contrary to the original intention of the "IPO green channel" policy for poverty alleviation. By relocating to poverty-stricken counties to achieve listing through the "IPO green channel" policy, enterprises should be based on the actual situation of poverty-stricken counties to complete the transformation of strategic management, to effectively protect the interests of minority shareholders through the fulfillment of their own business responsibilities, rather than being busy with the performance changes emptying the resources of listed enterprises. Only in this way can listed enterprises give full play to the operational advantages to realize the win-win situation of economic development of poverty-stricken areas and improvement of listed companies' operational quality.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

It is declared by the authors that this article is free of conflicts of interest.

Acknowledgments

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Research Article

Performance Appraisal System and Its Optimization Method for Enterprise Management Employees Based on the KPI Index

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Enterprise human resources management plays an important role in enterprise development, and it is an important support for the resisting the risk of market competition. The quality of enterprise managers and whether the performance appraisal is reasonable and effective directly affect the operation status and overall benefits of enterprises. Therefore, in order to enhance the competitiveness and achieve the development goals of the enterprise, the enterprise needs a set of scientific performance appraisal systems for enterprise management personnel. By combining the characteristics and research status of enterprise managers' performance evaluation, the shortcomings of the current popular enterprise managers' performance evaluation system were analyzed and pointed out in this paper, and the optimization method of enterprise managers' performance evaluation system based on KPI indicators was studied and put forward, which can provide a certain theoretical support for enterprises to improve their management level and market competitiveness.

1. Introduction

Since entering the 21st century, especially with the rapid development of science and technology and the market economy, all kinds of enterprises [1, 2] have also shown a vigorous development trend, and the competition among the enterprises has become increasingly fierce. In the increasingly fierce market competition environment, how to obtain competitive advantage and maintain the sustainable and stable development of enterprises is a problem that every enterprise must face and solve.

"Science and technology are the primary productive forces," which illustrates the extreme importance of talents to enterprises, society, and national development [3, 4]. For enterprises, talents are one of the indispensable resources and the key to the core competitiveness of enterprises. Therefore, modern enterprises pay more and more attention to human resource management. In order to improve the market competitiveness of enterprises, they have been committed to exploring effective methods of human resource management.

Performance management is the core of human resource management [5, 6]. It can be said that all the overall management and operation of the enterprise are management-oriented and are carried out around performance. Performance appraisal is the key link and core content of performance management [7, 8]. It is a process and method that an enterprise uses specific standards and indicators to evaluate employees' past work behavior and work performance under the established strategic objectives. And, the results are used to positively guide employees' future work behavior and work performance. As the basis of personnel employment, personnel training, determination of labor remuneration, and the means of personnel incentive, it is very important for the sustainable and healthy development of enterprises. So, a scientific, sound and perfect performance appraisal system has very important strategic significance to enhance the level of enterprise human resources development and enhance the competitiveness of enterprises. More and more enterprise managers [9, 10] pay attention to the methods of performance appraisal, many companies begun to use the performance appraisal to

manage enterprise. However, due to the long-term implementation of planned economy system in China, the overall performance appraisal level of enterprises in various industries is low. Many enterprises also regard performance appraisal as the evaluation of employees' daily work performance. The performance appraisal system is not clear, and the design of appraisal indicators is out of line with the enterprise strategy and positions. Improper weight distribution in the design of assessment indicators failed to give full play to the role and significance of performance assessment [11].

At present, commonly used enterprise personnel performance appraisal process is shown in Figure 1.

Figure 1 shows that, in general, the enterprise staff performance appraisal process can be divided into five stages. They are (1) stage 1—the signing stage of objectives and tasks. At this stage, according to the enterprise's development plan and annual work plan, the annual work priorities and objectives and tasks of the enterprise's managers are defined in the form of meetings, and the objectives and task statements are signed by the enterprise's managers. (2) Stage 2—target task implementation stage. In this stage, enterprise managers should formulate corresponding implementation plans according to the specific target tasks signed in stage 1 and implement them in the work of the whole year. (3) Stage 3—objective feedback stage. The HR department of the enterprise will regularly or irregularly give feedback to the managers of the business department on the completion of the objectives and tasks by e-mail, and the department director will communicate with all the managers by interview. (4) Stage 4—performance reward accounting stage. This stage is an important part of the enterprise management strategy, which is conducive to stimulating employees' work enthusiasm. The performance bonus work is to calculate and distribute the performance bonus to the employees of the enterprise according to the performance appraisal results after the end of the appraisal cycle of each quarter. (5) Stage 5—performance appraisal feedback stage. The superior decision-makers and managers of the enterprise communicate and feedback on the performance appraisal work. Managers can put forward the advantages and disadvantages of the current performance appraisal system according to their actual work and provide guidance and suggestions for the further improvement of the performance appraisal system.

As the backbone of the enterprise [12, 13], the managers of the enterprise are not only the executors of the enterprise strategy but also the makers of the enterprise tactics. They play a pivotal role in connecting the preceding and the following. They have the important function of dredging the decision-makers and the executive level of the enterprise. They are the indispensable backbone of the enterprise. Therefore, the exertion of managers' work efficiency plays a key role in improving enterprise performance and realizing enterprise strategic objectives. Performance appraisal is one of the important ways of enterprise human resource management. It is also an effective way to strengthen the management of enterprise managers, and it is also an effective method to motivate enterprise managers [14, 15]. However, due to the small proportion of enterprise managers in enterprise employees, the current performance appraisal means are mainly for general employees, while there are few studies on the performance appraisal of enterprise managers. Therefore, at present, the performance appraisal of enterprise managers usually has some shortcomings, such as the performance appraisal procedure is not detailed enough, the performance appraisal index setting is not reasonable enough, the performance appraisal method is not flexible, and the conclusion is not scientific and reasonable enough.

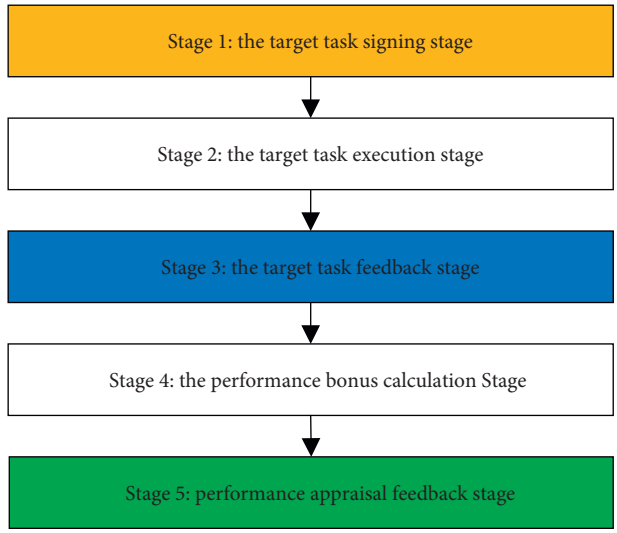

Figure 1: Performance appraisal process for enterprise staff.

It should be paid more attention to the performance appraisal of enterprise managers and the construction method of the corresponding evaluation system by combining the current characteristics of enterprise managers' performance management. The commonly used performance management methods and their shortcomings, and the characteristics of enterprise managers and the performance management methods applicable are comprehensively analyzed. An optimization method of enterprise managers' performance appraisal system based on KPI indicators is obtained. Finally, taking an enterprise as an example, by analyzing the characteristics of the current management mode of the enterprise and the shortcomings of the performance appraisal system of the enterprise's managers, the performance appraisal system of the enterprise's managers is constructed by applying the KPI index performance appraisal theory, and the key index system and evaluation methods of the enterprise's managers' performance appraisal are reasonably put forward to improve the enterprise's performance appraisal index system and make the enterprise's performance appraisal index system more comprehensive rationalize and scientific, make full use of performance evaluation and assessment means to mobilize the enthusiasm of enterprise managers, improve their work efficiency and management level, and provide strong support for the sustainable and stable development and growth of the enterprise.

The characteristics of current enterprise management personnel performance management is combined [16, 17]. The commonly used methods of performance management and the shortage of them are analyzed and studied in this paper. Through a comprehensive analysis of the enterprise management employees' characteristics and the performance management system for them, it is found out that enterprise management personnel performance appraisal should focus on the key points and the corresponding evaluation system of construction methods, and a kind of enterprise management personnel performance evaluation system based on KPI index optimization method is obtained. Finally, an enterprise is taken as a study example, by analyzing the characteristics of the current enterprise management mode [18, 19]. Then, the key index system and evaluation methods of the enterprise's managers' performance appraisal are reasonably put forward to improve the enterprise's performance appraisal index system and make the enterprise's performance appraisal index system more comprehensive rationalize and scientific. By making full use of the performance evaluation and assessment means to arouse the enthusiasm of enterprise management, improve their work efficiency and management level, which can provide strong support for the enterprise's steady development.

2. Related Works

In order to ensure that the human resource can play a positive role in enterprises, enterprises need to establish a scientific and effective performance appraisal system [20, 21]. As the core of employee management, performance appraisal plays a great role in promoting the core competitiveness of enterprises. After decades of development, Chinese market enterprises have initially established a series of assessment systems from the grass-roots level to the middle level and then to the top level. However, among the above systems, the assessment system for middle-level managers is the weakest. As an important component of the performance evaluation system, most enterprises adopt a unified set of indicators, which are applied to all employees of the enterprise at the same time [22, 23]. Although there are much study works on middle managers performance evaluation in China, most of them are about the performance appraisal model and existing problems, and there is still a lack of research on the general performance appraisal index system of middle-level managers in enterprises.

2.1. Related Theory about Enterprise Performance Management. Performance is a very important concept in the organization management. In order to improve the efficiency of organization and management, people have carried out extensive and indepth research on this concept [24, 25]. People's understanding of performance will vary according to their fields and disciplines.

In the view of sociological point, the meaning of performance is that each member of the society undertakes their own responsibilities according to the roles determined by the social division of labor. Their right to exist is guaranteed by the performance of others, and their performance guarantees the right to exist of others. Therefore, as a member of the society, if we benefit from the society, we must give back to the society. To complete our own performance is our obligation as a member of the society. If we benefit from society, we must give back to society [26].

In the view of management point, the performance is the result of organizational expectations. It is the effective output of organizations at different levels to achieve goals, including personal performance and organizational performance. The personal performance viewpoint in enterprises mainly includes performance is the result; performance is behavior; performance is the quality of ability; and performance is the unity of result, behavior, ability, and quality. The overall performance of an organization is the task and goal of the whole enterprise. It is based on individual performance. However, individual performance cannot guarantee organizational performance. Organizational performance is the coordination and integration of individual performance. There are both connections and differences between them.

In the view of economic point, performance and compensation are a group of corresponding relationships in the operation of enterprises. Performance is the degree of individual contribution to the enterprise, and compensation is a positive form of enterprise pay to individual. When employees enter the enterprise, they must complete the tasks assigned by the enterprise. At this time, the degree of personal performance is evaluated due to the tasks they completed. And, salary is a kind of reward for employees to complete the roles. This relationship fully reflects the law of equivalent exchange in the market economy.

Performance itself is an objective existence, but performance needs to be subjectively evaluated by reviewers and organized into effective performance information which will affect the organization's management decisions [27, 28]. Therefore, performance should refer to the work behaviors, methods, and results expected by the organization and evaluated through multiple levels in order to achieve the organization's goals. It should not only focus on the results but also on the process of achieving the results, which reflects the process of an employee complete a certain task.

2.2. Performance Evaluation for Enterprise. Performance appraisal [29, 30] refers to the process in which the subject of appraisal uses scientific appraisal methods to evaluate the completion of employees' work tasks, the performance of employees' work responsibilities, and the development of employees against the work objectives or performance objectives and feeds back the evaluation results to employees. Performance appraisal mainly assesses employee's contribution to the organization. It is a management communication activity for managers to improve the employee ability and performance and organization strategic objectives. Its essence is human resources management to develop existing staff information about existing employees and provide scientific basis for employees' compensation, promotion,

deployment, training, incentive, dismissal, and career management.

Performance evaluation mainly includes three meanings: (1) Performance appraisal takes the business objectives of the enterprise as a starting point, evaluates the employee's work process and result, and combines the evaluation results with the various functions of human resource management to effectively promote enterprise to achieve its goals. (2) Performance appraisal is an integral part of the human resource management system. It is an appraisal conducted by using a set of management system and some organizational institutional norms, processes, and methods. (3) Performance appraisal is an evaluation based on objective facts on the behavior, ability, attitude, and performance of the members of the organization in their ordinary work performance.

According to the viewpoint of modern management, performance appraisal is a process of learning, improvement, and control. Its main goal is not only to get a fair appraisal result but also to truly improve the performance of enterprises and employees and achieve the development goals of enterprises and the improvement of employees' quality through continuous, dynamic, and two-way communication. Performance appraisal mainly includes the formulation of performance standards, performance communication, performance appraisal, performance feedback and guidance, performance improvement and replanning, and application of performance appraisal results.

According to the viewpoint of modern management, performance appraisal is a process of learning, improvement, and control. Its main goal is not only to get a fair assessment result but also to truly improve the enterprise and the staff individual performance and achieve the development goals of the enterprise and the improvement of employees' quality through continuous, dynamic, and two-way communication. Performance appraisal work mainly includes the formulation of performance standards, performance communication, performance appraisal, performance feedback and guidance, performance improvement and replanning, and application of performance appraisal results.

Figure 2 shows the main methods of performance appraisal used currently.

It can be seen from Figure 2 shows that the main methods of performance appraisal at present include KPI method, objective management method and 360-degree performance evaluation method, and assessment center method.

Among them,

(1) The KPI refers to the calculation and analysis of key parameters at the input and output ends of the internal process of the enterprise. It is a kind of objective and quantitative management indicators to measure the process performance. It decomposes the strategic objectives of the enterprise, mainly focusing on the work results and performance of employees. Through the key indicators system, it can help enterprise decision-makers to clarify the main responsibilities of employees and further clarify the indicators to measure the quality and efficiency of employees' work. This method can link employee goal, department goal, and the overall goal of the enterprise, which is convenient for managers to evaluate and control the KPI output of the department and employees in stages, and guide employees to move towards the correct goal through the feedback mechanism.

(2) The balanced scorecard (BSC) is one of the commonly used methods of performance appraisal methods. It is a new performance management system that implements the enterprise's development strategy into operational measurement indicators and target values from the four perspectives of finance, customers, internal operation, learning, and growth. BSC mainly realizes strategic planning through charts, cards, and tables. The financial dimension measures the parallelism of a person's financial management level. The customer dimension reflects how customers view our problems. The internal process dimension mainly aims to meet shareholders' and customers' dimensional goals. The learning and growth dimension considers the ability improvement and talent training of the company's employees from the perspective of the company's long-term development. The design purpose of the balanced scorecard is to to establish a performance management system that meets the long-term development of the enterprise and fully reflects the strategic orientation of the enterprise, so as to ensure that the strategy of the enterprise can be effectively implemented. This method can effectively translate the strategic objectives of enterprise into the performance indicators and actions of all departments and employees of the enterprise, help all employees clearly grasp their personal goals and enterprise development goals, and is conducive to the learning and growth of the enterprise and employees and the improvement of core competence, providing some support for the realization of the long-term development of the enterprise and the improvement of the overall management level of the enterprise.

(3) The target management mainly includes two aspects: firstly, it must work with each employee to formulate a set of work objectives that are easy to measure. Secondly, it is to regularly discuss the achievement of their goals with the employees. Its essence is the overall planning based on the development stage, which is gradually decomposed into the strategic objectives of departments and individuals. Its implementation steps are as follows: (a) determine the enterprise objectives and formulate the annual plan objectives according to the enterprise's strategic objectives. (b) Determine the objectives of each department, and the enterprise decision makers and department leaders jointly formulate the annual objectives of the department based on the annual objectives of the enterprise. (c) Determine personal

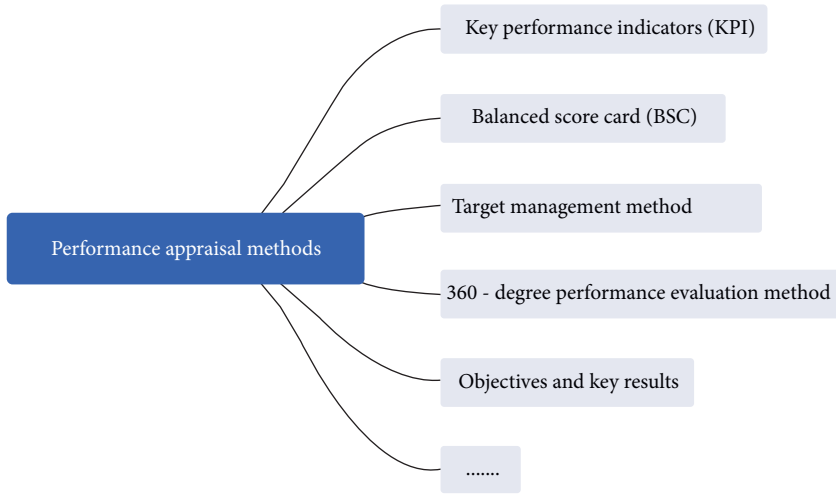

Figure 2: Main methods of performance appraisal.

goals. According to the annual goals of the enterprise and the goals of each department, each person in the enterprise shall formulate corresponding short-term implementable goals to jointly contribute to the development of the enterprise. (d) Job performance evaluation: the decision-makers and department leaders of the enterprise, within the scope of their respective authorities, compare the actual work performance of employees within a certain period of time with the personal goals formulated in the early stage, and review the work results of subordinate employees. (e) Provide performance evaluation feedback. Each department of the enterprise will give feedback on the performance evaluation work of the previous stage through regular work meetings, and each employee will discuss it and timely adjust the work objectives and efforts in combination with the performance feedback and the actual work situation.

(4) The 360-degree performance evaluation method, also known as "comprehensive evaluation method," is a relatively common performance evaluation method. It emphasizes that people-oriented should be taken into account on the basis of respecting objective facts, and multiangle evaluation should be conducted to ensure the fairness and comprehensiveness of the evaluation process, so as to enhance the credibility of the evaluation results. Its basic idea is to regard the test and examination scores of tests and examination as a linear combination of the true points and error scores. Among them, the true score is a theoretical value, which refers to the average value $E(X)$ obtained through numerous criteria measurements.

$$E(X) = T. \tag{1}$$

The relationship between the true scores and assume great score is

$$X = T + e, \tag{2}$$

wherein X is true score values, T is assuming that true score, and e is measurement error. In the process of enterprise operation, since the errors of all employees are random and the direction is also random, when the employees are combined enough and the enterprise operation reaches a certain length of time, the measurement errors can offset each other:

$$E(e) = 0. \tag{3}$$

According to the introduction of the basic principle of 360-degree performance appraisal method above, its main advantages and disadvantages are as follows: (A) Its appraisal is all-round and multiangle, and the results are objective. (B) On the basis of considering the work output, it also considers the deep-seated competency. (C) Heavy workload in the assessment process. (D) Focus on the comprehensive evaluation, with a large proportion of qualitative evaluation. (E) If the implementation process is not handled properly, it is easy to cause tension within the enterprise.

(5) The objective and key achievement method, whose main objective is to clarify the objectives of the enterprise and the team, as well as the measurable key results achieved by each objective. Its main features are (A) It can effectively avoid the deviation between the implementation process and the goal vision and solve the problem that some key indicators cannot be formulated and measured. (B) To a large extent, giving employees autonomy can stimulate employees' work enthusiasm and improve the overall work efficiency of the enterprise. (C) This method requires employees to have high quality, strong planning ability, and execution ability.

In this section, several kinds of performance appraisal methods commonly used currently in enterprise management are mainly introduced. The abovementioned performance evaluation methods have their own advantages and

disadvantages in which performance appraisal method an enterprise ultimately chooses should comprehensively consider such factors as the business, operation characteristics, and personnel structure characteristics of the enterprise.

2.3. A Performance Appraisal Management System Based on KPI. In this article, the enterprise management personnel performance appraisal method and assessment system construction are mainly researched. According to the introduction above, due to the relatively small number of enterprise managers, there is less research on the performance appraisal methods of enterprise managers at present.

In the progress of enterprises operation, enterprise management employees play an essential role [31, 32]. They are the backbone for the operation and implementation of enterprise strategic decisions and objectives. At the same time, they are also the key link for timely collecting feedback from grass-roots employees and making decisions. In terms of authority, they are the main leaders of each department of the enterprise and play an important role in the development and decision-making of their respective departments. In terms of salary, it is significantly higher than that of ordinary employees, which is directly related to their ability, quality, and responsibility. In different enterprises, due to the different nature and function division of each department, the management staff is usually not clearly defined. Because of the importance of their positions, enterprise managers are one of the important factors that determine the development of the enterprise [14, 33], which are mainly manifested as follows: (1) as a link connecting senior managers and ordinary employees, they are a transit station for information. Middle managers first need to have a strong knowledge reserve and solid professional knowledge, be able to accurately understand the strategic plan of the company's decision makers, and convert the plan into specific and operable steps. (2) Middle managers have the ability to solve problems and innovative thinking. They are not only familiar with daily production and operation activities but also have a certain overall thinking. They can help ordinary employees solve difficult problems in their work and give corresponding suggestions. (3) Excellent middle-level managers often become the role models and goals of subordinates. By encouraging subordinates to keep learning and making progress and improving their cultural quality and technical level, they can promote the development of the company's talent echelon. (4) As the head of the department, the middle-level managers often have business contacts with the personnel of other departments in their daily work. How to ensure that the relevant personnel has high cooperation satisfaction plays an important role in improving the internal work efficiency of the enterprise.

The high-quality enterprise management team can accurately understand the strategic objectives of the enterprise and sensitively perceive the changes in the business environment and lead the employees to respond quickly to determine the efficient operation of each department of the enterprise and timely adapt to the changes in the external environment. However, the enterprise management staff with insufficient ability and quality will not be able to effectively build a top-down communication bridge, which will greatly affect and hinder the normal operation and development of the enterprise. Therefore, the study of enterprise managers' performance appraisal system and its optimization is one of the important ways to improve enterprise human resource management mode and enhance enterprise market competitiveness.

Figure 3 shows the main components of current enterprise management employees' performance appraisal.

Figure 3 shows that, among the commonly used performance appraisal methods at present, the performance appraisal results of enterprise managers mainly consist of (1) department performance appraisal and the allocation weight of department performance score, (2) evaluation of enterprise decision makers, and (3) individual quarterly and annual work report evaluation. Based on the above, the performance appraisal for enterprise management staff is too subjective and unsystematic to be objective, fair, and just, which not only fails to achieve the expected effect of enterprise performance appraisal but also has an adverse impact on the work enthusiasm and efficiency of enterprise management staff. Therefore, it is urgent to carry out research on the construction and optimization of enterprise management staff performance appraisal system.

Based on the above characteristics, such as the small number of enterprise management staff, the decisive role in each department of the enterprise and the great impact on the operation of the enterprise, this paper studies application of KPI to build and optimize the performance appraisal system of enterprise management staff.

Figure 4 shows the main ways in which enterprise management employees play a role in the realization of enterprise target A in the process of enterprise operation.

As can be seen from Figure 4 that, (1) at the target level, the enterprise formulates a strategic objective by comprehensively considering its own business characteristics, scope, market demand, and other factors. (2) At the implementation criteria level, according to the enterprise strategic objectives set by the enterprise decision-makers, all departments of the enterprise should respond quickly under the leadership of their respective competent leaders and formulate several implementation criteria according to the division of responsibilities and tasks of the departments. (3) The scheme level, with the cooperation of the management staff of each department of the enterprise, formulates the practical operation scheme according to the implementation criteria. The operation scheme specifies the task division and completion time nodes of each department.

According to the main process of realizing the strategic objectives of the enterprise as shown in Figure 4, in order to build a performance appraisal system for enterprise management employees, firstly, it is necessary to clarify the key capabilities that the enterprise management employees should have to achieve the strategic objectives of the enterprise. Secondly, evaluate the relationship between the capabilities and the realization of the strategic objectives of the enterprise. Thirdly, reevaluate the weight relationship

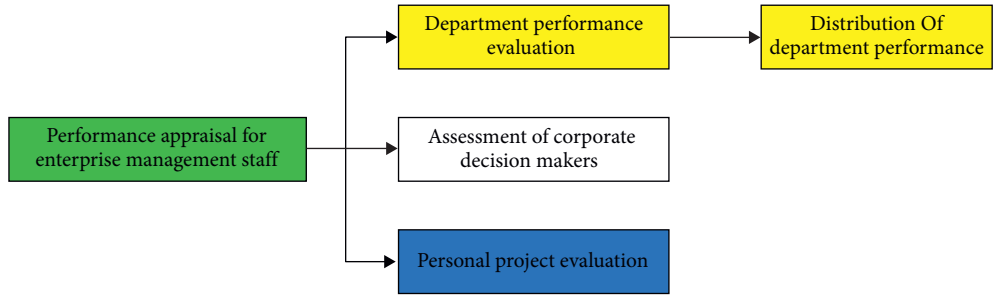

Figure 3: Main components of enterprise management employees' performance appraisal.

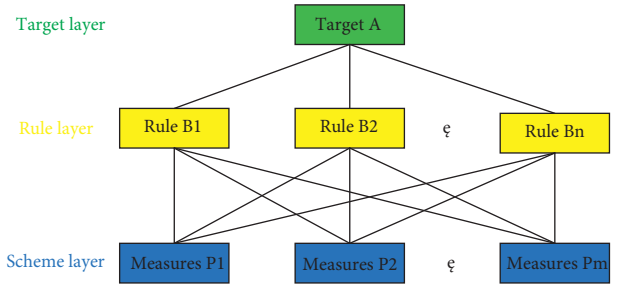

Figure 4: Main flow for enterprise strategic target implementation.

between the main competencies of enterprise management staff. Finally, the enterprise management staff performance appraisal system and its optimization method are obtained. In the construction progress of the enterprise management staff performance appraisal system, the principles of diversification of KPI indicators, evaluation subjects, and indicator weights should be followed.

Figure 5 shows the construction process of enterprise management employee performance appraisal system based on KPI.

Figure 5 shows the construction process of the enterprise management employees' performance appraisal system based on KPI. It is mainly as follows: (1) evaluation subjects are diversified. In order to avoid the subjective bias of evaluators, when evaluating the performance of different management employees in the enterprise, a number of evaluators are selected from various aspects and different groups. (2) The KPI indicator system is diversified. According to the business characteristics of the enterprise, the KPI indicators for the performance appraisal of enterprise management employees are layered. In the figure, the KPI indicator system for the performance appraisal of enterprise management employees is divided into two levels. (3) Calculate the weights of multiple indicators.

The specific calculation process can be as follows:

According to the characteristics of enterprises and market concerns, by consultation with various parties (such as experts from colleges and universities, enterprise managers, and grass-roots employees), the weight relationships of different KPI indicators at all levels of the enterprise management staff performance appraisal system are compared, and the weights of various factors are calculated by using mathematical algorithms.

Determine the weight judgment matrix A of factors in the same level, and its mathematical formula can be expressed as

$$\mathbf{A}_{\mathbf{n}\times\mathbf{n}} = \left(a_{ij}\right)_{n\times n} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{n2} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \tag{4}$$

where a_{ij} represents the importance relationship of the index i than index j, and their specific values can be found in Table 1. The relationship between a_{ij} and a_{ji} is

$$a_{ji} = \frac{1}{a_{ij}}. \tag{5}$$

The weight calculation steps are as follows: calculate the maximum eigenvalue of the judgment matrix and its corresponding eigenvector and take the eigenvector corresponding to the maximum eigenvalue of the matrix through consistency solution as the weight vector.

(1) Calculate the elements of judgment matrix every line of products M_i

$$M_i = \prod_{j=1}^{n} a_{ij}, \quad (i = 1, 2 \cdots, n). \tag{6}$$

(2) Calculate the nth root of each M_i:

$$\overline{W}_i = \sqrt[n]{M_i}. \tag{7}$$

(3) The characteristic vector normalization processing obtains the corresponding weight coefficient:

$$W_i = \frac{\overline{W}_i}{\sum_{i=1}^{n} \overline{W}_i}. \tag{8}$$

(4) Consistency check: its purpose is to judge whether the constructed matrix is reasonable and to calculate the maximum eigenvalue of the judgment matrix.

$$AX = \lambda_{\max} X, \tag{9}$$

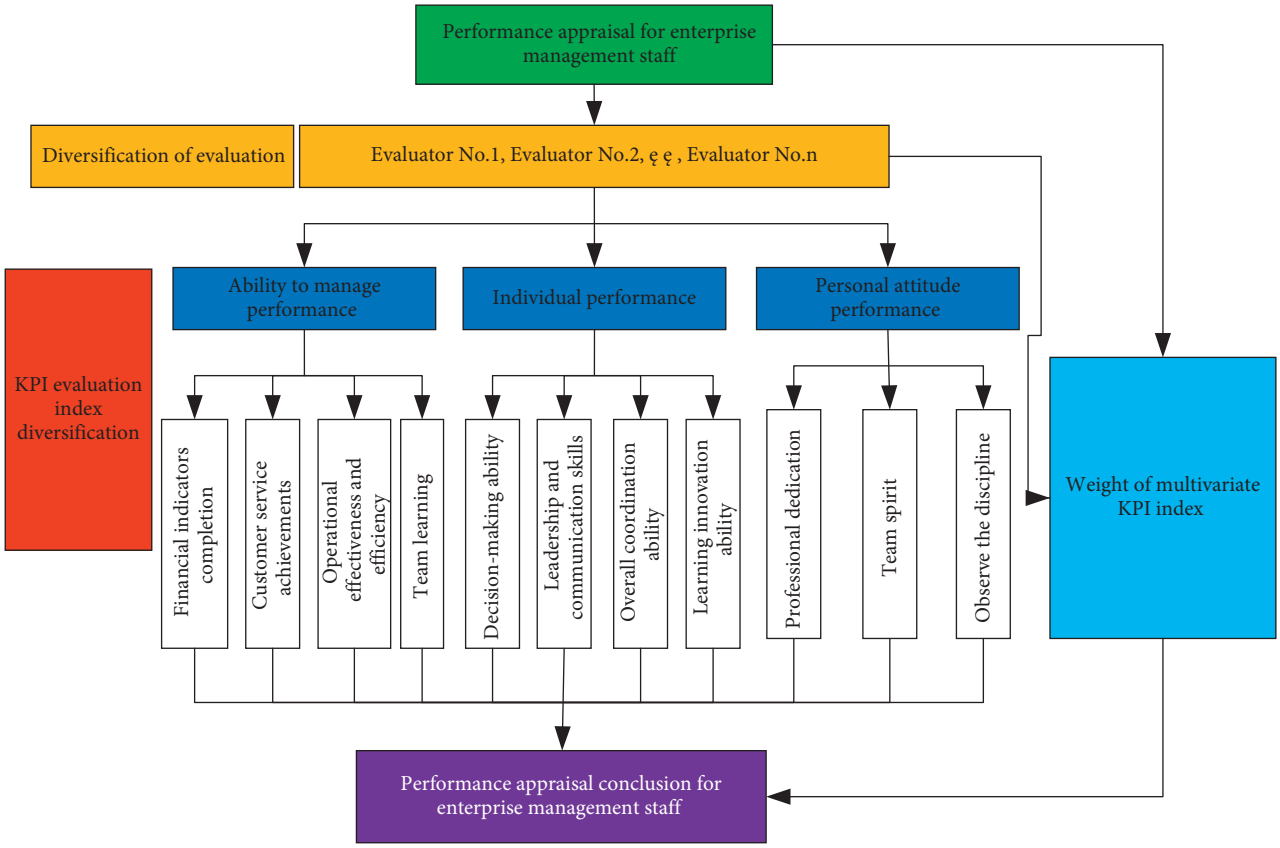

Figure 5: Flow diagram of the construction process of enterprise management employees' performance appraisal system based on KPI.

Table 1: The judgment matrix scale method.

Scale	Definition
1	Two factors are equally important
3	The ith index is slightly more important than the jth index
5	The ith index is more important than the jth index
7	The ith index is obviously more important than the jth index
9	The ith index is extremely more important than the jth index
2, 4, 6, 8	Between the two adjacent judgment value

where $\boldsymbol{X}$ is the eigenvector corresponding to the largest characteristic root $\lambda_{\max}$ of the judgment matrix.

The weight calculation of different KPI indicators in other levels adopts the same process as above and will not be repeated here.

Assuming enterprise management staff performance appraisal system is divided into two layers, the score can be calculated by the following formula.

$$F = \sum_{i=1}^{n} \left(W_i \times \sum_{j=1}^{m} E_{ij} \right). \tag{10}$$

In the formula, it is assumed that the established performance appraisal system for management employees of an enterprise is divided into two levels, of which the first level has n KPI indicators; There are m KPI indicators in the second level corresponding to each indicator in the first level. W_i is the ith index weight in the first level; E_{ij} is the weight of the ith indicator in the first level and the jth indicator in the second level.

3. A Practical of Enterprise Management Employees' Performance Appraisal Optimization

3.1. Introduction to an Enterprise. The target enterprise studied in this paper is a large enterprise mainly engaged in passenger cars and special vehicles. The company has experienced more than 60 years of development, its market occupation is leading in China. It has a good corporate image in the hearts of consumers and has formed a unique corporate culture. There are more than 6000 employees in the enterprise. Among the existing employees, the comparison between the number of enterprise management employees and ordinary employees, educational background, and age structure are shown in Figures 6~8, respectively.

Figures 6~8 show that (1) the number of management employees is far less than the ordinary employees, only 6.53% of the total staff number. (2) Most employees have bachelor degree or above, and the majority of them are undergraduates and masters, which indicates that the quality of talents in the enterprise is high. (3) The number of employees under the age of 35 is the largest, accounting for

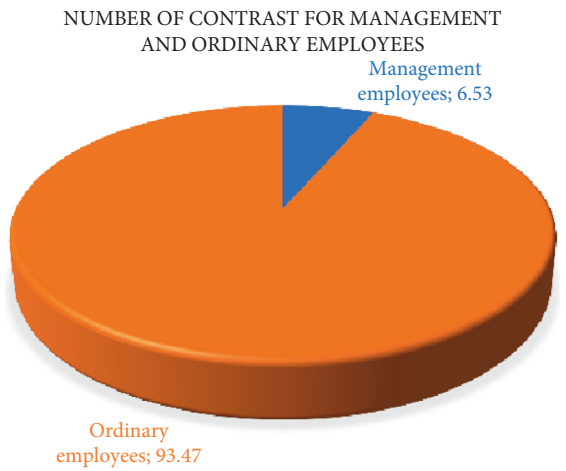

Figure 6: Comparison with ordinary employees and management employees.

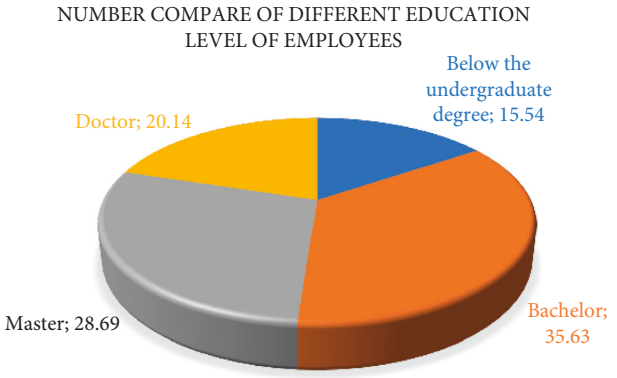

Figure 7: Enterprise employee's academic degree.

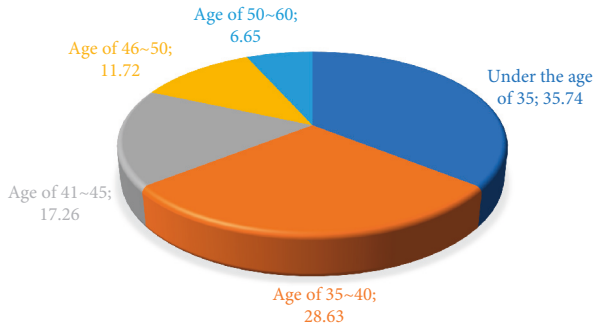

Figure 8: Enterprise employees' age structure.

35.74% of the total number of employees. Those aged 35–40 took the second place, accounting for 28.63% of the total. The above two groups are in their prime of life, and they are also the main body of the employees of the enterprise, indicating that the employees of the enterprise can adapt to work with greater intensity, and the development potential of the enterprise is great.

Figures 9 and 10, respectively, show the market share of the two types of vehicles mainly operated by the enterprise in recent 5 years and the profitability of the enterprise in recent 5 years.

According to the comprehensive analysis of Figures 9 and 10, it shows that (1) the bus market share of the enterprise is significantly higher than that of special vehicles. (2) The market share and corporate profits of the two vehicles have shown a relatively stable upward trend in the past five years. However, due to the outbreak of COVID-19 in 2020, the market share and profits of the year have declined. (3) Based on the employee structure and strength of the enterprise, the enterprise still has a great upward trend by optimizing the enterprise's human resource management strategy.

3.2. Construction of Enterprise Management Staff Performance Appraisal System. According to the construction method of performance appraisal system for enterprise management employees based on KPI indicators analyzed in Section 2.3, and referring to Figure 5, the performance appraisal system for enterprise management employees is constructed as follows. (1) Establish the evaluation subject. In order to conduct performance appraisal for enterprise management employees fairly and objectively, the enterprise specially organizes grass-roots employees. A certain number of management staff and enterprise decision makers are transferred to form an enterprise management staff performance evaluation team. (2) Determine the KPI indexes. According to the opinions of the enterprise management staff performance appraisal evaluation team, the indexes of the management staff performance appraisal system are divided into two levels. Among them, the KPI indexes of the first level include management performance, personal ability performance, and personal attitude performance. Based on this, the evaluation judgment matrix A of the first level indexes can be constructed.

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}. \tag{11}$$

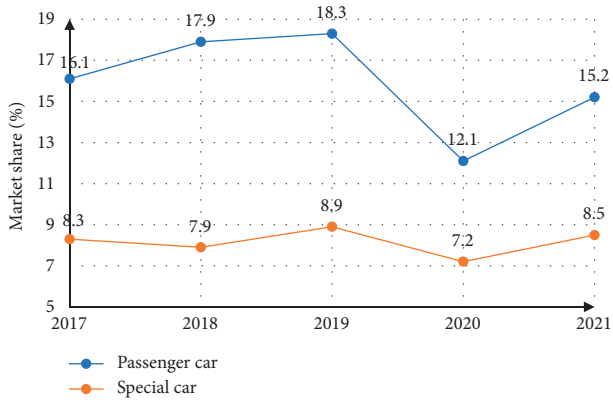

Figure 9: Market shares of company mainly engaged two kinds of cars in nearly five years.

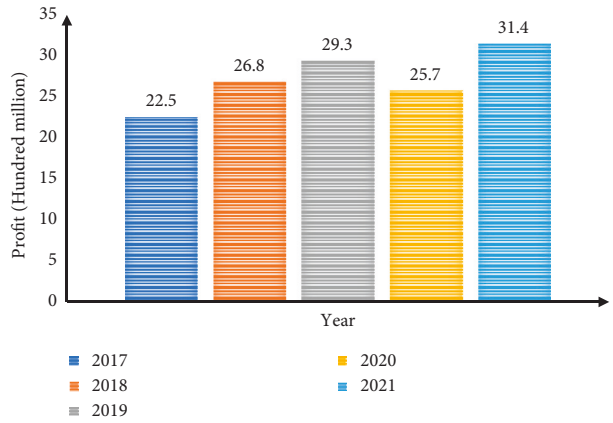

Figure 10: Corporate earnings in nearly five years.

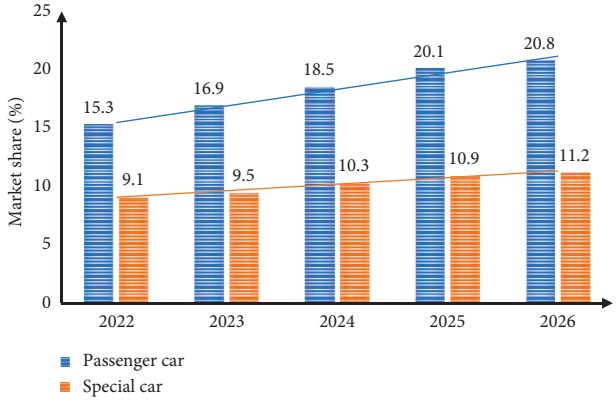

Figure 11: Market share forecast of the two types of vehicles mainly operated by the enterprise in the next five years.

The second level indexes corresponding to each of the first level indexes are the completion of financial indexes, customer service achievements, internal operation effects, and internal team learning and growth. Decision making ability, overall planning and coordination ability, leadership and communication ability, learning and innovation ability;

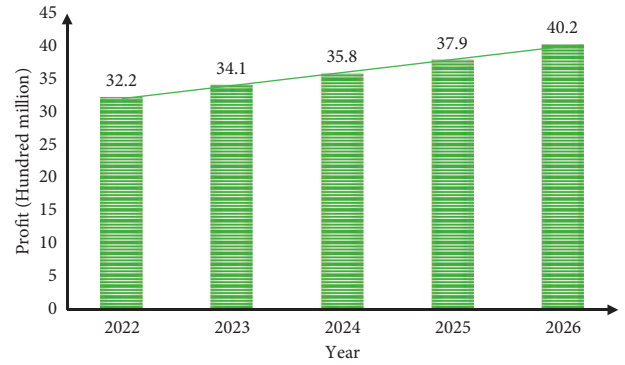

Figure 12: Profit forecast of the enterprise in the next five years.

professional dedication, sense of responsibility, team spirit, and discipline.

Thus, judgment matrix, B_1, B_2, and B_3 of the second level index evaluation can be built as follows.

$$B_1 = \begin{bmatrix} b_{111} & b_{112} & b_{113} & b_{114} \\ b_{121} & b_{122} & b_{123} & b_{124} \\ b_{131} & b_{132} & b_{133} & b_{134} \\ b_{141} & b_{143} & b_{143} & b_{144} \end{bmatrix},$$

$$B_2 = \begin{bmatrix} b_{211} & b_{212} & b_{213} & b_{214} \\ b_{221} & b_{222} & b_{223} & b_{224} \\ b_{231} & b_{232} & b_{233} & b_{234} \\ b_{241} & b_{243} & b_{243} & b_{244} \end{bmatrix}, \quad (12)$$

$$B_3 = \begin{bmatrix} b_{311} & b_{312} & b_{313} & b_{314} \\ b_{321} & b_{322} & b_{323} & b_{324} \\ b_{331} & b_{332} & b_{333} & b_{334} \\ b_{341} & b_{343} & b_{343} & b_{344} \end{bmatrix}.$$

According to formulas (6)~(8) and the judgment matrix of the above four evaluations indexes, the weight values of the two-level evaluation indicators of the enterprise's management staff can be calculated. Combined with formula (10), the performance appraisal results of the enterprise's management staff can be calculated. Using this performance appraisal method can objectively and fairly get the evaluation results of enterprise management staff, which has a positive effect on stimulating the work enthusiasm of management staff, improving the sense of belonging and well-being. At the same time, it can also activate the working atmosphere of the enterprise and improve the vitality and market competitiveness of the enterprise.

3.3. Enterprise Operation Forecast after Optimization of Management Staff Performance Appraisal System. In view of the shortcomings of the current performance appraisal system for management employees in an enterprise, the previous article analyzed the current performance appraisal characteristics, business scope and market position of the enterprise are analyzed, and the construction and

optimization method of the performance appraisal system for enterprise management employees based on KPI indexes is proposed.

Figures 11 and 12, respectively, show that the market share forecast and earnings forecast of the two types cars of the enterprise mainly engaged in the next five years after the optimization of the enterprise management staff performance appraisal system.

Figures 11 and 12 show that, after the optimization of the performance appraisal system for the management staff of the enterprise, (1) market share of the two types of automobiles mainly operated by the enterprise and the profitability of the enterprise have been steadily improved, indicating that the market competitiveness of the enterprise has been effectively improved. (2) In combination with the comparison of Figures 9 and 10, the market share of the two types of automobiles mainly operated by the enterprise in 2002, and the only small increase in enterprise profits, it shows that the enterprise has a certain adaptation period for the adjustment of the performance appraisal system.

4. Conclusions

In this paper, the characteristics and related research status of enterprise staff performance appraisal was combined, and the deficiencies of current enterprise management staff performance appraisal are pointed out. Based on the analysis of the structure, job responsibilities, and functions of enterprise management staff, the construction and optimization method of enterprise management staff performance appraisal system based on KPI was put forward. Finally, an automobile enterprise was taken as an example, and its shortcomings of the current performance appraisal of the enterprise were analyzed. Applying the process results of the enterprise management employee performance appraisal system based on KPI studied in this paper, establishing a diversified management employee performance appraisal team, putting forward a diversified and multilevel enterprise management employee performance appraisal index system, and optimizing the enterprise management employee performance appraisal system. Based on the operation of the enterprise in the past five years, the profit forecast of the enterprise in the next five years and the market share of the two types of automobiles mainly operated by the enterprise were forecasted after the optimization of the performance appraisal system of the management staff. The results show that, after the optimization of the performance appraisal system of the management staff, the enthusiasm of the management staff has been improved, and the vitality and market competitiveness of the enterprise have been enhanced.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Internal Economic Management and Performance Evaluation Method of Enterprise Based on Balanced Scorecard

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In order to evaluate the performance management level of the enterprise, it is necessary to use the Balanced Scorecard to establish the performance evaluation system of the enterprise. On the basis of pointing out the specific problems and deficiencies existing in the enterprise, suggestions for improving the performance level of the enterprise are put forward. Then, a detailed analysis of the performance evaluation of Company A is carried out. Through the analysis of various aspects of Company A's performance, the problems and deficiencies in its performance evaluation are found. According to the specific problems of Company A, a performance evaluation system is designed based on the balanced scorecard. The Balanced Scorecard is a management tool for measuring performance in multiple dimensions. Starting from multiple aspects, scientifically combining strategic objectives with multiple dimensions, this management method not only is suitable for the current market environment, but also improves the company's internal management system. Through the investigation of the company's performance management, it is found that there is a problem in the company's performance management. In view of the existing problems, the Balanced Scorecard of management accounting is used as a management tool to design a feasible performance appraisal plan for the company from the four dimensions of finance, customer, internal process, and learning and growth. Recommendations for full participation can be made for its implementation. The results show that the comprehensive score of Company A's performance in 2022 is 70 points. It can be seen from the evaluation results that the financial performance evaluation level of the company is average. The company's customer performance levels are average as well. The internal operation level of the enterprise is at a high level. The level of learning and growth performance of the business is very good. At the same time, according to the reliability test standard, the reliability coefficient of the questionnaire is 0.866, indicating that the reliability is acceptable.

1. Introduction

With the deepening of social change, companies that play a key role in development have also undergone tremendous changes. The level of competition among enterprises, the complex environment that they face, and the expected profits have also changed dramatically [1–3]. In order to obtain higher corporate competitiveness, create more profits, and mobilize the enthusiasm of corporate employees, corporate leaders must effectively manage and control the various resources that they have. By realizing the reasonable allocation of tangible and intangible assets and increasing the research on management mode, enterprises can obtain greater profits in short-term operation and occupy more opportunities in long-term development. The necessary tools to achieve effective management and a set of scientific performance management system have become more and more important [4].

As far as the current domestic performance management level is concerned, the performance management of enterprises still has a large room for improvement. Although the current enterprises have implemented performance management to promote the rapid improvement of enterprise management level, performance evaluation is not enough in most enterprises [5]. The assessment of corporate performance is mainly in terms of profit indicators and quality indicators. There may be no way to integrate the enterprise evaluation system into the strategic direction of the

enterprise. Therefore, there is no strong link between evaluation and feedback mechanisms. The guiding direction of performance appraisal indicators hinders each other and even has a counterproductive effect. According to the company's own characteristics, development environment, and market competitors, it is particularly important to choose a performance management system that is suitable for the company itself and in line with its own development characteristics [6, 7]. Through the scientific judgment of the enterprise itself, it can improve the prediction of the future development environment and improve the learning and growth and innovation ability of the enterprise and employees. On this basis, long-term and healthy development can be achieved by improving management efficiency [8].

The significance of the study of the Balanced Scorecard on the internal economic management and performance evaluation of enterprises in this paper is as follows [9–11].

1.1. Theoretical Significance. For the academic theory research of enterprise strategic performance evaluation, some achievements have been achieved at home and abroad. Part of the theory has already completed its original purpose in the process of enterprise performance evaluation. The strategic performance evaluation system can be said to be the product of enterprise strategic management and a response to the needs of enterprise management in the context of the new era.

Since its inception in 1992, the Balanced Scorecard theory has been used by more than 50% of fortune 500 companies. It can not only help enterprise managers to evaluate the entire business process, but also play a practical role in the improvement of enterprise management level through feedback on the formulation or revision of enterprise strategies. After more than 20 years of theoretical and practical discussions, the Balanced Scorecard is not only an initial performance evaluation tool, but also a strategic management tool that has gradually developed to meet the needs of the strategic era and also a strategic performance evaluation method.

The research on enterprise system and management methods is the first to rise abroad and is slowly introduced into China, and the same is true for the research and application of performance evaluation system.

Therefore, the understanding and application of performance evaluation and strategic management in Chinese enterprises are not as good as those in Western countries, so that the implementation has not produced the effect that it should have. Although many scholars are actively studying the application and implementation of the Balanced Scorecard in China, the constraints of the harsh environment of enterprises cannot be avoided. Differences in corporate environment at home and abroad limit the reference objects of the Balanced Scorecard in China. Contingency theory shows that management strategies all have certain environmental dependencies. Any management method or management tool is unique and cannot be applied universally. Therefore, if strategic performance evaluation is to inject vitality into Chinese enterprise management, it should proceed from the actual situation of Chinese companies. By focusing on localization in the process of theoretical research, it promotes the fullness of relevant performance evaluation theories.

1.2. Practical Significance. Most Chinese enterprises still remain in financial performance evaluation in performance evaluation, and the limitation of only focusing on the financial status and operating results of the company in the past period is still inevitable. However, the strategic performance evaluation system has not received enough attention and promotion. Even if they realize the importance of nonfinancial performance indicators, the application of the strategic performance evaluation system has higher requirements for enterprises. For example, it is necessary for enterprises to clarify their own strategic goals, their managers have high performance evaluation and management quality, and enterprises have relatively good information management systems, which often lead to being shelved or even ignored.

This paper mainly takes Company A as the research object. The present situation of the performance evaluation system of case Company A is pointed out, and its existing problems are analyzed concretely. From the perspective of the balanced scorecard, a specific performance evaluation system is designed for Company A. This performance evaluation system is then applied to A to evaluate the current performance level of the enterprise. It pointed out the specific problems and deficiencies of the company. Finally, some suggestions are put forward to improve the performance level of Company A.

2. Related Concepts and Theoretical Basis

2.1. Performance. Performance refers to the appraisal subject's work evaluation of employees. The assessment method should be reflected through the work objectives and performance standards set by the company [12]. It is evaluated in a reasonable and scientific way, and reward and punishment measures are given according to the evaluation results. Performance can effectively improve corporate profits. There are also two basic principles in the achievement of performance: target management and responsibility requirements. Through the establishment of goals, the development of individuals and organizations can be made without divergence. Appropriate rewards can be given when goals are achieved. Responsibilities are the requirements for employees' work and life. Performance in most cases refers to efficiency. Effectiveness consists of two aspects: discipline and conduct. The embodiment of discipline in an enterprise is mostly its internal rules and regulations. Character refers to the personal behavior and morality of employees [13]. When transferring personnel, not only their personal performance, but also their personal character should be considered comprehensively. Organizational performance refers to macroaspects. From the organizational level, it analyzes the completion of organizational tasks in a period of time. Organizational performance and individual

performance complement each other, and individual performance is an effective foreshadowing of organizational performance. The effective achievement of organizational performance requires everyone's efforts. Organizational performance is achieved when each individual achieves his or her individual performance goals.

Performance has the following characteristics. One is the ability of integrating multiple factors to effectively analyze performance advantages. Second, when designing the weights of evaluation indicators, comprehensive performance evaluation objectives should be determined. Third, performance occurs in dynamic changes. When time and environment change, performance evaluation methods will also change accordingly.

2.2. Performance Management

2.2.1. The Concept of Performance Management [14–16]. Performance management refers to the continuous cyclic process of performance plan formulation, performance coaching and communication, performance appraisal, application of performance results, and performance goal improvement in which managers and employees participate in order to achieve organizational goals. Performance management is not only to effectively improve the performance of individual employees, but also to improve the overall performance of the company. According to its definition, performance management is a comprehensive management that pays attention to the details of the work process. Performance management cannot be ignored in the production and operation process of any enterprise. Through effective performance management, the goals of the staff and management can be aligned, and the achievement of organizational goals and personal goals of employees is also taken into account.

2.2.2. Principles of Performance Management [17, 18]. A company should adhere to the following principles when conducting assessment management. First of all, the principle of objectivity and fairness should be guaranteed. Through open and fair performance management, employees can accept their management methods heartily, so as to improve the application of their performance management results in the company. Secondly, performance management should be combined with the company's financial principles. The other three dimensions should focus on the financial dimension, and the company should combine multidimensional assessment to improve the company's financial level. Finally, it must comply with the principle of combining rewards and punishments. The efforts brought by excellent employees to the company cannot be ignored, or the mistakes of uncooperative employees.

2.2.3. Performance Management System and Process. The overall process of performance management can be divided into three steps. The first is performance planning. As the primary link of performance management, its role is to guide the company's performance management. Only scientific and reasonable plans are more suitable for the company's management, operation, and development. The second is performance coaching and communication. As the basic link of performance management, only through coaching and communication can the formulated performance plan be close to the company's own development and in line with the working state of the company's employees, so that the performance plan can reach a feasible state. The third is performance appraisal. As the central link of performance management, scientific index construction is the performance appraisal center. Different from performance appraisal, performance management focuses on the interaction between management and employees. Through the exchange of feedback, the management can gain a deeper understanding of the employees' working ability and set career goals for employees that are suitable for their own development. By striving to achieve their goals and getting a return that matches their efforts, employees embody a win-win situation between the enterprise and management.

2.3. The Relevant Theoretical Basis of the Balanced Scorecard

2.3.1. The Core Idea and Basic Framework of the Balanced Scorecard. The Balanced Scorecard believes that the lagging financial indicators lack guiding significance for the strategic management process of enterprises. In the era of fierce competition in the new economy, traditional performance evaluation methods can no longer meet the needs of enterprise strategic management [19]. Companies must also focus on the competitive performance indicators that drive the achievement of strategic goals. The Balanced Scorecard develops financial and competitiveness performance indicators closely related to corporate strategy from four levels: finance, customers, internal operations, and learning and growth. It not only pays attention to the balance of various indicators, but also devotes itself to the implementation and achievement of corporate strategies. In turn, it can help enterprises to form a lasting core competitive advantage [20].

In 2004, Kaplan and Norton proposed a strategic map (as shown in Figure 1). A strategy map can clearly show the causal relationship between strategic objectives at each level in the Balanced Scorecard [21]. The intangible assets of an enterprise lay the cornerstone of enterprise value creation. The process of enterprise value creation creates value for customers. High customer value can lead to good and lasting financial performance for a business. This progressive causal relationship shows that any part of the four levels of the Balanced Scorecard is an inseparable whole.

2.3.2. The Four Levels and Interrelationships of the Balanced Scorecard. The Balanced Scorecard transforms the mission and strategic objectives of an enterprise into four levels of business strategic objectives. Corresponding performance evaluation indicators are guided from the strategic objectives to evaluate and improve the performance level of the enterprise. In turn, it can provide relevant information feedback for enterprise managers [22]. On this basis, through

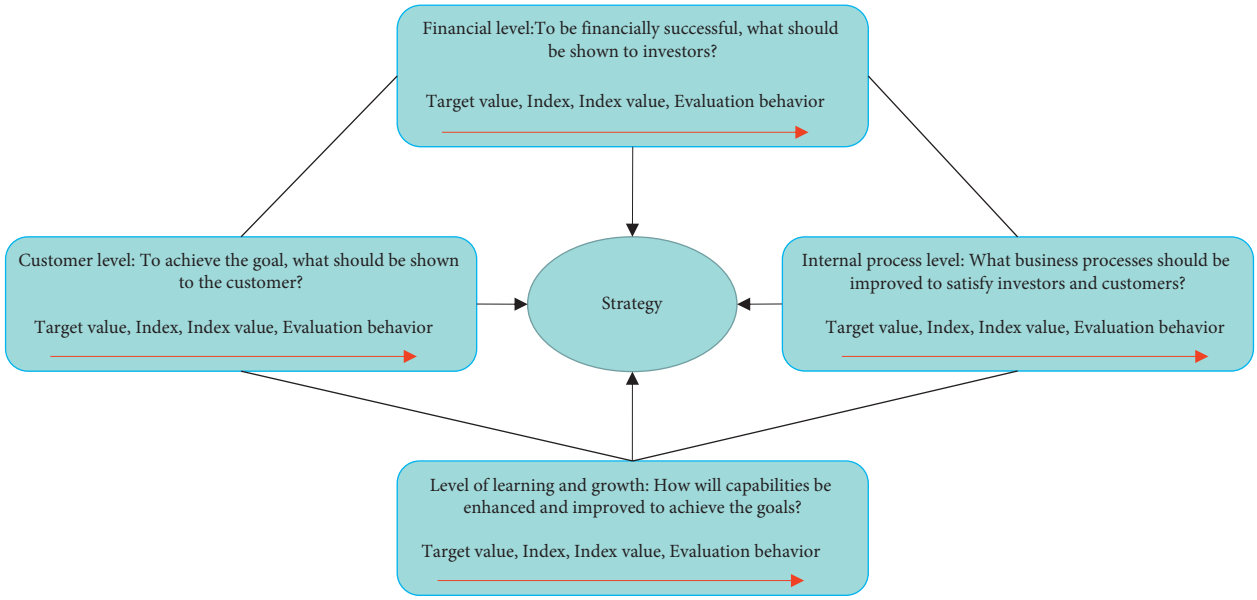

Figure 1: Strategic map.

timely discovery and resolution of problems, the achievement of strategic goals will be promoted [23, 24].

The strategy elaboration process is shown in Figure 2.

The performance indicators at the financial level usually reflect the performance of the company's solvency, profitability, operating ability, and growth.

(1) Financial Level. The performance indicators at the financial level usually reflect the performance of the company's solvency, profitability, operating ability, and growth. The strategic objectives and indicators at the financial level can often be developed and designed from the three strategic themes of financial growth, effective cost control, and asset utilization improvement. The life cycle of an enterprise should be considered when selecting financial performance metrics. Determine the financial goals according to the stage where it exists, so that the performance evaluation results truly reflect the performance level of the enterprise.

(2) Customer Level. Customer-level goals and indicators generally consider five aspects: market share, customer retention rate, customer acquisition rate, customer satisfaction, and customer profitability. The customer level focuses on the target market and target customers in which the company competes and can also reflect the company's strategic planning. Customers are the source of business revenue for a business. Enterprises should establish a correct customer view. Businesses need to define their target customers and the value proposition of their products and services.

(3) Internal Management Level. At the internal management level, indicators can be developed from three aspects: innovation process, operation process, and after-sales service. Internal operations are the internal processes required to create customer and corporate shareholder value. The quality of an enterprise's products and services often depends on the value creation process of the enterprise's internal value chain. Limited resources require companies to benchmark against customer needs and shareholder preferences. Combining the strengths and weaknesses of the enterprise, resources can be invested in the correct strategic goals and a lasting core competitive advantage can be created. The Balanced Scorecard starts from the strategic goals of the enterprise and meets the needs of target customers, so as to formulate strategic goals and performance indicators for internal operations.

(4) Learning and Growth Level. The level of learning and growth is an intangible asset of an enterprise. It includes the human capital and organizational capital of the enterprise. This level is the source from which the goals of the above three levels can be achieved. It has laid the foundation for enterprises to create higher customer value and shareholder value. The learning and growth dimension generally includes three main goals, that is, to improve the technical ability level of employees, improve information system capabilities, and increase incentives, authorization, and cooperation.

(5) The Relationship between the Four Levels of the Balanced Scorecard. Different from traditional performance evaluation methods, the most important design of the Balanced Scorecard is that it establishes four levels of goals and the causal relationship between goals and indicators. Under a series of causal relationships, it identifies performance indicators at different levels that are closely related to the company's strategic goals and core competitiveness and fits the particularity of the company. On the basis of the above, by driving the enterprise to form and maintain the core competitive advantage, the strategic goal has been achieved.

(3) The Smooth Implementation of the Balanced Scorecard Requires Enterprises to Meet the Following Basic Conditions. On the basis of summarizing the relevant research and

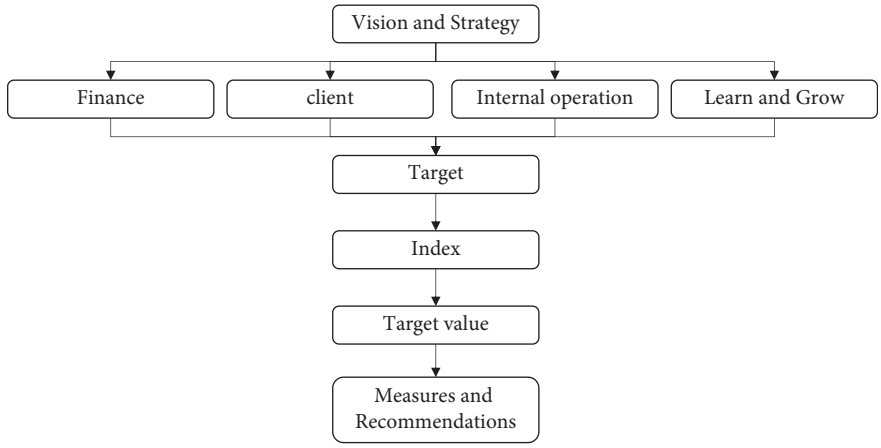

Figure 2: The strategy elaboration process.

experience in the theoretical and practical circles, this paper argues that the smooth implementation of the Balanced Scorecard requires enterprises to have the following basic conditions [25, 26].

(1) Businesses have clear and correct strategic goals.
(2) The company has a relatively complete organizational structure.
(3) The company has a relatively stable operating status.
(4) Enterprises have a sound information platform.
(5) The introduction of the Balanced Scorecard requires the approval of personnel at all levels of the enterprise.

3. Analysis of Problems and Reasons in the Process of Company Performance Appraisal

3.1. Introduction to the Company's Human Resources. Company A currently has a total of 4,522 employees, including 1,276 self-employed employees, 1,751 dispatched employees, and 1,495 employed employees. There are 1,357 middle-level and above managers and 3,165 other employees. The company has 1,112 senior engineers, 1,365 intermediate engineers, and 1,145 junior and below personnel. Doctoral degree accounted for 5.2%. Master's degree accounted for 15.8%. Bachelor degree accounted for 48%. College degree accounted for 25%. Others accounted for 6%. The proportion of employees at each level of Company A is shown in Figure 3.

In 2022, Company A will add 217 new employees, including 118 school recruits, 99 social recruits, and 6 job transfers. Company A reduces 201 employees, of which 192 are resigned, 5 are transferred out, and 4 are retired. The employee turnover rate is 14%. The employee turnover rate decreases by 2 percentage points from the previous year. The turnover rate of undergraduates and above was 6.6%, a decrease of 2.5 percentage points from the previous year (as shown in Figure 4).

3.2. Performance Appraisal Method for the Company. Company A has established a "target-performance" full-staff assessment system. The company develops a schedule at the beginning of the year. The person in charge of the department signs the target responsibility guarantee with the company. The company needs to sign a target responsibility letter with the person in charge of party building, business performance, quality management, safety production, and environmental management. At the end of the year, the assessment will be carried out according to the degree of completion of the plan. This is the basis for evaluating the performance salary of the department. Employee appraisal is similar to department appraisal. At the beginning of the year, set personal annual goals according to the content of departmental goals and responsibilities. At the end of the year, it will be reviewed according to the completion of the target. The results of performance appraisal are used in the evaluation of excellence, salary adjustment, job promotion, and job resignation.

3.3. Problems with Performance Appraisal. Through the exploration of the performance appraisal model of Company A, the following questions can be obtained.

(1) The proportion of management positions in the company is relatively reasonable. The company's management staff accounted for 29.8%. According to the French Graicunas theory, when the proportion of management talents in the organization is more than 20%, the organization's management of personnel is relatively less complex and easier to control. It can be seen that the proportion of management personnel of the company is more appropriate according to this theory.
(2) A shortage of high-end talent: the proportion of senior engineers in the company is 24.2%, and the proportion of graduates or above is only 21%. This shows that Company A lacks high-end technical talents. There is an urgent need to introduce favorable measures to attract high-level technical talents or to strengthen the training of internal employees. It can enrich the proportion of high-end technical personnel in the enterprise.
(3) The brain drain rate of the companies is relatively high. The employee turnover rate of Company A in

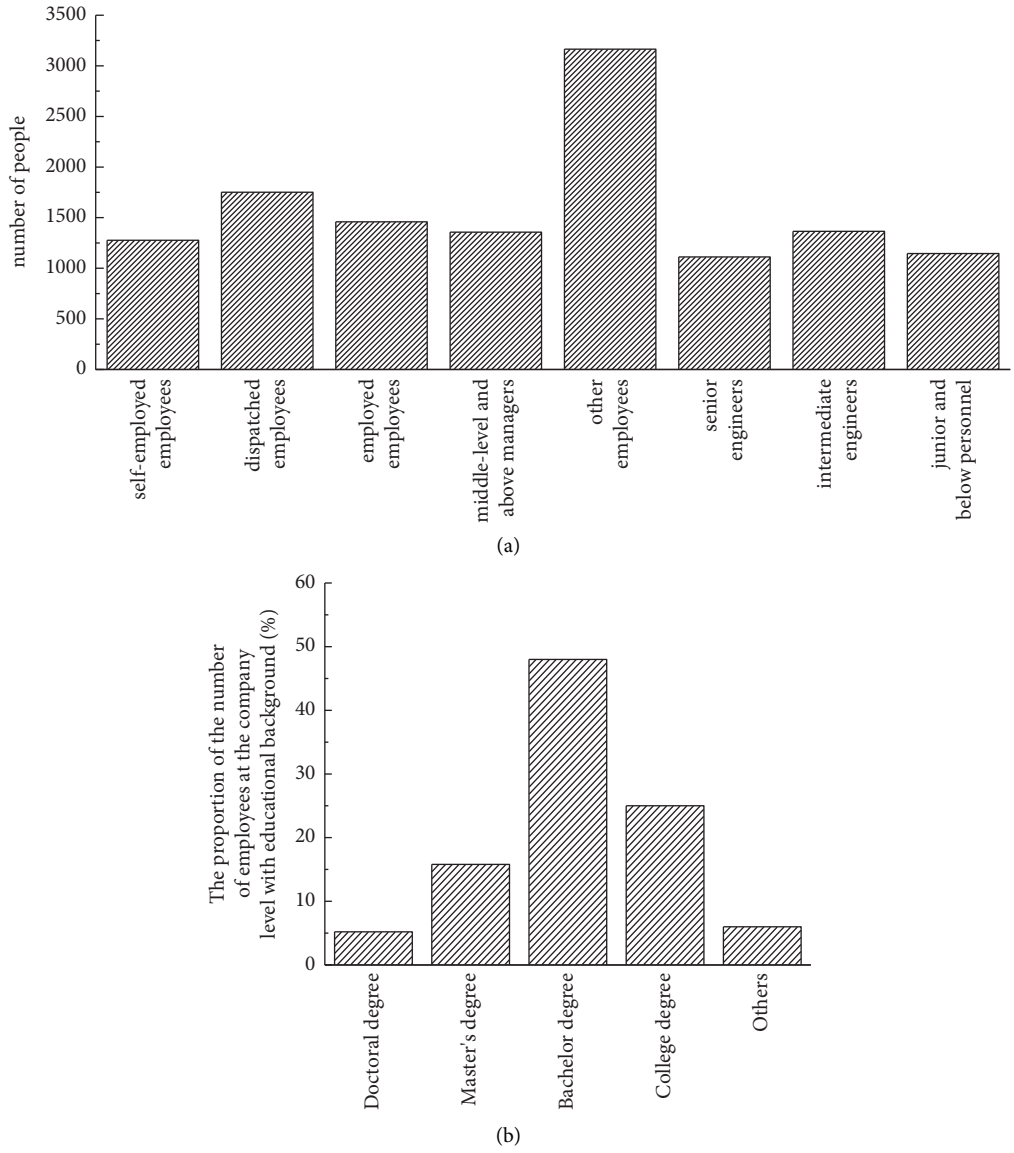

Figure 3: The proportion of employees at each level of Company A. (a) The number of company personnel. (b) The proportion of the number of employees at the company level with educational background.

2022 is 14%, a decrease of 2 percentage points from the previous year. Among them, the turnover rate of undergraduates and above is 6.6%, a decrease of 2.5 percentage points from the previous year. Although it is lower than that in 2021, the high brain drain rate will still bring great losses to enterprises. It shows that the company's human resource management needs to be further strengthened.

(4) Company A's performance appraisal belongs to the "MBO + 360" (target-performance appraisal method + comprehensive performance appraisal method) comprehensive appraisal model. This model can not only implement the overall goals and responsibilities to the established responsible persons, but also avoid problems such as unequal levels of authority and unclear powers. At the same time, the subjective evaluation of various sources of information caused by this model is relatively strong, and the degree of objectivity is not enough. It is difficult to compare the job performance of different employees and different departments horizontally, and it is impossible to provide a basis for employee promotion decisions.

MBO refers to the measurement of employees' achievement of set goals and implementation of work standards according to certain indicators or evaluation standards. Corresponding rewards can be given according to the measurement results. It is an evaluation method for employees under the system of "target management" implemented in the whole organization.

The 360 performance appraisal theory comes from the British Army think tank and is fully developed at Intel. It is a method of evaluating people from all angles and from all perspectives by themselves, their supervisors, direct deployment, colleagues, and even customers. Assessments may

include communication skills, interpersonal skills, leadership skills, administrative skills, and more.

3.4. Cause Analysis. Through the analysis of Company A's performance appraisal, it can be summed up in the following three points.

(1) The performance evaluation system focuses more on economic indicators. The performance evaluation system is not obvious for the exploration of the potential of the company's employees, which is not conducive to effectively improve the enthusiasm of employees.

(2) The backwardness of performance management concept: Company A is not strong enough in innovation awareness and is weak in accepting new management concepts. In recent years, the company has gradually increased the recruitment of outstanding business talents, but the introduction of management talents is not enough. The company's leadership and middle-level leaders are in urgent need of progress in learning and improving management concepts.

(3) Performance feedback is not strong enough. The company does not work hard enough on performance feedback. The company lacks a smooth communication mechanism from high level to middle level to the grassroots, which makes it impossible to detect problems and correct them in time. This is not conducive to the smooth progress of the company's overall performance management.

4. Establishment of Company A Performance Evaluation System Based on Balanced Scorecard

4.1. The Principle of Setting Up the Performance Evaluation System [27–29]

4.1.1. Scientific Principle. The scientific principle refers to the design of an evaluation index system that can objectively and correctly reflect the status of the enterprise through scientific methods.

4.1.2. The Principle of Specificity. The principle of specificity means that the evaluation index is a specific and clear index. It is a targeted indicator that can be proposed on a specific aspect of the e-commerce business performance, rather than a vague and unclear indicator.

4.1.3. Measurable Principle. The principle of measurability means that the evaluation index of the evaluation index system should be measurable. No matter how perfect and beautiful an evaluation index system is, the relevant data of its indexes should be available and can be quantified and easily calculated.

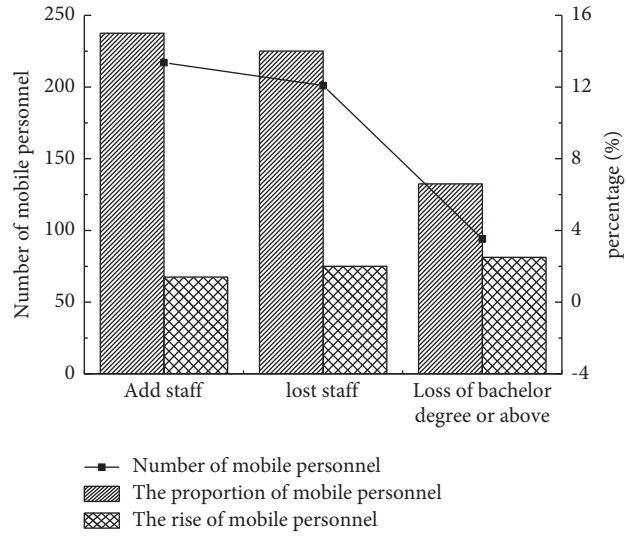

Figure 4: The flow of personnel in the company.

4.1.4. The Principle of Achievability. The principle of achievability means that the specific indicators in the evaluation index system can be adopted by relevant personnel and departments and applied to practical work.

4.1.5. General Comparability Principle. The general comparability principle means that the purpose of performance evaluation is not only to require the managers of the enterprise to master and implement the performance evaluation system, but also to make it understandable by stakeholders such as investors and creditors.

4.1.6. Incentive Principle. The incentive principle refers to the evaluation of the performance of the enterprise to judge whether the enterprise goal has been achieved and the current operation status of the enterprise.

4.1.7. Cost-Effectiveness Principle. The cost-benefit principle means that the performance evaluation system is formulated with the purpose of helping enterprises to make profits.

4.2. Determination of Evaluation Index Based on Balanced Scorecard. Based on the principle of performance evaluation, this paper selects some representative indicators that can reflect the performance of Company A.

Starting from the financial dimension (A1), four specific measurement indicators including current asset turnover ratio (b1), inventory turnover ratio (b2), cost profit margin (b3), and sales gross profit margin (b4) have been set. From the customer dimension's (A2) point of view, four specific indicators of market share (b5), customer retention rate (b6), customer acquisition rate (b7), and new click-through rate (b8) have been set. From the perspective of internal operation dimension (A3), four specific measurement indicators including the variety and quantity of commodities (b9), the out-of-stock rate of commodities (b10), the number of payment methods (b11), and the on-time delivery rate of

commodities (b12) have been set. Based on the dimension of learning and growth (A4), four specific indicators including employee loyalty (b13), employee ability (b14), employee motivation (b15), and employee efficiency (b16) are set up.

4.3. Determination of Weights of Performance Evaluation Indicators Based on AHP (Analytic Hierarchy Process)

4.3.1. Constructed Judgment Matrix. The relative importance of the four dimensions of finance, customers, internal operations, and learning and growth are scored. The relative importance of the indicators under each dimension level is scored, and the judgment matrix is constructed by these methods. The mutual importance of each index is judged, and B_{ij} represents the relative importance of B_i to B_j (as shown in Table 1).

4.3.2. Determining the Weight Coefficient of Single-Level Sorting. To determine the largest eigenvector and largest eigenroot of the matrix A, the sorting value can be obtained by solving $A * W =$.

4.3.3. Consistency Check. The next step after calculating the weights is to perform a consistency check. The final calculated results are analyzed, and it is judged whether the constructed judgment matrix can pass the consistency test. If it can pass the consistency test, it means that the specific weight of each evaluation index determined is reasonable. The judgment matrix can be constructed using YAAHP software, and the consistency will be automatically detected by the system.

4.3.4. The Total Ranking and Composite Weight of Each Level Index in Performance Evaluation. Through the calculation of the target layer, the criterion layer, and the scheme layer, this paper takes the value of a group of elements obtained in the scheme layer as the weight value of an element in the corresponding previous layer. This paper finally gets the final weight value of each element. The last layer of the scheme is used as the weight of the target ranking of this article, so as to facilitate the selection of the scheme in this article. The final weight value is obtained by synthesizing the weight value under the single criterion from top to bottom, and then the overall weight values are sorted. The specific synthesis method is to multiply the weight of the index layer relative to the criterion layer by the weight of the criterion layer relative to the target layer. By obtaining the composite weight of the index layer relative to the target layer, the final total ranking of the layers is obtained.

5. Comprehensive Evaluation of Performance Based on Fuzzy Comprehensive Analysis

5.1. Constructing the Index Factor Set. The first step of fuzzy comprehensive evaluation is to establish an index factor set [30]. It is a collection of various elements that affect the evaluation object. The model of the factor set is expressed as follows.

Table 1: Importance judgment matrix.

	B_1	B_2	...	B_n
B_1	1	B_{12}	...	B_{1n}
B_2	B_{21}	1	...	B_{2n}
...	...	...	1	...
B_n	B_{n1}	B_{n2}	...	1

$$U = (U_1, U_2, U_3, U_4), \tag{1}$$

where U is the factor set.

The subfactor sets are

$$\begin{cases} U_1 = (u_{11}, u_{12}, u_{13}, u_{14} \cdots) \\ U_2 = (u_{21}, u_{22}, u_{23}, u_{24} \cdots) \\ U_3 = (u_{31}, u_{32}, u_{33}, u_{34} \cdots) \\ U_4 = (u_{41}, u_{42}, u_{43}, u_{44} \cdots) \end{cases}, \tag{2}$$

where U_1, U_2, U_3, and U_4 are the subfactor sets. u_{ij} is the factors in a subfactor set.

5.2. Constructing the Language Comment Set. The language comment level is a set composed of the evaluation results of the object. The language rating scale is established as follows.

$$\begin{aligned} V &= (V_1, V_2, V_3, V_4, V_5) \\ &= (\text{very good, good, average, poor, very poor}), \end{aligned} \tag{3}$$

where V is the language comment set. V_n is the factor of language annotation sets.

5.3. Determining the Weight Vector Set. Since the importance of each indicator to the evaluation object is different, in order to distinguish the importance of each indicator from the evaluation object, a corresponding weight is assigned to each indicator. W is the indicator to determine the weight vector using AHP.

$$W = (W_1, W_2, W_3, \ldots, W_n), \tag{4}$$

where W_n is the weight vector.

5.4. Determining Indicator Membership. When the evaluation level is determined, a questionnaire survey method is used to obtain the evaluation value of each index. The membership degree R corresponding to the five comment levels is

$$R = (R_1, R_2, R_3, R_4), \tag{5}$$

where R_n is the set of factors in R.

The calculation of index membership is divided into two steps. The first step is to obtain the actual value of each index. The second step is to evaluate the actual value of each indicator by experts through a questionnaire survey.

6. Application of Performance Evaluation System Based on Balanced Scorecard in Company A

The four dimensions of finance, customers, internal operations, and learning and growth are set as the first-level evaluation indicators.

$$A = (A_1, A_2, A_3, A_4), \tag{6}$$

where A_1 represents finance, A_2 represents customers, A_3 represents internal operations, and A_4 represents learning and growth.

Based on the determined evaluation indicator, the second-level index factor set is determined.

$$\begin{cases} A_1 = (b_1, b_2, b_3, b_4) \\ A_2 = (b_5, b_6, b_7, b_8) \\ A_3 = (b_9, b_{10}, b_{11}, b_{12}) \\ A_4 = (b_{12}, b_{14}, b_{15}, b_{16}) \end{cases}. \tag{7}$$

Based on the performance evaluation index hierarchy chart, the relative importance of each index in the analytic hierarchy process is compared. After combining the opinions of experts and individuals, the following judgment matrix can be obtained.

$$\begin{aligned} A &= \begin{bmatrix} 1 & 2 & 3 & 3 \\ 1/2 & 1 & 2 & 3 \\ 1/3 & 1/2 & 1 & 2 \\ 1/3 & 1/3 & 1/2 & 1 \end{bmatrix}, \\ A_1 &= \begin{bmatrix} 1 & 1/2 & 1/5 & 1/4 \\ 2 & 1 & 1/4 & 1/3 \\ 5 & 4 & 1 & 3 \\ 4 & 3 & 1/3 & 1 \end{bmatrix}, \\ A_2 &= \begin{bmatrix} 1 & 3 & 2 & 4 \\ 1/3 & 1 & 1/2 & 2 \\ 1/2 & 2 & 1 & 3 \\ 1/4 & 1/2 & 1/4 & 1 \end{bmatrix}, \\ A_3 &= \begin{bmatrix} 1 & 3 & 5 & 2 \\ 1/3 & 1 & 3 & 2 \\ 1/5 & 1/3 & 1 & 1/2 \\ 1/4 & 1/2 & 2 & 1 \end{bmatrix}, \\ A_4 &= \begin{bmatrix} 1 & 1/2 & 2 & 1/5 \\ 2 & 1 & 2 & 1/5 \\ 1/2 & 1/2 & 1 & 1/3 \\ 5 & 5 & 3 & 1 \end{bmatrix}. \end{aligned} \tag{8}$$

All the above judgment matrices pass the systematic consistency test. Based on the above data, the weights of all 16 indicators for the performance evaluation of Company A are automatically calculated by the YAAHP software. Figure 5 shows the index weights of each layer and the total ranking weight.

Taking the obtained actual data of Company A in 2022 as an example, the index membership degree is calculated. The performance indicators of Company A are shown in Figure 6.

Through a questionnaire survey of 20 experts from Company A, the scoring results of the indicator data are shown in Figure 7.

The reliability of the questionnaire is analyzed. The Alpha (reliability test coefficient) coefficient is often used as an indicator to measure the reliability. The smaller the Alpha coefficient value, the smaller the reliability, and otherwise the higher. There is no uniform standard for the numerical size of the reliability coefficient. In general, when Alpha > 0.9, the reliability is very good. When $0.8 \le \text{Alpha} \le 0.9$, it means that the reliability can be accepted. When $0.7 \le \text{Alpha} \le 0.8$, it means that the scale needs to be greatly revised, but it is still useful. When Alpha < 0.8, it means that the questionnaire should be redesigned. The reliability coefficient of this part is 0.866, indicating that the reliability is acceptable.

6.1. Fuzzy Comprehensive Evaluation. The judgment matrix of financial A_1 is

$$R_1 = \begin{bmatrix} 1/20 & 1/5 & 7/10 & 1/20 & 0 \\ 1/20 & 3/10 & 3/5 & 1/20 & 0 \\ 0 & 7/20 & 7/20 & 3/10 & 0 \\ 2/5 & 2/5 & 1/5 & 0 & 0 \end{bmatrix}. \tag{9}$$

According to the weight of each index of the financial dimension, the matrix A_1 is calculated.

$$A_1 = (0.117, 0.333, 0.357, 0.170, 0). \tag{10}$$

The judgment matrix of customer A_2 is

$$R_2 = \begin{bmatrix} 3/10 & 2/5 & 3/10 & 0 & 0 \\ 1/10 & 3/5 & 3/10 & 0 & 0 \\ 1/20 & 1/5 & 11/20 & 3/20 & 1/20 \\ 0 & 2/5 & 2/5 & 1/10 & 1/10 \end{bmatrix}. \tag{11}$$

According to the weight of each index of the customer dimension, the matrix A_2 is calculated.

$$A_2 = (0.170, 0.377, 0.379, 0.051, 0.023). \tag{12}$$

The judgment matrix of internal operations A_3 is

$$R_3 = \begin{bmatrix} 3/5 & 1/5 & 1/5 & 0 & 0 \\ 1/10 & 1/2 & 2/5 & 0 & 0 \\ 7/10 & 1/5 & 1/20 & 1/20 & 0 \\ 4/5 & 1/10 & 1/10 & 0 & 0 \end{bmatrix}. \tag{13}$$

According to the weight of each index of the internal operations dimensions, the matrix A_3 is calculated.

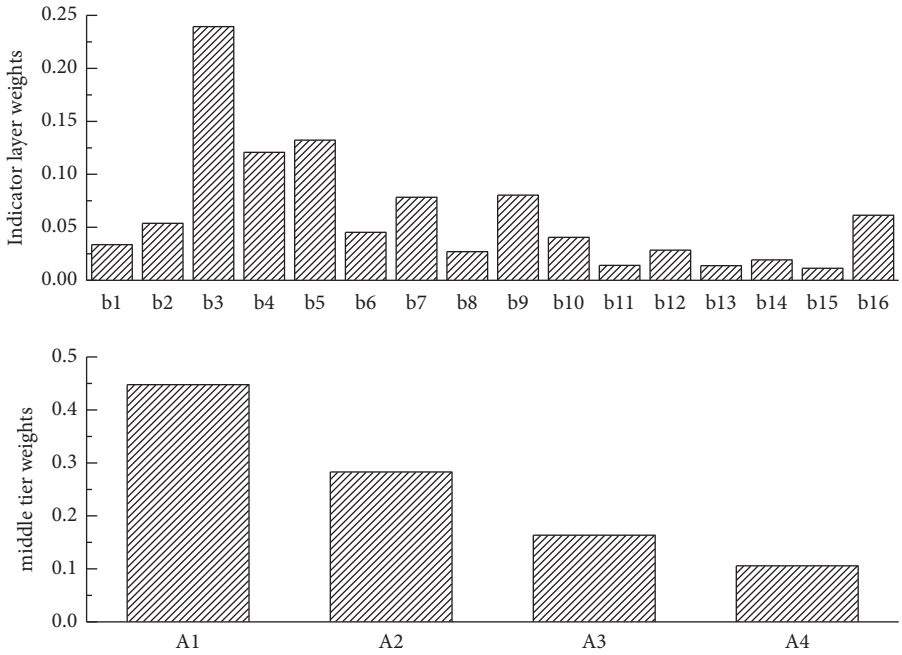

Figure 5: The weight of each layer index and the total ranking weight.

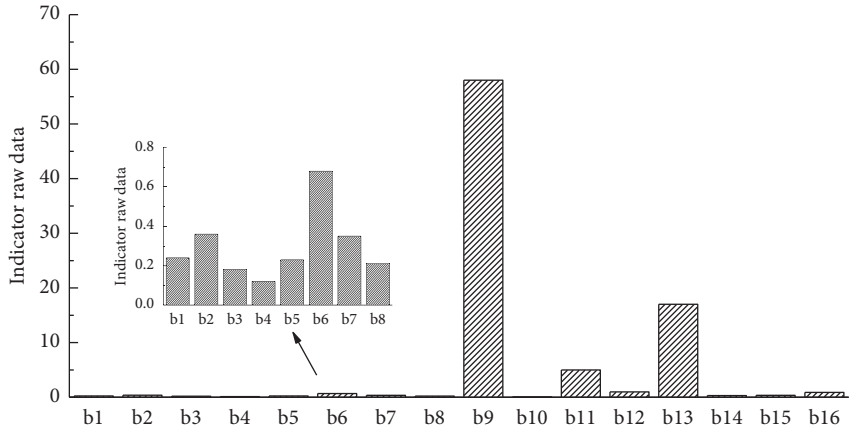

Figure 6: The performance indicators of Company A.

$$A_3 = (0.520, 0.257, 0.219, 0.004, 0). \tag{14}$$

The judgment matrix of learning and growth A_4 is

$$R_4 = \begin{bmatrix} 1/10 & 1/4 & 3/5 & 1/20 & 0 \\ 7/10 & 3/20 & 1/10 & 1/20 & 0 \\ 1/20 & 1/5 & 7/10 & 1/20 & 0 \\ 1/2 & 2/5 & 1/20 & 1/20 & 0 \end{bmatrix}. \tag{15}$$

According to the weight of each index of the learning and growth dimensions, the matrix A_4 is calculated.

$$A_4 = (0.436, 0.314, 0.201, 0.050, 0). \tag{16}$$

From the above calculation data, the judgment matrix R of the first-level index can be obtained as

$$R = \begin{bmatrix} 0.118 & 0.333 & 0.366 & 0.170 & 0 \\ 0.170 & 0.377 & 0.379 & 0.051 & 0.023 \\ 0.058 & 0.257 & 0.219 & 0.004 & 0 \\ 0.436 & 0.313 & 0.201 & 0.050 & 0 \end{bmatrix}. \tag{17}$$

By combining formula (17), the matrix A can be obtained.

$$A_4 = (0.232, 0.331, 0.328, 0.097, 0.007). \tag{18}$$

Figure 8 shows the overall budget performance evaluation results of Company A in 2022.

According to the results of the above fuzzy evaluation, scores are in a percentage system. By assigning different weights to the five levels (very good, good, fair, poor, and

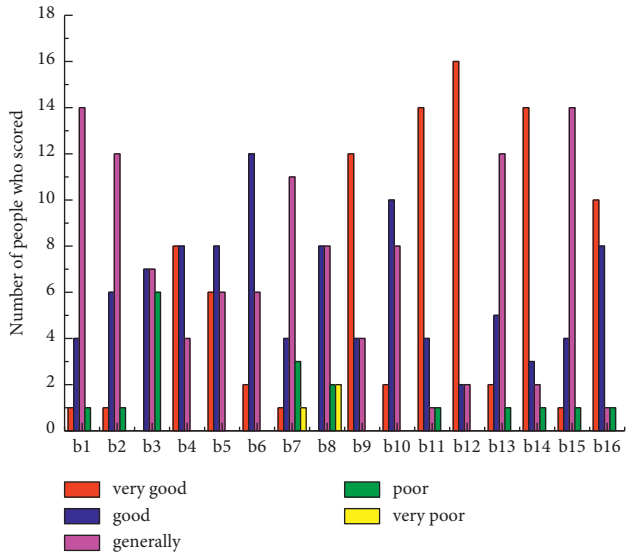

Figure 7: The expert scoring results of the indicator data.

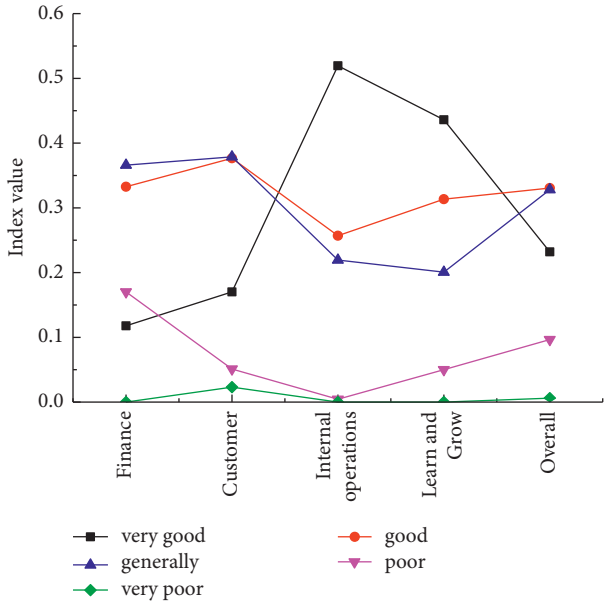

Figure 8: Overall budget performance evaluation results in 2022.

very poor), the weights are (90, 75, 60, 45, and 30). According to the above comprehensive evaluation results, the comprehensive score of performance evaluation of Company A in 2022 is calculated as 70.

7. Comprehensive Analysis of Evaluation Results and Suggestions for Improving Performance

Specifically, Company A can improve its performance level from the following four aspects.

7.1. Financial-Level Advice. Company A's financial performance evaluation level is average. The company needs to make efforts at the financial level to improve its performance level. First, because the enterprise mainly conducts marketing through the network platform, the enterprise can strengthen the effective use of the network sales platform. Company A needs to reduce the cost of product sales to achieve the result of increasing product profit margins. Secondly, the network market has great potential for exploration and development. Enterprises can vigorously develop the potential customer groups in this market, so as to achieve the purpose of increasing their sales revenue. Finally, the investment in sales plays a very important role in the development of the enterprise.

7.2. Customer-Level Advice. The level of customer performance of the firm is average. The company needs to make efforts at the customer level to improve its own performance level. First, businesses still need to maximize customer satisfaction. This can reduce the operating cost of the enterprise. As the differences in the means of competition among competitors in the e-commerce industry are decreasing day by day, individual e-commerce companies in the industry are striving to optimize their service quality and widen the gap with their competitors in terms of service quality.

7.3. Internal Operational-Level Advice. The internal operation level of the enterprise is very good. This result shows that the enterprise attaches great importance to the internal operation of the enterprise. But there are still some steps to be taken to improve the internal operation of the enterprise. First, more product styles can be developed and the number of varieties of goods can be increased. Secondly, it is necessary to ensure the supply of sources of goods and sufficient inventory, so as to ensure the supply of goods and reduce the rate of shortage of goods. Again, more payment methods can be provided to facilitate customers to make payments. Finally, a logistics company with fast logistics can be chosen and the on-time delivery rate of goods can be improved.

7.4. Learning and Growth Level Advice. The learning and growth performance level of the enterprise is very good. The enterprise can maintain the learning and growth performance level of the enterprise from the following aspects. First of all, it can improve the wages and benefits of employees. Excellent employees can be retained as much as possible and the personnel turnover rate can be reduced. Then, employees can be encouraged to express their opinions. Opinions that are beneficial to the development of the enterprise should be considered for adoption. Secondly, regular training can be carried out to improve the relevant professional level of employees, so as to provide better service to customers. Third, through the reasonable organization and configuration of the employees of the enterprise, the talents are dedicated. Through education and training to improve the professional level and quality of employees, the labor productivity of employees has been improved.

8. Conclusions

As an important management method of an enterprise, performance appraisal occupies an important position in the long-term development of an enterprise. Scientific performance appraisal can not only effectively improve individual performance at the employee level, but also achieve performance goals at the organizational level, so as to achieve the strategic goal of long-term development of the enterprise. Therefore, this paper adopts the Balanced Scorecard theory to evaluate the internal economic management and performance of enterprises.

According to the results of the above fuzzy evaluation, scores are in a percentage system. By assigning different weights to the five levels (very good, good, fair, poor, and very poor), the weights are (90, 75, 60, 45, and 30). According to the above comprehensive evaluation results, the comprehensive score of performance evaluation of Company A in 2022 is calculated as 70. Through the evaluation results, it can be seen that the financial performance evaluation level of the enterprise is general. The level of customer performance of the firm is average. The internal operation level of the enterprise is very good. The learning and growth performance level of the enterprise is very good.

Aiming at the specific problems of Company A obtained from the analysis, the corresponding suggestions for improving Company A's performance are put forward. Corresponding suggestions are made from the four perspectives of finance, customer, internal operation, and learning and growth. It is hoped that Company A can achieve better and faster development by taking these measures.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Risk Assessment of OFDI for Technology-Based Enterprises under the Background of "One Belt One Road"

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With the proposal of "One Belt One Road" initiative, more and more technology-driven enterprises in China are going abroad for foreign direct investment (FDI). But at the same time, due to the special geographical location of the countries along the "Belt and Road," the turbulent geopolitical pattern, weak economic growth, and constant conflicts between religious civilizations, all these will make Chinese technology-driven enterprises' investment in the countries along the "Belt and Road" face a nonnegligible risk. Thus, how to correctly assess and reasonably prevent OFDI risk has become urgent task for enterprises. This paper takes 20 countries along the "Belt and Road" as the research object and combines the characteristics of technology-oriented enterprises to determine the risk assessment indicators at all levels from four aspects: politics and policy, economy and finance, society and culture, and technological risks. Using fuzzy cluster analysis, the countries along the "Belt and Road" are classified into four groups: low, medium-low, medium-high, and high risks and corresponding countermeasures are proposed. Technology-oriented enterprises should raise their political risk awareness, comprehensively assess the economic and financial environment of host countries before making FDIs, implement "localized" operation and management, and pay attention to the protection of intellectual property rights.

1. Introduction

With the proposal of the "One Belt, One Road" initiative, more and more technology-driven enterprises have begun to go abroad to conduct foreign direct investment, covering 14 industries such as transportation, tourism, technology, real estate, metals, and logistics. In 2020, China's foreign direct investment was US $132.9 billion, ranking among the top in the world. Among them, the nonfinancial direct investment in countries along the "Belt and Road" was 17.79 billion US dollars, an increase of 18.3%. In particular, investment in key industries achieved rapid growth, with investment in equipment manufacturing, information technology, scientific research, and technical services increasing by 21.9%, 9.6%, and 18.1%, respectively.

But at the same time, there are many problems in the countries along the "Belt and Road," such as turbulent geopolitical structure, unbalanced economic structure, weak growth, and conflicts between religions and civilizations, which make Chinese technology-driven enterprises' investment in the countries along the "Belt and Road" face a nonnegligible risk.

Therefore, according to the characteristics of technology-based enterprises, a reasonable assessment of risks in countries along the "Belt and Road" should be conducted to help Chinese technology-driven enterprises objectively understand the investment opportunities and risks in the "Belt and Road" regions and strengthen their grasp of the overseas investment environment. Furthermore, it improves the ability to prevent and control foreign direct investment risks. This is of great significance and also the research value of this paper.

Specifically, this paper attempts to select corresponding evaluation indicators from four dimensions of political policy, economy and finance, social culture, and technology, and uses the fuzzy clustering analysis method to conduct country risk analysis on 20 emerging countries along the "Belt and Road". The results corresponded to 4 groups of low

risk, medium-low risk, medium-high risk, and high risk, respectively. And put forward corresponding countermeasures and suggestions: technology-driven enterprises should comprehensively improve their awareness of political risk prevention, comprehensively assess the economic and financial environment of the host country before foreign direct investment, implement "localized" management, and pay attention to the protection of intellectual property rights.

2. Related Work

Currently, there are many domestic and foreign research literature studies on the OFDI risks of the "Belt and Road," and most of the research results are mainly made by Chinese scholars. Zhu and Yang [1] introduced the ICRG country risk indicator and found that Chinese enterprises' investments along the "Belt and Road" have significant political risk and financial risk preference. Sun et al. [2] used SWOT analysis to divide countries along the "Belt and Road" into four types and proposed differentiated strategies according to different types of investment risks. Song and Liang [3] used the mutation series method to construct a country's risk assessment model and conducted a quantitative study on the investment risk level of countries along the "Belt and Road." Hu and Wang [4] used the method of multivariate statistical analysis to quantitatively analyze the risks of 65 countries along the "Belt and Road" and believed that the countries along the "Belt and Road" had relatively high country risks, among which the political risk factor was the most important factor. Zhou et al. [5] pointed out that among the countries along the "Belt and Road," China's OFDI in most Central and Eastern European countries has relatively small political, economic, and financial risks, while social and cultural risks are generally large.

However, the research on the risk of foreign direct investment by technology-driven enterprises is still limited. Zhou [6] contended that risks regarding product development, technology leakage, technology introduction, and technology barriers are the main risks encountered by high-tech Chinese enterprises in overseas operations. Dai [7] argued that in countries that are more conservative with foreign investment and which, for example, impose high taxes on foreign-funded enterprises and do not allow them to participate in domestic science and technology programs, technology-based enterprises intending to invest in these countries will face higher risk of policy changes. Shen and Chen [8] pointed out that, in the context of rigorous industry regulation, host country governments try to prevent foreign companies from acquiring important domestic enterprises to protect their own national security and develop their own weak industries. For capital-intensive technology-based companies, political risks may turn their investments into sunk costs that are difficult to recover, and the payback period of investments will also be elongated.

Qiu and Deng [9] pointed out that the degree of protecting intellectual property rights in countries along the "Belt and Road" is generally low, which will expose Chinese technology-based companies to the risk that their intellectual property might be acquired by the countries that their investment goes to. Fang and Song [10] believe that as many as five intellectual property-related risks are associated with trademark operation, namely, infringement of independent patents, disclosure of trade secrets, intellectual property assessment in cross-border mergers, acquisitions, and intellectual property barriers in countries along the "Belt and Road" will be the biggest obstacles to OFDI for Chinese companies in the context of the "Belt and Road" initiative. Ma and Shi [11] explored the causes of intellectual property-related risks from five viewpoints, namely, policies and laws and regulations, capital market, management, technology, and education, and put forward countermeasures and suggestions for establishing and improving China's investment system against intellectual property-related risks.

To sum up, there are not many studies on the risk of foreign direct investment by technology-based enterprises. The research mainly focuses on risk classification and intellectual property rights, and there are few studies on the country risk of countries along the "Belt and Road" [12–14]. This paper hopes to make useful additions in this regard.

3. Research Method

3.1. Selection of Evaluation Indicators. This article considers the characteristics of technology-based enterprises and the various risk factors that may be encountered in investment in countries along the "Belt and Road" and attempts to determine the indicators of risk assessment at all levels, from the political policy, economy and finance, social culture, and technology perspectives (see Table 1).

3.1.1. Political Policy-Related Risk. Political policy-relatd risk is one of the important risks in OFDI country risk under the background of "Belt and Road." The most remarkable difference between political policy-related risk and other types of risks is that it is largely caused by government actions. This kind of risk will entail immense losses to enterprises because political policy-related risks are highly uncertain, and it is often difficult for enterprises to predict and respond promptly. We select five indicators to measure it, namely, political stability, the degree of government corruption, policy changes, military intervention, and legal perfection.

3.1.2. Economic and Financial Risks. Economic and financial risks mainly refer to the possibility of changes in the market environment because of changes in the economic structure of the host country or changes in the financial market, which will cause losses to the investment returns of enterprises. The risk indicators that bear on the economy and finance include inflation, exchange rate fluctuation, unemployment rate, and per capita national income.

3.1.3. Sociocultural Risks. The differences in social environment and culture between China and the host countries will cause uncertainty for the OFDI of Chinese companies. When enterprises make foreign investments, whether they

Table 1: System of risk indicators.

Tier 1 indicator	Tier 2 indicator	
Political policy	Political stability	X_1
	Degree of government corruption	X_2
	Policy changes	X_3
	Military intervention	X_4
	Legal perfection	X_5
Economy and finance	Inflation	X_6
	Exchange rate fluctuation	X_7
	Unemployment rate	X_8
	Per capita national income	X_9
Socioculture	Education level of the populace	X_{10}
	Religious beliefs	X_{11}
Technology	Number of R&D personnel	X_{12}
	R&D expenditure/GDP	X_{13}
	High-tech products/exported finished products	X_{14}

can adapt to the local market environment remains an important factor when making decisions on investment and production. The indicators for measuring these risks include the education level of the populace and their religious beliefs.

3.1.4. Technical Risks. The key to maintaining and enlarging the competitive advantage of an enterprise is to continuously improve its technological level to maintain the vitality of enterprise development. The risks involved are mainly concerning the R&D, introduction, and protection of technology. Among them, the risk regarding technology R&D and technology introduction is mainly caused by the host country's lack of technical resources and the decline in its technological level. Therefore, the number of R&D personnel in various countries, the proportion of R&D expenditure in GDP, and the proportion of high-tech products in exported finished products are adopted as the indicators. The risk of technological protection is measured by the indicator of legal perfection. Given that the legal system has been used as the indicator in the measurement of political risk, it will not be reused in this article.

3.2. Sample Selection and Data Sources. Considering the availability of data, we select 20 countries along the Belt and Road as the research object, namely, those in Asia, including Singapore, Malaysia, Indonesia, Philippines, India, Thailand, Turkey, Israel, Saudi Arabia, UAE, Greece, Egypt, and Kazakhstan, and those in Central and Eastern Europe, namely, Russia, Ukraine, Hungary, Czech Republic, Poland, Romania, and Bulgaria [15]. These 20 countries are dominated by emerging economies, which include only five developed economies, namely, Singapore, Israel, Greece, the Czech Republic, and Hungary [16–18].

The data are mainly derived from the World Bank's Worldwide Governance Indicators (WGI) database, World Development Indicators (WDI) database, National Bureau of Statistics, Ministry of Commerce, and The Hofstede Center. All data are collected from 2009 to 2018.

3.3. Empirical Analysis and Results

3.3.1. Normalization of Risk Indicators. Given the considerable difference in order of magnitude and different directions among the indicators, each secondary indicator must be standardized to transform them into a dimensionless indicator within the range of [0, 1]. In addition, the data direction is unified: the larger the value, the smaller the risk. The normalization equation is as follows:

$$W_{ij} = \frac{X_{ij} - \min(\max) X_i}{\max(\min) X_i - \min(\max) X_i}. \quad (1)$$

In the equation, X_{ij} represents the ith risk value of country j, X_i represents the ith risk value of all sample countries, and W_{ij} represents the normalized risk value of the ith risk indicator of the jth host country.

3.3.2. Build Fuzzy Similarity Matrix. Let X and Y be two nonempty sets, then a fuzzy subset $\widehat{R}$ of the direct product $X \cdot Y = \{(x, y)(x \in X \mid y \in Y)\}$ is called a fuzzy relation from X to Y. The affiliation function $\delta\widetilde{R}$: $X \cdot Y \longrightarrow [0, 1]$ is used to describe the fuzzy relation $\widehat{R}$, a real number inside $[0, 1]$ is used to measure the case that two elements belong to the same set, which is called the affiliation degree and reflects the degree of correlation of (x, y) under the fuzzy relation $\widehat{R}$, denoted as $\widehat{R}(x, y)$. When and only when fuzzy relation satisfies, then

(1) Reflexivity: $\widehat{R}(x, x) = 1$

(2) Symmetry: $\widehat{R}(x, y) = \widehat{R}(y, x)$

At this point, $\widehat{R}(x, y)$ denotes the degree of similarity between x and y.

3.3.3. Cluster Analysis. Based on the fuzzy similarity matrix obtained above, the minimum fuzzy transfer matrix can be solved by the least squares method, i.e., the fuzzy equivalence matrix. The specific algorithm starts from the fuzzy similarity matrix R and iteratively self-multiplies to find R^2, R^4, ... when the first occurrence of $R^\tau \cdot R^\tau = R^\tau$ is the transfer closure, which is also called the fuzzy equivalence matrix.

In the actual clustering, the elements of the fuzzy equivalence matrix are assigned to θ, in order of their numerical magnitude, the θ is used for truncating matrix; that is, the elements of the fuzzy equivalence matrix are compared with different θ, and if the elements of the matrix $A_{ij} = \theta$, the indicator x_i and indicator x_j are clustered into one category, thus obtaining different classifications, and so on. The determination of the value θ during the classification is usually based on the actual situation (e.g., the number of classifications desired) to select, and the final classification results is obtained by the value of θ.

On the basis of the results of the cluster analysis, the 20 countries along the Belt and Road are divided into four groups according to low-risk (A), medium-low-risk (BBB), medium-high-risk (BB), and high-risk levels (B). See Table 2 for details.

Table 2: Risk assessment of OFDI by technology-based enterprises in countries along the "Belt and Road."

Country	Risk level	Group
Singapore	A	1
Malaysia Israel UAE Hungary Czech Poland Romania	BBB	2
Indonesia Philippines India Thailand Turkey Saudi Arab Greece Kazakhstan Russia Bulgaria	BB	3
Egypt Ukraine	B	4

Table 2 reveals that the only low-risk country in the first group is Singapore, a developed country. This is largely attributable to Singapore's perfect infrastructure, social stability, sound legal environment, and clean and efficient business environment.

There are seven moderately low-risk countries in the second group, in which Israel and the Czech Republic are developed countries. Among the countries in the Middle East, the Israeli government transfers power very stably, affords good policy continuity, and creates relatively low investment risks. The Czech Republic ranks 29th among 140 countries and regions in terms of global competitiveness, it ranks 35th among 190 global economies in terms of business environment where the investment risk is relatively low.

As many as 10 moderately-high-risk countries appear in the third group, and only Greece is a developed country. After being hit hard by the European debt crisis, the current investment environment in Greece is improving by degrees, but appreciable risks exist for investors.

The highest-risk countries in Group 4 are Egypt and Ukraine, of which the political situation and economy have been turbulent and where policies are unsustainable, hence investor confidence is insufficient and investment risks are high.

4. Suggestion and Discussion

4.1. Raise the Awareness of Political Risk Prevention. When faced with international competition and making FDIs, Chinese technology-based enterprises should actively examine the political environment of the host country in advance, especially the laws, regulations, and policy restrictions concerning technology protection. Priority should be given to FDIs in low-risk and moderately-low-risk regions. If investment in moderately-high-risk and high-risk regions is necessitated by business needs, applying for political risk guarantees for overseas investment can be an option. If the investment is damaged due to political risks, the People's Insurance Company of China can bear up to 90% of the risk responsibility [19].

Due to the complexity of political risks, enterprises cannot rely on their own strength to avoid all risks. Therefore, inter-governmental communication is an important way to promote and ensure enterprises' investment in countries along the "Belt and Road." The Chinese government should make the countries along the "Belt and Road fully aware of the benefits of the "Belt and Road" initiative, fully mobilize the enthusiasm of the countries along the "Belt and Road," and create a win-win concept of "Belt and Road" cooperation, so as to lay a good foundation for enterprises to "go global" smoothly. At the same time, the government should establish specialized information service agencies to regularly release reports regarding investment environment and risk assessment in different countries to help companies understand the political and economic environments of relevant countries in a timely manner to effectively avert investment risks. Policy support must be provided for some overseas investments of strategical significance, which, for example, are intended to acquire advanced foreign technology and expand markets and to help companies improve their relationships with local governments and reduce operational risks.

4.2. Comprehensively Assess the Host Country's Economic and Financial Environment. The government should organize relevant departments and experts to analyze the scientific research results, materials, and statistical data of the host country, and guide enterprises to conduct on-the-spot investigations to obtain first-hand information. Only by fully investigating and evaluating various investment indicators of the host country and comprehensively investigating its management model and financial status can enterprises reduce investment risks to the greatest extent.

In low-risk countries, such as Singapore, the economic and financial environment is relatively well developed, and more attention must be directed to assessing the development of their financial system, and technology-based companies can operate as sole proprietors. In moderate-risk countries, such as Malaysia and India, the impact of changes in their economic policies should be given deserved attention, and technology-based enterprises may be considered to reduce risks through joint ventures. In high-risk countries, such as Egypt and Ukraine, the economic and financial environment is underdeveloped, and companies should focus on assessing and preventing the indirect impact of industrial changes on the FDIs oriented to the acquisition of technologies. Concurrently, given the financing needs of technology-based enterprises, risks can be passed on to the host country's government, enterprises, or financial institutions through financing.

4.3. Implementation of "Localized" Management. Due to the differences in cultures and systems of countries along the "Belt and Road," Chinese enterprises need to follow the local

culture and management system and improve their ability to adapt to the environment in order to achieve the goals and strategies of overseas investment.

The business philosophy of "localization" encompasses multidimensional, multilevel connotations, including not only the localization of production management but also the localization of R&D and talent management [20]. Only by implementing "localized" business management and integrating the development of enterprises into the economic and cultural development of the host country can enterprises prevent risks caused by social and cultural differences to the utmost. They can seek support from overseas Chinese to gain an in-depth understanding of local customs and values, reduce differences in managerial notions between the two parties, and prevent the loss of important employees and high-quality customer resources.

4.4. Improve the R&D Capability and Reinforce Intellectual Property Protection. The government should strengthen the protection of intellectual property rights, form an efficient international intellectual property risk early warning and emergency response mechanism, build a foreign-related risk prevention and control system for intellectual property rights, and increase assistance to Chinese enterprises in overseas intellectual property rights protection.

Technology-based enterprises should try their best to enhance their own capability in scientific research and reinforce their own advantages in technological resources. After reaching the technical level required to absorb overseas reverse technology spillovers, they can make FDIs to reduce the risks concerning technology R&D. In addition, special attention should be paid to the host country's preferential policies, technological protection barriers, policy openness to accept investments, and preferential tax policies, which are aimed for cooperative R&D in high-tech industries, and they should prevent risks accompanying technology introduction. When making direct investments abroad, technology-based enterprises should equip themselves with the ability to protect their own intellectual property rights, and they should also be well informed about the local intellectual property laws in the host country to curb the risk of technology loss.

5. Conclusions

This paper focuses on assessing the comprehensive risks faced by technology-oriented enterprises when investing in countries along the "Belt and Road." For the 20 countries along the Belt and Road, four primary risk indicators are selected: politics and policy, economy and finance, society and culture, and technological risks, and further refined into 14 secondary risk indicators. Using fuzzy cluster analysis, similar indicators are clustered into one category to classify the risks of 20 countries along the Belt and Road into low-risk, medium-low-risk, medium-high-risk, and high-risk levels. The specific findings are as follows:

(1) The only low-risk country is Singapore, a developed country. Among the "Belt and Road" countries, Singapore is the safest country for investment, with perfect infrastructure, social stability, sound rule of law environment, and clean-fingered and efficient government. Standard & Poor's, Moody's, and Fitch all have "stable" sovereign rating outlooks for Singapore.

(2) There exist seven countries with medium-low risk, among which Israel and the Czech Republic are developed countries. Among the countries in the Middle East region, Israel has a smooth regime change and good policy continuity. The Czech Republic ranks among the top countries in the world in terms of global competitiveness and business environment. Hence, these two countries have low investment risks. The remaining five countries are not developed countries, but they have high levels of economic development, its political situation is basically stable, thus it is also ranked among them.

(3) There exist 10 high-risk countries, and only Greece is a developed country. After being hit by the European debt crisis, although the current investment environment in Greece is gradually improving, due to the relatively poor business environment, weak technology base, and long-term lack of attractiveness of foreign trade, the scale of attracting foreign investment will always be ranked near the bottom in the EU.

(4) The countries with the highest risks are Egypt and Ukraine, respectively. These two countries are deeply stuck in the battlefield of the great power game externally and face multiple conflicts internally, such as leadership transition, democratic political transformation, and ethnic conflicts. Their political situation and economy have been in continuous turmoil, thus, investors' confidence is low and the investment risk is high.

A total of 56 countries exist along the "Belt and Road," and only 20 countries are selected as the research target of this paper for convenience, which is a small sample size. The selection of risk indicators exist subjective will, which will affect the accuracy of risk assessment. It is also a problem to be solved in future research.

Abbreviations

FDI: Foreign direct investment
OFDI: Outward foreign direct investment.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Analytic Hierarchy Process and Its Application in Rural Tourism Service Performance Evaluation

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In contemporary China, tourism is being upgraded to a modern service industry and strategic pillar industry. With the rapid development of modern information and communication technology and the continuous refinement of tourism market demand, tourism has entered a new era of smart tourism. Information runs through the whole process of tourism activities and is the key to determine the quality of tourism. Tourism public service is a very important basic support for tourism activities. It is of great significance to meet the diversified needs of tourists and optimize various services and government management functions. Based on the analysis of the connotation of tourism supply chain performance evaluation, this paper constructs a tourism supply chain performance evaluation index system and performance evaluation model suitable for analytic hierarchy process and studies the product price, production capacity, credit, complaint rate, and management level of its upstream tourism supply enterprises. To test the effectiveness of AHP on tourism supply chain performance evaluation, the comprehensive evaluation results and relevant suggestions for improving performance are obtained, which also proves the extensibility of the performance evaluation index system and provides an effective method for improving the performance of each link of China's tourism industry and tourism service quality.

1. Introduction

In recent years, driven by information technology, China's economy is developing rapidly, per capita income is increasing, and people's demand for spiritual culture is getting higher and higher. Tourism has become an important way for mass leisure and entertainment [1]. According to the statistical report, at the beginning of 2012, there were 13,513 star-rated hotels, 23,690 travel agencies, 56,000 tourist buses, and more than 20,000 tourist attractions, driving more than 13 million people to directly engage in tourism employment. However, there is a huge potential for development. At the present stage, many problems have been exposed in all aspects of tourism industry. Therefore, it is urgent to cooperate and coordinate with many enterprises in the service supply chain to establish an efficient tourism service performance evaluation system, so as to timely meet the diversified and personalized needs of tourists and promote the sustainable growth of tourism consumption. Tourism industry can be studied by the theory of service supply chain management [2–4].

With the arrival of popular tourism, competition for tourists is increasingly fierce among tourism enterprises. Facing the personalized needs of tourists, tourism enterprises are facing the pressure of improving the quality of tourism services and reducing the cost of tourism products [5]. The competition between each other is also transformed from the original competition among individual tourism enterprises. Therefore, we should not only think about the development of enterprises [6] but also the influence of the impact of the development of the whole supply chain on tourism supply chain performance, which can make tourism enterprises to better grasp the operation of the supply chain system and improve its ability to continuously improve and tourism large and complex system [7–9].

At present, the competition among tourism enterprises is gradually changing to the competition between tourism supply chain and tourism supply chain [10]. The performance of tourism supply chain will become the key to win in the competition and also a basic means to judge

whether it is effective to the evaluation of tourism supply chain. Tourism supply chain performance evaluation of the premise condition is necessary to define the connotation of tourism supply chain, the current academic circles of tourism supply chain performance evaluation did not give a true definition, but for the definition of supply chain performance evaluation is more, such as Jia-Zhen Huo [5] for integrated supply chain performance from the perspective of value chain are defined, and focuses on the process performance [11, 12]. That is, to create value through production operation information development of tourist services and tourism marketing and other activities, tourism supply chain performance evaluation should be closely around the supply chain objectives. In its business process, it analyzes and evaluates the overall operation situation of each node enterprise in the tourism supply chain and the business relationship between each node enterprise in all aspects. The performance evaluation indicators of the tourism supply chain generally take nonfinancial indicators as the main aspect [13]. It includes a series of operational relationship evaluation indexes which can reflect the dynamic operation of the tourism supply chain and the upstream and downstream node enterprises [14–16].

Traditional indicators cannot adapt to the current tourism supply chain management, only to establish a set of systematic performance, evaluation indicators of tourism supply chain can make the effective operation of tourism supply chain sustainable. Specifically, the tourism supply chain performance evaluation can adjust and improve the business process and operation state of the tourism supply chain and can also make the decision makers of the tourism supply chain pay attention to its advantages and disadvantages [17–19].

At present, supply chain performance evaluation indicators are generally set for manufacturing or retail, measuring supply chain performance including delivery, total logistics management cost, cash flow turnover time, and asset turnover rate and other 11 evaluation indicators [20]. Considering the general characteristics of tourism supply chain, the tourism performance evaluation index is proposed based on its overall performance and the impact of tourism service process on environment. By the end of 2014, there were 1.9 million rural families and 100,000 rural tourism villages in China. The total annual operating income reached 320 billion yuan, up to 15% year on year, and the annual reception of tourists reached 1.2 billion person-times, about 1/3 of the total domestic tourism reception, a large number of tourists to the public transport services to bring greater pressure. With the increase of per capita car ownership, self-driving travel has become the choice of more and more people. With the increasing proportion of self-driving tourists, the demand for supporting public transport services is increasing, which requires a more reasonable transport service supply structure. Thus, higher requirements are put forward for the construction of parking spaces in rural tourist spots, road construction, traffic indication system construction and self-driving service point construction, etc., and there is a greater demand for the construction of rural tourist special lines and other public transport systems [21, 22].

Facing the increasing demand of tourists for public transport service and the correctness of investment decisions of public transport service in rural tourism spots, it is scientifically feasible to construct a performance evaluation model of public transport service and use to guide the supply of rural tourism public transport service. At present, China's rural tourism industry is in an important period of transformation and upgrading. Smart tourism not only improves the development of tourism from the aspects of service and management but also an urgent need for the successful regional tourism. Tourism public service-based support is very important in tourism activities, and evaluation of rural tourism is an important index of public service. In order to form an efficient, honest, perfect, and all-round public service network, providing a platform and service support for the development of rural tourism performance evaluation, therefore, the research of this topic not only has important theoretical significance but also has practical application value. Specific performance is in the following three aspects:

(1) To provide theoretical support for the construction of evaluation platform for rural tourism services:

The construction of smart tourism public service platform is bound to need the support of theory. From the current situation of smart tourism construction in China, practice precedes theory, and the lag of theory is obviously not conducive to the development of tourism services. Therefore, this study will make a breakthrough in theory and form a sound public service system and evaluation system of smart tourism, thus providing strong theoretical guidance for the construction of tourism public service platform and laying a foundation for further research in this field.

(2) To provide a basis for government decision-making:

The development of tourism is in the forefront of the country, but in the context of smart tourism, rural tourism public service construction. There are still many problems; traditional public service construction has been unable to meet the development needs of modern tourism, the development of wisdom. The study of tourism public service evaluation can not only provide the basis for the government to make the decision of realizing the integration and sharing of tourism resources in the whole province but can also play a promoting role in promoting government tourism intelligent management and intelligent service level.

(3) Provide technical support for the development of smart tourism public service platform:

In this study, the rural tourism public service platform is analyzed and designed, and the theory is really applied to practice. Feasible construction

implementation plan realizes real-time sharing of tourism information resources and avoids "information island," for tourists. It provides one-stop all-round tourism service and provides certain technical support for the performance evaluation of smart tourism public service. The layout of this paper is as follows: Section 2 gives the related work; Section 3 is the rural tourism public service performance evaluation by AHP. The experimental results and analysis are given in Section 4. Finally, the conclusions are shown in Section 5.

2. Related Work

Francesco et al. [23] studied the tourism recommendation system. Kelliher et al. [24] proposed a new method to achieve tourism marketing strategy for Turkish travel agencies based on recommendation tools, pointing out that recommendation tools are a common model, the example. An intelligent travel plan recommendation system is developed by inference algorithm, which enables new users to make optimal travel plans based on previous practical cases. Garrigos-Simon et al. [25] pointed out that intelligent system is different from the intelligence system; there are two factors of the behavior to evaluate from the response of the environment.

Generally speaking, advanced tourism countries such as Europe, Singapore, and South Korea have relatively perfect public service system construction and a higher degree of modernization. At the same time, the government has provided huge support in the investment of tourism public service infrastructure. These countries have a relatively perfect tourism public service system, practical research of tourism public service. Through field investigation of communities in northern Canada, Cirillo et al. [26] pointed out the role in ecotourism.

Hong et al. [27] suggested to strengthen government investment, by adjusting the project structure and regional structure, promote investment in infrastructure construction in poor rural areas, and expand the source of funds, and effectively improve the transport facilities in rural areas in phase. Zhang et al. [28] explored the optimization of rural transportation based on reality. Considering that the actual demand of public transportation for tourism in rural areas is relatively low and the destinations of residents in rural communities are different, fixed bus operation is not a wise choice in this case. Thus, a more flexible transport mode, namely, DAR system based on mixed integer programming, is proposed. Kristjánsdóttir et al. [29] believed that the performance evaluation of rural transportation projects is a relatively weak link, and there are often many uncertain factors and high evaluation costs in the existing evaluation. Therefore, the author analyzed the project effect of capital management, ecological environmental impacts, and social and economic benefits. This paper constructs the corresponding evaluation system and evaluation method and carries on the empirical analysis to the rural transportation project of Zhejiang Province. Ristić et al. [30] conducted special research on public infrastructure such as transportation system.

Analytic hierarchy process (AHP) is a common evaluation method that combines qualitative and quantitative methods. Petrova-Antonova et al. [31] comprehensively evaluated the performance level and differences of the five blessings mode of rural tourism by using the AHP, effectively understood the benefits of various service modes, and provided a basis for the study on the rationality of passenger transportation structure. Zhao et al. [32] evaluated the current tourism public service evaluation from five aspects including operation organization and social and economic benefits of safe investment capital by using the analytic hierarchy process and came to the conclusion that the operation mode of bundled area of rural passenger transport was more suitable for the development and management of rural passenger transport. Tien et al. [33] evaluated the performance of rural tourism projects by using analytic hierarchy process and found that the performance of rural transportation projects was good. Petrović et al. [34] put forward the performance evaluation method of logistics service supply chain based on grey analytic hierarchy process and conducted an empirical study based on the integration of automobile logistics supply chain in Chongqing [1]. In the tourism service supply chain model, hotels, shopping facilities, entertainment facilities, passenger transport centers, and scenic spots are the suppliers of products and services. Tourists are demanders and consumers of products and services, including individual travelers and groups. With the improvement of transportation conditions, and the strong support from government departments, tourism industry has become a driving force and an advantageous industry to promote the transformation of regional economic development mode [2].

3. Rural Tourism Public Service Performance Evaluation by AHP

3.1. Structure of Rural Tourism Public Service Performance Evaluation System. The fuzzy analytic hierarchy process (FAHP) and AHP are a systematic analysis method combining qualitative and quantitative methods proposed in 1970s. This method provides a basis for quantitative evaluation index and selection of optimal scheme and has been widely used [5]. The whole system of the method is given in Figure 1.

From Figure 1, we know that the proposed system mainly includes the following four main parts: (1) to determine the key factors of each service, (2) to assign the priority (weight) of factors to each service evaluation factor, (3) to determine the performance evaluation calculation scheme of public services of each tourist attraction, and (4) to generate an ecotourism suitability evaluation result.

3.2. FAHP Algorithm. In FAHP, the importance of one factor to another factor can be expressed quantitatively. If the factor has the following properties, the fuzzy judgment matrix A can be obtained:

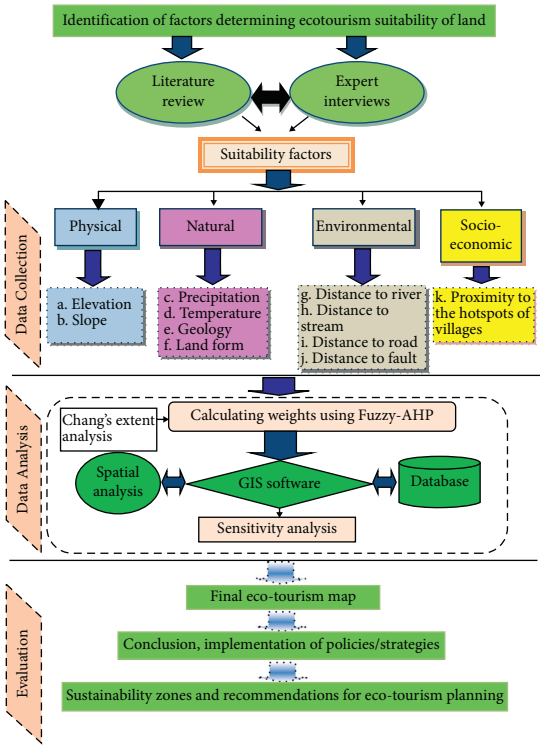

Figure 1: Structure of the proposed FAHP method.

$$\begin{aligned} a_{ii} &= 0.5, \quad i = 1, 2, \ldots, n, \\ a_{ij} + a_{ji} &= 1, \quad i, j = 1, 2, \ldots, n_i, \end{aligned} \tag{1}$$

where a_{ij}, a_{ji} are the elements of matrix A, and a_{ii} are the diagonal elements.

According to the above digital scale, factors A_1, A_2, and A_N are compared with each other to obtain the following fuzzy complementary judgment matrix:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n^1} & a_{n^2} & \cdots & a_m \end{bmatrix}. \tag{2}$$

This paper deduces a general formula for solving the weight of fuzzy complementary judgment matrix as follows:

$$W_i = \frac{\sum_{j=1}^{n} a_{ij} + n/2 - 1}{n(n-1)}. \tag{3}$$

The method of using the compatibility of fuzzy judgment matrix to test its consistency principle is deduced

$$I(A, B) = \frac{1}{n^2} \sum_{j=1}^{n} \sum_{i=1}^{n} a_{ij} + b_{ij} - 1. \tag{4}$$

It is called the n-order matrix

$$W\star = \left(W_{ij}\right)_{n\times n}. \tag{5}$$

For practical problems, the pair-wise comparison judgment matrix on the same factor set X is usually given by multiple experts:

$$A_K = \left(a_{ij}^{(k)}\right)_{n\times n} (k = 1, 2, \ldots, m). \tag{6}$$

They are all fuzzy complementary judgment matrices, so the sets of weight sets can be obtained, respectively,

$$W^{(k)} = \left(w_1^{(k)}, w_2^{(k)}, \ldots, w_n^{(k)}\right), \quad (k = 1, 2, \ldots, m). \tag{7}$$

Then, the consistency test of fuzzy complementary judgment matrix should be done in the following two aspects:

$$\begin{aligned} I\left(Ak, W^{(k)}\right) &\le A, \quad k = 1, 2, \ldots, m, \\ I\left(A_k, A_l\right) &\le A, k \ne l; \quad k, l = 1, 2, \ldots, m. \end{aligned} \tag{8}$$

It can be proved that when fuzzy complementary judgment matrix is uniformly acceptable,

$$W = (W_1, W_2, \ldots, W_n), \tag{9}$$

where

$$W_i = \frac{1}{n} \sum_{k=1} W_i^{(k)}, \quad (i = 1, 2, \ldots, n). \tag{10}$$

From the above analysis, the rural tourism public service platform is built based on cloud computing. The main construction contents of the rural tourism cloud service system include cloud infrastructure, facilities, cloud data center, cloud application center, unified rule collection, unified standard storage, and release on various platforms in accordance with unified exchange standards, so as to finally realize tourism information, intelligent management, and service to maximize the value of intelligent tourism.

The construction of rural tourism cloud service system must achieve data standards, basic information, geographic information, exchange interface, and the unity of the five aspects such as the technology platform, using a centralized, most of the distributed system architecture, build rural tourism information data center of cloud, for the cities and counties (districts), provides centralized upload data entry. At the same time, it still needs to establish data exchange standard provincial tourism bureau and provide exchange interface to each city and county (district), so that their existing information system can realize data synchronization and exchange with the cloud center; cloud data center includes database cloud, management cloud and support cloud construction, and database cloud mainly includes basic database, business database, service database, and decision database. The performance evaluation framework diagram of rural tourism public service proposed in this paper is shown in Figure 2 [11]. From the figure, we know that there are 4 main parts in Figure 2: application, access, cloud data, and infrastructure, the relationship between them is mutually reinforcing.

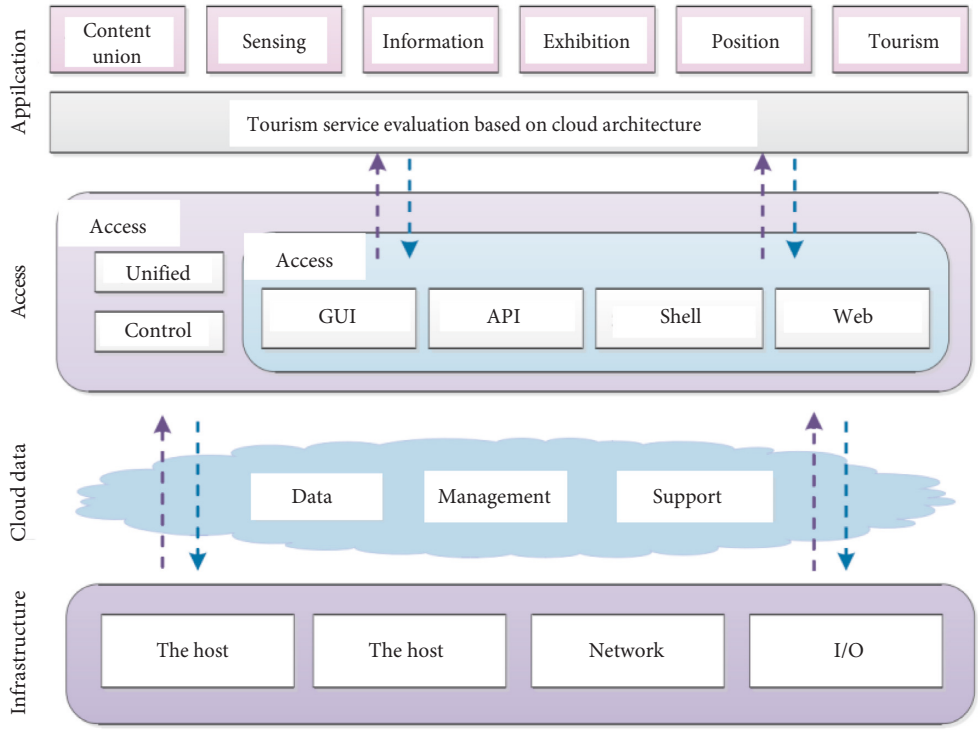

Figure 2: Performance evaluation framework of rural tourism public service.

4. Experimental Results and Analysis

4.1. Introduction to Experimental Environment and Data Set. Taking a village as an example, the author conducted a field questionnaire survey in this village around the Spring Festival of 2018. This survey was conducted by on-site questionnaire distribution and real-time recycling. A total of 200 questionnaires were sent out, 184 were recovered, and 176 were valid, with a recovery rate of 92.0% and an effective rate of 88%. In addition, due to a small number of data samples, the author also collected 180 electronic questionnaires, 167 of which were effective and the effective rate was 92.7%. Therefore, the effective rate of formal research was 343 and the effective rate was 90.2%.

After the preliminary determination of the questionnaire, in order to test the reliability and validity of the questionnaire, the author conducted a predictive test of the questionnaire scale. In the predictive test, the author distributed the questionnaire in a village before the Spring Festival of 2018. A total of 100 questionnaires were collected, of which 84 were valid, with an effective rate of 84%, since the whole questionnaire has the perception of importance and satisfaction of each evaluation index.

4.2. Experimental Results Analysis. Firstly, the comparison of the results of areas of performance appraisal is given in Figure 3. Before this section, the importance perception significance factor was not used, because the evaluation of public health quality of rural tourism perceived by tourists is mainly based on tourist satisfaction. High tourist satisfaction means that tourists have a high evaluation of a public health service quality factor. On the contrary, the evaluation is low, and the importance perception mainly describes the importance of tourists to a certain tourism public health service project, which does not directly affect tourists' satisfaction, and then affects tourists' perception of tourism. Overall evaluation of public health services is performed, so the factor of perceived importance has not been used in previous studies. In this section, the paired T-test is performed on perceived importance and perceived satisfaction. In order to analyze the gap between tourists' expectation of service quality and their actual satisfaction, it is necessary to study tourists' perception of importance and satisfaction.

It can be seen from Figure 4 that the selected village is located at the foot of the Zhaoling Mausoleum of Li Shimin, the world-famous Emperor Taizong of Tang Dynasty, north of Yanxia Town, Liquan County, Xianyang City, Shaanxi Province. It is 78 kilometers away from Xi'an and about an hour's drive. It used to be a backwater with barren land and inconvenient transportation. Since the 1970s, the whole village has been united in developing the collective economy and pursuing common prosperity.

In 1993, Yuanjiacun established the agricultural and industrial integration of agricultural and industrial joint head office, under the jurisdiction of 12 subsidiaries, to achieve the transformation of the industrial structure from agriculture to industry Yuanjiacun in just 10 years to achieve the village of 62 households, 286 people out of poverty to get rich, solve 3000. In 2006, Yuanjiacun focused on creating the tourist destination brand of Guanzhong Impression experience place and innovatively adopted the full-staff and bottom-up scenic spot management model 10. In the past

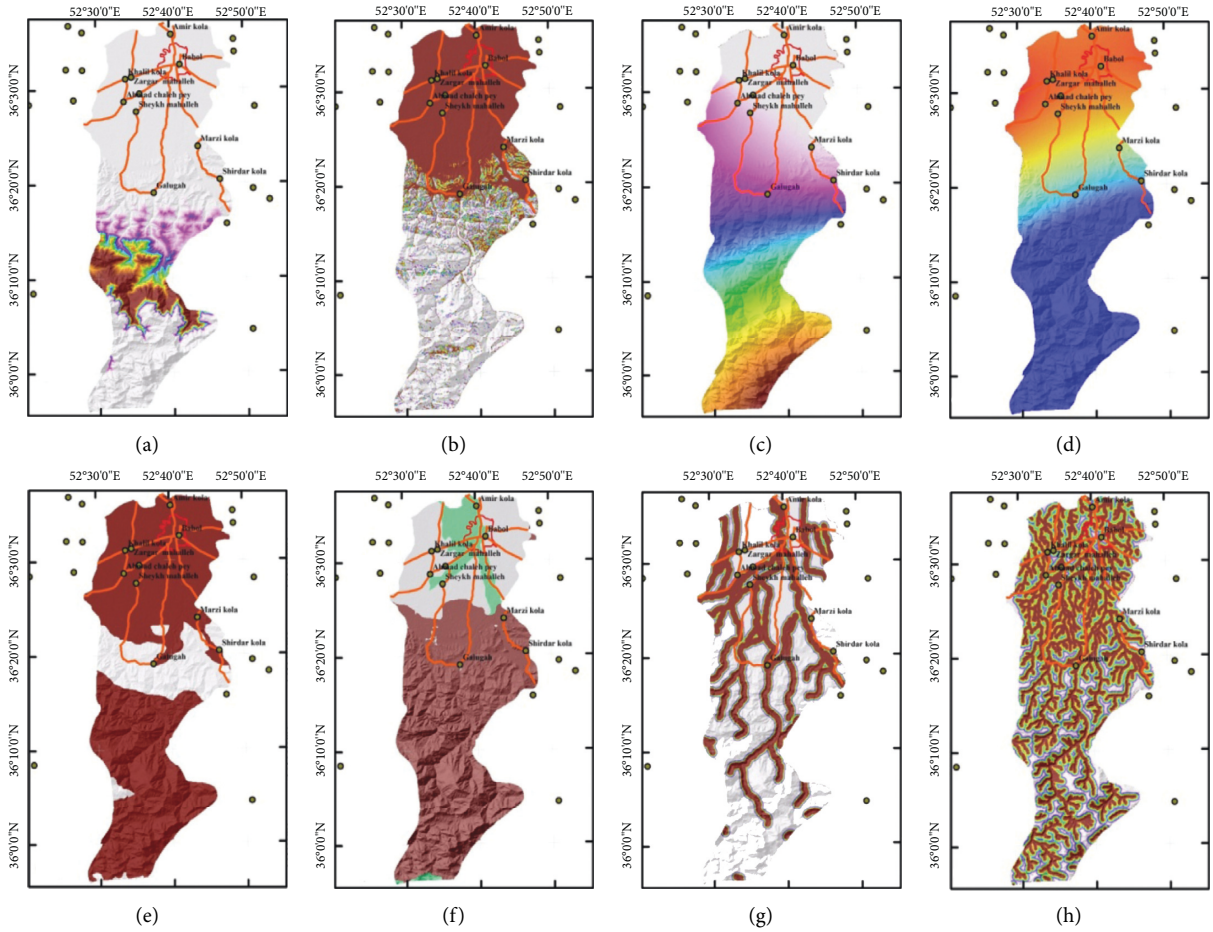

Figure 3: Areas of performance appraisal: (a) elevation, (b) slope, (c) precipitation, (d) temperature, (e) geology units, (f) landform, (g) distance to river, and (h) distance to stream.

Figure 4: The spatial layout of the village selected for this article.

years, Yuanjiacun has gradually developed from the original single Guanzhong Impression and experience place with Kangzhuang old street as the main body into a rural tourist resort integrating food, accommodation, travel, shopping, and entertainment, perfectly realizing the third transformation and upgrading from industry to cultural tourism industry.

In recent years, YuanJia village begin building the snack street in Guanzhong Plain Hui street, Ancestral temple street, college street, bar coffee street, art gallery, and YuanJia ancestral temple. A phantasy thatched cottage. The Guanzhong summer, etc., will the Guanzhong area of folk traditional culture and the combination of modern tourism attracts a steady stream of visitors. Among them, the catering is one of the features of YuanJia village; mesh tofu, yogurt, Laozao, chili vinegar, vermicelli, rapeseed oil, and other stock cooperatives have been formed, which are operated by the subordinate companies of the village committee for the purpose of achieving common prosperity for the villagers. Each household of the snack street cooperative is 3 : 7,4 : 6,7 : 3. According to the income, the profit is divided. The ratio of high income decreases. Low yield ratio increases, but not to earn money and snack street essential category cooperatives subsidies. The results of importance-performance analysis (IPA) are shown in Figure 5.

As shown in Figure 6, according to the t-test results of paired samples, there are 24 indicators with significant differences between importance perception and satisfaction perception, among which 19 are significantly higher in importance perception than in satisfaction perception, and 5 are lower in satisfaction perception than in importance

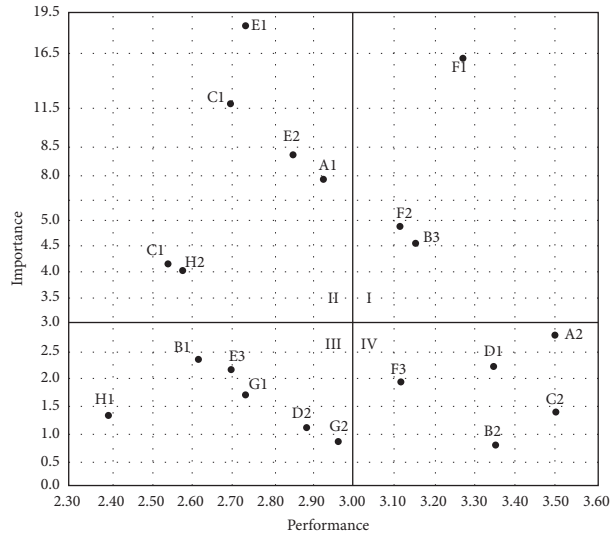

Figure 5: Management efficiency of sports events before and after optimization.

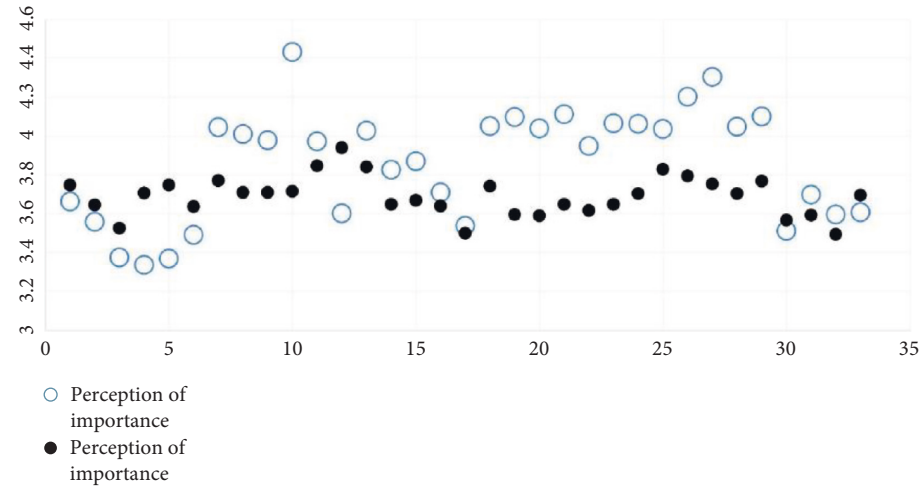

Figure 6: Perception of importance versus perception of satisfaction.

perception. The importance of more than half of the 33 indicators is significantly higher than satisfaction, indicating that tourists are not satisfied with the current public services.

The mean difference analysis of importance and sensitivity is shown in Figure 7. According to the analysis of the importance and satisfaction perception mean difference (importance perception average-average satisfaction perception), 24 of the mean difference are positive and that of tourists for YuanJia village rural tourism service quality of public health importance of sensory evaluation is lower than their actual satisfaction for its sensory evaluation, said YuanJia village rural tourism public health service quality. Quantity cannot fully meet the actual quality of health service demand of tourists. That is to say, the quality of these public health services should be improved.

In order to facilitate the analysis of the distribution and characteristics of indicators in each quadrant, the author drew the IPA positioning analysis chart of tourists' evaluation of public health service quality of rural tourism in Yuanjiacun as given in Figure 8. Quadrant 1: there are 13 rural tourism public health service indicators located in this quadrant. According to the interpretation of the principle of IPA, these indicators are not only important for improving tourists' tourism experience but also Yuanjiacun rural tourism has done relatively well in these aspects, the mean values of satisfaction perception of these rural tourism public health service indicators among surveyed tourists are all lower than the mean values of importance perception, indicating that Yuanjiacun rural tourism destination needs to continuously improve the quality of public health service in these aspects to maintain this advantage. Quadrant 2: there are 6 rural tourism public health service indicators located in this quadrant, the mean values of the perceived importance of these rural tourism public health service indicators are all higher than the perceived satisfaction of the surveyed tourists. According to the interpretation of IPA principle, these indicators of tourism public health service quality in the view of tourists need to increase investment and focus on improvement. Quadrant 3:

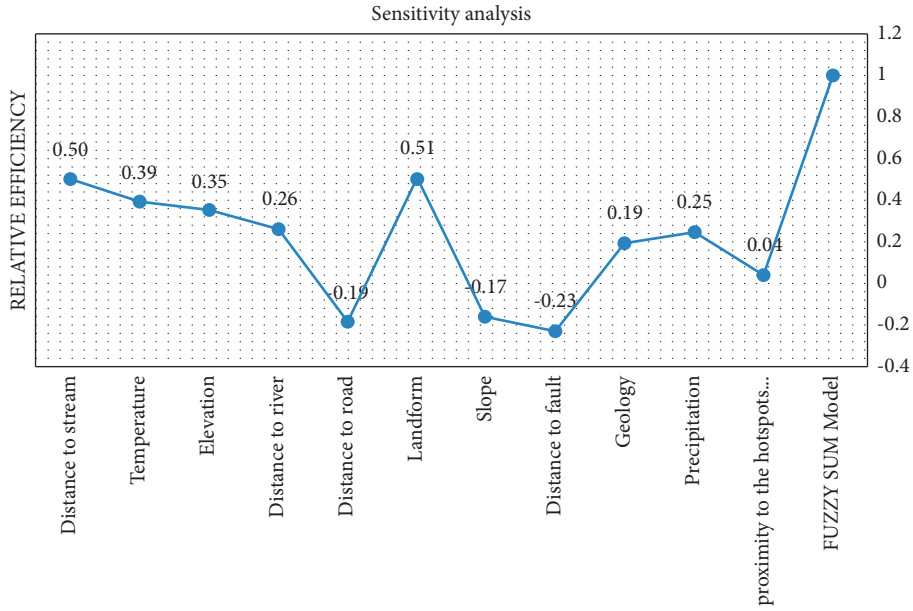

Figure 7: Sensitivity analysis of the propped FAHP.

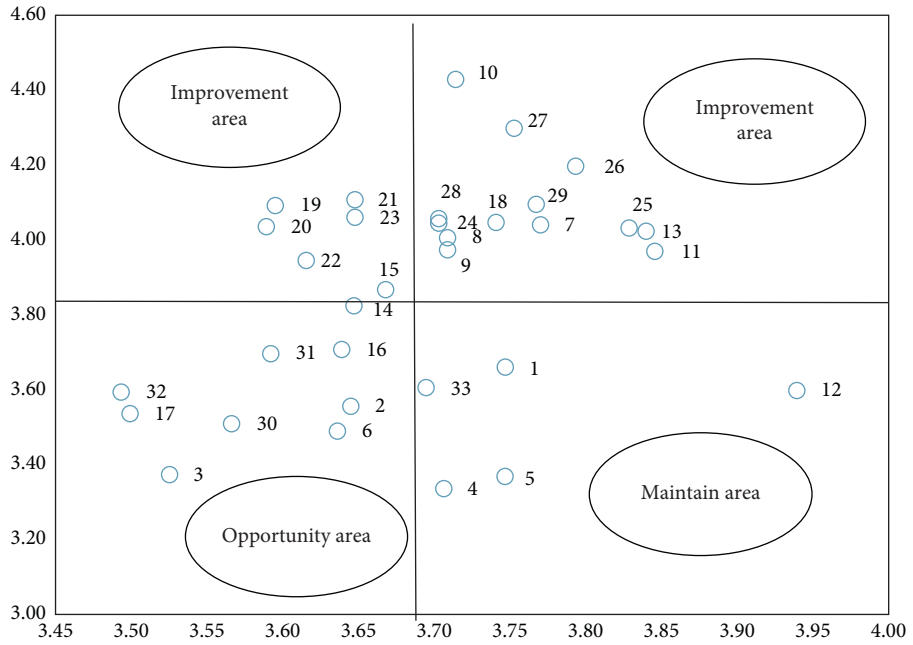

Figure 8: Analysis of public health service quality of rural tourism in Yuanjiacun.

there are 9 rural tourism public health service indicators located in this quadrant. Including 2, 3 June, 30 indicators project satisfaction perception average higher than the average importance perception, 16, 17, 14, 31, 32 indicators project importance perception average below average satisfaction perception, although these indicators in the aspect of the present stage of tourists perception belongs to low priority. But, the rural tourism public health service of Yuanjiacun still needs to be improved in these aspects. Quadrant 4: it can be seen from the five quantitative indexes in this quadrant that tourists have higher satisfaction with public health service projects.

5. Conclusions

This article is based on tourists angle to discuss the rural tourism public health service quality evaluation scale and model building in Xianyang YuanJia village as an example, through field investigation data analysis, validation, and improve the rural tourism public health service quality evaluation scale, and the model of the reliability of the research lies in the following three aspects. (1) A relative effective evaluation scale of rural tourism public health service quality was designed. (2) The evaluation model of rural tourism public health service quality is constructed. (3) The

countermeasures and suggestions to improve the quality of rural tourism public health service are put forward.

Although this paper has carried out an in-depth analysis on the evaluation of rural tourism public health service quality, due to the limitations of personal knowledge and research ability and economic conditions, this study still has certain limitations. In the future, it can be further studied from the following aspects to deepen the topic selection of this study.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Target Tracking Algorithm in Football Match Video Based on Deep Learning

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After the introduction of online learning mechanism, the traditional target tracking algorithm in football game video based on TLD has good tracking ability, but it will lose the target when the target is seriously obscured. Therefore, a soccer game video target tracking algorithm based on deep learning is proposed. The target detection algorithm of GoogLeNet-LSTM is used for faltung to obtain the feature mapping array. After processing, a high reliability candidate box for training and matching is obtained, and the feature maps of the detection results are collected to obtain the depth features required for tracking. Scale space discriminant tracking algorithm and Markov Monte Carlo algorithm are used to track single target or multi-target, respectively. Experimental results show that the average frame rate of the algorithm is maintained above 35 Hz, and the tracking time is about 12.5 s. The average center position deviation index is 39, the average coverage index is 40, and the resource utilization is low. The algorithm can track the target in the football game video well.

1. Introduction

In modern life, sports video is the important video that is popular among the majority of viewers. It has a large proportion in existing TV programs and the Internet [1, 2]. With the continuous improvement of people's quality of life and the rapid advancement of technology, people's demands for sports video are also rising. In terms of sports competition viewing, passive and flat viewing methods will gradually fail to meet the requirements of TV viewers [3–5]. The broadcasters need to add various visual effects to meet the visual requirements of the audience. In terms of game analysis, the team coach needs to extract relevant data from the football game video to assist the coach in researching the tactics. In terms of commercial applications, the broadcasters also need to more fully explore the commercial value of the football game broadcast. These need to analyze the video data of the game and process the game images for different requirements in order to meet the requirements of the game video [6–8]. Among the many sports competitions, football matches have the largest number of viewers and the highest level of attention. Therefore, the detection, extraction, location, and tracking of moving targets in the video have high practical and practical significance.

The extraction and tracking of targets in the football game video are hot spots in the current sports field image and video processing. The technology required covers many areas of image processing analysis and computer vision. In general, football match video scene consists of background and goal, where the goal is the important part of the video, which contains important information. Therefore, quickly and efficiently segmenting objects in video and tracking the target of interest are the bases for subsequent image analysis [9].

Although the research of target tracking has made great progress and breakthrough to some extent, the robust target tracking algorithm has been full of challenges due to the complexity of the environment and the influence of target deformation. The core problem of target tracking is feature representation. The early features are manually selected, and the appropriate features are selected according to the different application scenarios, but the effect is far from meeting the actual needs. Since the advent of deep learning technology, the field of computer vision has developed

rapidly, and deep learning techniques were first used for image classification problems [10–12]. In recent years, the multi-target tracking algorithm based on deep learning has also made some breakthroughs. Multi-target tracking is the very challenging research direction in the field of computer vision and has a wide range of practical applications, for example, intelligent video monitoring control, abnormal behavior analysis, and mobile robot research. Traditional multi-target tracking algorithms tend to have poor tracking performance due to poor target detection. Depth-based learning detectors can achieve better results, which in turn improves tracking accuracy. Therefore, how to achieve effective combination of target tracking and deep learning has become the focus of researchers.

Traditional target tracking algorithms have many problems. For example, the block-based scale-adaptive CSK rigid body target tracking algorithm proposed in Document 4 does not consider the confidence of the candidate box, and the tracking result has low precision. The KCF (kernelized correlation filter)-based tracking algorithm in Document 5 is only applicable to single-target tracking and has limited limitations. The TLD tracking algorithm proposed in the literature 6 causes the target to be lost when the target is severely occluded. The new target tracking algorithm that combines SIFT (scale-invariant features) and compression features is proposed in Document 7. This algorithm has poor effect on feature extraction, which results in lower center position error and coverage, and higher resource occupancy rate of the algorithm. Deep learning is a new research direction in the field of machine learning. It is introduced into machine learning to make it closer to the original goal—artificial intelligence (AI). Deep learning is the internal law and representation level of learning sample data. The information obtained in the learning process is very helpful to the interpretation of data such as text, image, and sound. Its ultimate goal is to make the machine have the ability of analysis and learning like human beings, and can recognize characters, images, sounds, and other data. Deep learning is a complex machine learning algorithm, which has achieved far more results in speech and image recognition than previous related technologies.

In response to the above problems, the target tracking algorithm in the football match video based on deep learning is proposed in this paper. GoogLeNet is used to perform convolution to obtain the feature map array through target detection algorithm-based GoogLeNet + LSTM. After processing, candidate boxes of high confidence used to perform training and matching are obtained to achieve target detection. The feature map of the detection result is pooled to obtain the depth feature required for tracking. According to this feature, the discriminant scale space tracking algorithm and the Markov Monte Carlo algorithm are used to achieve single-target or multi-target tracking.

2. Materials and Methods

2.1. Target Detection-Based GoogLeNet + LSTM. Target detection is the basis of the multi-target tracking algorithm based on data association. The GoogLeNet + LSTM framework is used for target detection for problems such as small targets and occlusions in football video. First use GoogLeNet for convolution. In the last layer, the $1 \times 1024 \times 15 \times 20$ feature map array is obtained and transposed into 300×1024 feature map array. Each 1024-dimensional vector corresponds to the area of 139×139 in the original picture.

The 300×1024 feature map array is obtained by GoogLeNet convolution, and then, each 1024-dimensional vector is processed in parallel by the LSTM sub-module. The hidden state of each output goes through two different fully connected layers: the position and width of direct output box, and the confidence of this box through the softmax layer. The LSTM sub-module has a total of five such units; that is, each input can predict 5 boxes and confidences. In the training, the frame is concentrated at the 64×64 position in the center of the sensing area, and the confidence is ranked from high to low.

After processing, five detection frames corresponding to 64×64 small blocks in the original image and confidence levels can be obtained. The processing of the sub-module needs to filter all the detection frames of the video frame and then remove the frame with low confidence by the given thresholds. Finally, detection result can be obtained [13–17].

The specific process is as follows: if the candidate box intersects with the determined frame, the candidate box is removed. A determined box removes at most one candidate box. In the above matching, the cost is expressed as (m, d), m means whether the two intersect, the value is $\{0, 1\}$, and d is the Manhattan distance between the two boxes. The importance of m is greater than that of d; that is, the result obtained by the two matching schemes is first compared with the size of m. If the conclusion cannot be reached, the size of d is compared. The Hungarian algorithm is used to find the least costly match [18–20]. Assume that the filter's confidence threshold is 0.5, then those boxes with the confidence below 0.5 are removed.

In order to effectively train the target detection model, the following training method is adopted: more candidate boxes are obtained in the LSTM sub-module [21, 22], but there are detection errors.

There are three types of errors [23, 24]:

(1) Point out the place that is not the tip of the person.

(2) The difference between the predicted and the true value frame positions.

(3) Multiple prediction frames are generated for the same target.

The lower confidence level is assigned to the candidate box to prevent the occurrence of Case 1. The error is corrected to avoid the occurrence of Case 2; the lower confidence is given to the prediction boxes generated by the same target to eliminate the problem of Case 3.

The loss function of the model training is

$$L(G, C, f) = \alpha \sum_{i=1}^{|G|} l_{\text{pos}}\left(b_{\text{pos}}^{i}, \widehat{b}_{\text{pos}}^{f(i)}\right) + \sum_{j=1}^{C} l_{c}\left(\widetilde{b}_{\text{pos}}^{j}, \left\{f^{-1}(j)\right\}\right), \quad (1)$$

where G is the true value of the box, C is the candidate box, f is the matching algorithm, b^i_{pos} means the i th box in the truth box, $\widehat{b}^j_{\text{pos}}$ means the $\widehat{b}^j_{\text{pos}}$ th box in the to-be-selected box, l_{pos} is the Manhattan distance between the two, and l_c is the cross-entropy loss, which is the softmax loss in the corresponding network [25–27]. The first term of this loss function represents the position error of the candidate box and the matching truth box, the latter represents the confidence of the candidate box, and α adjusts the balance between the two losses.

The matching algorithm is the Hungarian algorithm, and the comparison function used is

$$\Delta\left(b_i, \widehat{b}_j\right) = \left(o_{ij}, r_j, d_{ij}\right), \tag{2}$$

where o_{ij} is $\{0, 1\}$. If the center of the to-be-selected box falls in the true value box, it is 0; otherwise it is 1. r_j is the sequence number generated for the candidate box. The goal is to have high confidence frame first generated when matching [28–30]. Therefore, when matching the same target, the lower the ranking is, the lower the cost is [31, 32]; d_{ij} is the distance between the two boxes, that is, the distance error.

The target detection results in the football match video are obtained by the detection algorithm-based GoogLeNet + LSTM. Based on this, deep learning is used to extract depth features.

2.2. Extraction of Depth Features. The corresponding box position obtained in the upper section is the position of the human head in the video, which is enlarged by certain scale to cover the whole body [33]. After obtaining the position and size of the target frame, the feature map array obtained by the last layer convolution of GoogleNet is used to extract features. The depth features of each target detected can be obtained by pooling the feature map, because each feature is highly abstract and can well characterize the appearance characteristics of the target in the football match video.

The feature of the proposed algorithm is that the feature map is used for pooling to obtain the depth features required for target tracking without re-training. Therefore, under the premise that the real-time performance of the target tracking algorithm is unchanged, the accuracy of target tracking in the football game video is improved.

2.3. Single-Target Detection-Based DSST. The discriminant scale spatial tracking algorithm is simply referred to as DSST tracking algorithm. After obtaining the depth features, the DSST algorithm is used to track the single target in the video. DSST combines the two-dimensional positional filter with one-dimensional scaled filter. The candidate position is first determined by using the two-dimensional position correlation filter, and this area is used as reference area for the one-dimensional scale filter calculation. In this way, candidate blocks of different scales are obtained, and the scale with high matching degree is searched. The principle of scale selection is as follows:

$$a^n P \times a^n R, n \in \left\{\left[-\frac{S-1}{2}, \ldots \left[\frac{S-1}{2}\right]\right]\right\}, \tag{3}$$

where P and R are the width and height of the target in the previous frame; a is the setting factor, and its value is set as 1.02; and S indicates the number of scales, with the setting of 33. The scale in the formula is not linear relationship, but only the detection process from fine to coarse and from inside to outside.

In extracting image features and generating filters, MOSSE correlation filters are employed [34]. In this way, a series of image blocks are extracted from the target as training samples, which are, respectively, recorded as $y_1, y_2, y_3, \cdots, y_n$. The corresponding filter response values are Gaussian functions, which are, respectively, recorded as $g_1, g_2, g_3, \cdots, g_n$. The peak is at the center, and the end result is to find a filter that meets the minimum mean square error.

The MOSSE optimal correlation filter formula is

$$\varepsilon = \sum_{j=1}^{t} \left\| h_t * y_j - g_j \right\|^2 = \frac{1}{MN} \left\| H_t Y_j - G_j \right\|^2, \tag{4}$$

where G is Gaussian function, $*$ represents complex conjugate, and H_t means the minimum value of the filter. The right equal sign is derived from the Parseval theorem. The right side of the equal sign is the frequency domain equation, and the left side is the airspace equation. This calculation can be used to transform the problem from spatial domain solution to frequency domain solution. In the frequency domain, the minimum value of the filter is as follows:

$$H_t = \frac{\sum_{j=1}^{t} G_j}{\sum_{j=1}^{t} Y_j}. \tag{5}$$

After the correlation filter is obtained, the determination of the target position of the next frame is determined by the functional response of the correlation score [35]. The area with high response value is the new target position, and the response formula is

$$x = Y^{-1}(HtZ). \tag{6}$$

In this algorithm, (4) uses the extracted depth feature and Gaussian function G to obtain the correlation filter H. t indicates the response time. When a new frame is input, the feature Z extracted by the image block is used as an input to calculate with the correlation filter H using (5), and the response score x is obtained to get the candidate target [36].

DSST designs the input y of the image into the feature vector of the d dimension. The input signal y represents a certain image block of the input image. The optimal correlation filter H is established by the MOSSE idea. The formula is as follows:

$$\varepsilon = \sum_{t=1}^{d} \left\| h^l * y^l - g \right\|^2 + \lambda \sum_{t=1}^{d} \left\| h^l \right\|^2, \tag{7}$$

where l is one dimension of the feature and λ is regular coefficient, and the solution of the obtained minimum value is as follows:

$$H^l = \frac{\overline{G}Y^l}{\sum_{k=1}^{d} \overline{Y}^k Y^k + \lambda} = \frac{A_t^l}{B_t}. \tag{8}$$

Since the pixel points in the image block directly solve the $d \times d$-dimensional linear equation, the calculation amount is too large and time consuming. Therefore, a robust approximate solution is obtained by updating the numerator and the denominator in the above equation. The formula is rewritten as follows:

$$A_t^l = (1-\eta)A_{t-1}^l + \eta \overline{G}_t Y_t^l,$$
$$B_t = (1-\eta)B_{t-1} + \eta \sum_{k=1}^{d} \overline{Y}_t^k Y_t^l, \tag{9}$$

where η is learning rate. The position of the target in the new frame, that is, the maximum response value of the correlation filter, can be obtained by

$$x = Y^{-1}\left\{\frac{\sum_{l=1}^{d} \overline{A}^l Z^l}{B+\lambda}\right\}. \tag{10}$$

The DSST algorithm uses the dual correlation filter to track the single target in football match video. The algorithm is more portable and efficient, but the problem still exists. When tracking multiple targets, the occlusion of the target will inevitably reduce the accuracy of the tracking, and the interference discrimination of similar targets is not strong. Therefore, the Markov Monte Carlo (HDDMCMC) algorithm is adopted when tracking multiple targets in the football match video.

2.4. Multi-Target Tracking Based on HDDMCMC Algorithm

2.4.1. MCMC Algorithm in the Segment. In the multi-target tracking algorithm, considering the stability and continuity of motion (the same target in the front and rear frame video data), the appearance characteristics will not change drastically.

In the intra-segment MCMC algorithm, the depth feature in Section 2.2 is used to measure the similarity of the target trajectory.

Each detection target is treated as a node and is described by the intra-segment time $[t, t+T]$. Suppose the set of nodes of the video frame in t is $N_t = \{N^t(1), N^t(2), N^t(3), \cdots, N^t(i), \cdots, N^t(N^t-1), N^t(N_t)\}$, and the posterior probability $P(w|D)$ is as

$$P(w \mid D) = P\left(\{\tau_1, \tau_2, \tau_3, \ldots, \tau_K\}|D\right) = \left(\prod_{k=1}^{K}\prod_{n=1}^{N_k-1} P\left(N^{n+1}(k) \mid N^n(k)\right)\right) \times \left(\prod_{k=1}^{K} e^{-\left(1/l_k\right)}\right) \times \left(e^{-|\tau_0|}\right), \tag{11}$$

where $N^n(k)$ and $N^{n+1}(k)$ represent the nth and $n+1$th nodes in the kth pedestrian trajectory, respectively. $P(N^{n+1}(k)|N^n(k))$ is the similarity of two nodes, and it can be calculated by the cosine of the angle of the two-node depth feature. l_k is the length of different tracks, and $|\tau_0|$ represents the number of false alarms to ensure that the false alarm rate is low.

2.4.2. Inter-Segment MCMC Algorithm. The data used are mainly the target trajectory generated by the MCMC algorithm in the segment. The main actions taken by the algorithm include fusion, splitting, and switching operations. After passing the intra-segment MCMC algorithm, many more reliable target trajectories are generated. At this time, if there is a case where the same target trajectory is broken, it is caused by unstable detection data. Therefore, the purpose of the inter-segment MCMC is to further combine the target trajectory data of the two time periods. In the current state, the posterior probability is updated as follows:

$$P(w \mid D) = P\left(\{\tau_1, \tau_2, \tau_3, \ldots, \tau_K\}|D\right) = \left(\prod_{k=1}^{K}\prod_{n=1}^{N_k-1} P\left(N^{n+1}(k)|N^n(k)\right)\right) \times \left(\prod_{k=1}^{K} e^{-\left(1/l_k\right)}\right), \tag{12}$$

where false alarm factors are no longer considered because they are mainly used to divide the target trajectory [37]. For fusion operations, the allowed time interval is set as $t_{\text{gap}} = 10$ and the frame difference at the junction between the track segments of the two targets cannot exceed 6. The standard deviation of the probability is set to $3\sigma = \text{size}(d_t^i)$. In this way, the unit that can be transferred between different states is a relatively complete target trajectory segment that has been generated previously [38–40].

The inter-segment MCMC algorithm moves the target that has gone out of the video scene out of the current data set. The current data set is assumed to be τ'. After the MCMC gets the trajectory in the next segment, it is matched by the inter-segment MCMC algorithm. That is to continue to build on the previous target data, combined with the current target data, to further data integration to optimize. The entire algorithm is continuously performed in such a sliding manner.

3. Results

In order to verify the superiority of each aspect of the proposed algorithm, it is compared with some traditional algorithms such as CSK, KCF, Struck, CT, and TLD. The experimental object is the video of football match. The threshold set by the accuracy is 20 pixels, and the threshold of the success rate is set as $t_0 = 0.5$. The results are shown in Tables 1 and 2.

By comparison, the accuracy of the algorithm is up to 0.88, and the success rate is up to 0.81. Although the effect of this algorithm is not optimal for some video sequences, the algorithm is robust to the overall performance. When the

Table 1: Accuracy of different algorithms and comparison results.

	Tracking algorithm					
Video sequence	CSK algorithm	KCF algorithm	Struck algorithm	CT algorithm	TLD algorithm	Algorithm in this paper
1	0.49	1.77	0.46	0.35	0.69	0.78
2	0.48	0.80	0.39	0.37	0.82	0.84
3	0.56	0.76	0.42	0.35	0.43	0.80
4	0.45	0.81	0.48	0.40	0.63	0.82
5	0.56	0.82	0.47	0.42	0.84	0.83
6	0.46	0.17	0.45	0.43	0.32	0.88
7	0.26	0.23	0.41	0.38	0.52	0.77
8	0.35	0.88	0.43	0.39	0.83	0.84

Table 2: Comparison of success rates of different algorithms.

	Tracking algorithm					
Video sequence	CSK algorithm	KCF algorithm	Struck algorithm	CT algorithm	TLD algorithm	Algorithm in this paper
1	0.40	1.52	0.52	0.32	0.42	0.71
2	0.45	0.46	0.46	0.28	0.78	0.68
3	0.28	0.45	0.35	0.30	0.37	0.75
4	0.33	0.53	0.53	0.31	0.46	0.67
5	0.29	0.47	0.41	0.28	0.39	0.81
6	0.40	0.48	0.38	0.25	0.44	0.48
7	0.34	0.46	0.46	0.18	0.36	0.52
8	0.45	0.53	0.32	0.33	0.41	0.63

Table 3: Average center position deviation of different algorithms (pixel).

Video sequence	CSK algorithm	KCF algorithm	Struck algorithm	CT algorithm	TLD algorithm	Algorithm in this paper
1	121.6	18	—	103.8	62.1	12.0
2	9.9	276.7	—	7.0	40.3	10.9
3	86.7	165.4	—	82.4	3.0	3.5
4	27.8	75.6	—	30.5	5.5	3.6
5	18.9	18.8	10.4	19.4	14.2	13.0
6	134.6	104.3	14.3	125.3	20.4	11.6
7	75.1	181.6	—	90.3	12.8	16.0
8	212.3	154.8	—	212.7	7.0	9.7

Table 4: Average coverage of different algorithms (%).

Video sequence	CSK algorithm/ %	KCF algorithm/ %	Struck algorithm/ %	CT algorithm/ %	TLD algorithm/ %	Algorithm in this paper/ %
1	20.8	60.3	—	20.8	35.4	50.9
2	62.2	1.0	—	69.1	37.2	49.6
3	22.5	7.5	—	20.5	76.3	77.3
4	41.2	41.2	—	34.2	72.3	85.3
5	32.4	35.5	72.0	32.1	52.7	60.8
6	4.1	10.7	41.6	2.5	48.0	39.6
7	24.1	10.2	—	30.5	74.6	71.5
8	13.5	29.4	—	12.1	73.7	60.4

target is partially occluded, the algorithm can still accurately track the target.

The center position error refers to the center deviation of the tracking frame from the real target frame, and the coverage ratio is the proportion of the intersection of the tracking frame and the real target frame in the merged portion. In order to evaluate the tracking performance of different algorithms on the entire video series, the experiment will use the average center position deviation and average coverage as indicators to test, and the results are shown in Tables 3 and 4.

It can be seen from Tables 3 and 4 that among the eight tracking video sequences, the average center position deviation index of the algorithm has three groups of best and two groups of two; the average coverage has two groups of best and four groups of second. The experiment used the scoring method to evaluate the two indicators separately. The rule is to sort the two indicators according to their

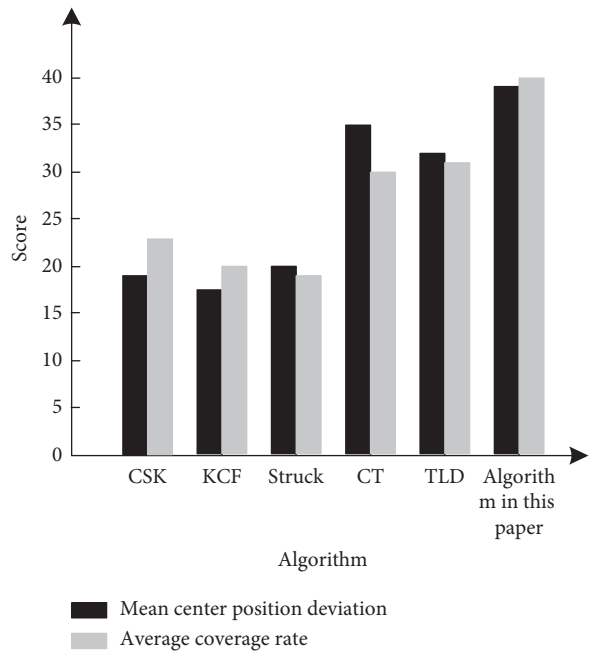

Figure 1: Performance comparison between average center position deviation and average coverage rate of different algorithms.

Table 5: Average frame rate comparison results of different algorithms (Hz).

Video sequence	CSK algorithm/ Hz	KCF algorithm/ Hz	Struck algorithm/ Hz	CT algorithm/ Hz	TLD algorithm/ Hz	Algorithm in this paper/ Hz
1	25.3	27.6	—	27.3	24.6	38.2
2	20.8	25.3	—	26.9	28.4	35.9
3	24.6	21.7	—	29.2	24.8	37.6
4	22.7	22.4	—	30.6	29.3	40.4
5	26.8	20.8	19.9	31.4	27.2	39.3
6	24.5	23.2	22.7	28.4	30.6	38.6
7	23.9	24.5	—	29	33.7	40.2
8	21.2	23.6	—	30.1	25.5	37.5

performance from high to low, and then score them in 6, 5, 4, 3, 2, and 1. Each video sequence is scored in turn, and finally, they are summed and used as their final result, as shown in Figure 1.

Analysis of Figure 1 shows that the algorithm scores 39 points on the average center position deviation and 40 points on the average coverage rate, which are better than other algorithms. This shows that the algorithm is better in the listed tracking algorithms.

The video frame rate is a measure used to measure the number of displayed frames and reflects the smoothness of the tracking results. The average frame rate of the eight video sequences is compared using different algorithms, and the results are shown in Table 5.

Analysis Table 5 can be obtained that the average frame rate of the algorithm in this paper is higher than other algorithms, both above 35 Hz. This shows that the tracking results using the algorithm of this paper are more fluent.

In order to verify the efficiency of the algorithm, the iterations and time consumption of different algorithms are compared, respectively, and the results are described in Figure 2.

It can be seen from Figure 2 that the iteration number of the algorithm is similar to the number of CT algorithms, with an average of 1–2 times, which is significantly lower than the CSK algorithm. In the comparison of time consumption, the time consumed by the algorithm is similar to the CSK algorithm, with an average of 12.5 s, which is significantly lower than the CT algorithm. The comparison results show that the tracking efficiency of the algorithm is higher.

To verify the stability of the proposed algorithm, three algorithms are used to track the target in the same experimental environment. The average outage probability of different algorithms is compared, and the results are shown in Table 6.

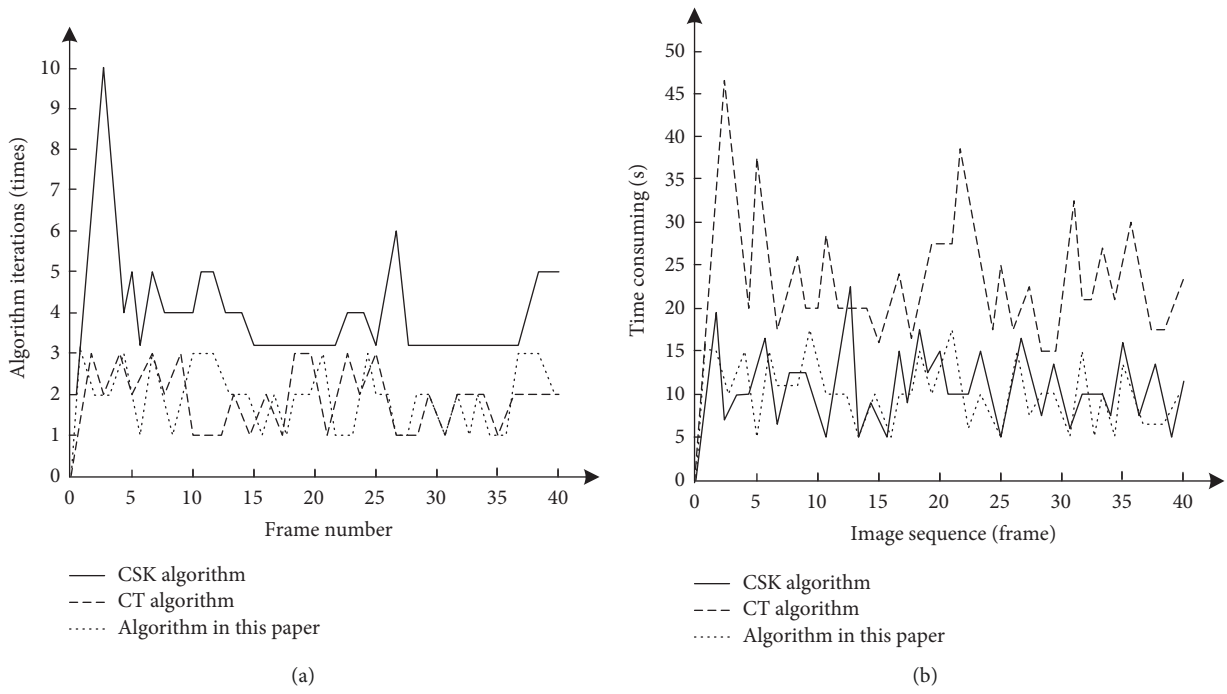

Figure 2: Comparison of efficiency of different tracking algorithms. (a) Comparison of iterations. (b) Time consumption contrast.

Table 6: Comparison of average outage probability of different location systems.

Average signal-to-noise ratio/dB	Algorithm in this paper	CSK algorithm	CT algorithm
0–5	0.012	0.014	0.011
5–10	0.014	0.014	0.015
10–15	0.017	0.016	0.018
15–20	0.264	0.383	0.461
20–25	0.297	0.455	0.518
25–30	0.306	0.498	0.624
30–35	0.325	0.534	0.659
35–40	0.330	0.607	0.768
40–45	0.384	0.711	0.839
45–50	0.422	0.793	0.972
Average value	0.2371	0.4025	0.4885

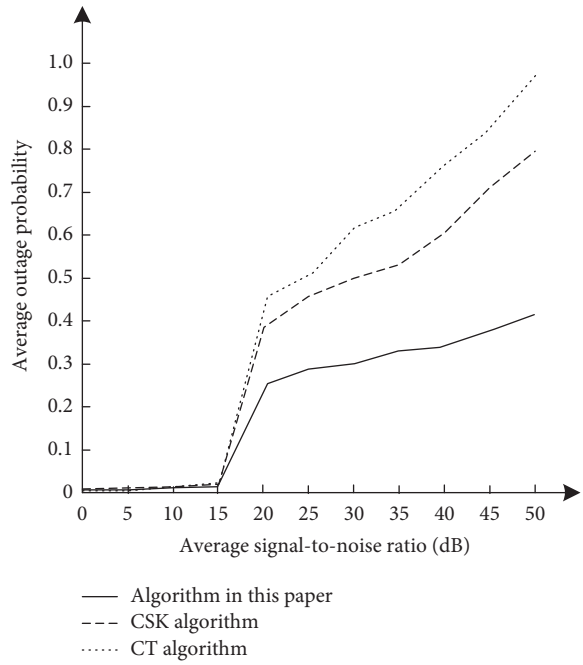

Figure 3: Comparison of average outage probability of different location systems.

In order to more clearly show the stability of the algorithms, the data in Table 6 are described by the implementation of the line graph, as shown in Figure 3.

Analysis of Table 6 and Figure 3 shows that the average outage probability of the algorithm is 0.2371, which is lower than the other two algorithms. The experimental results show that the proposed algorithm has better stability when tracking the target in the football match video.

In order to test the resource occupancy rate of the proposed algorithm, it compares and analyzes the target detection, feature extraction, single-target tracking, and multi-target tracking. The results are shown in Table 7.

It can be seen from Table 7 that the CPU and memory usage of the proposed algorithm are 26%–34% and 7%–17%, respectively. The usages of the CSK algorithm are 64%–70% and 33%–41%, respectively. Those of the CT algorithm are 64%–72% and 29%–39%, respectively. The experimental results show that compared with the other two algorithms, the algorithm of this paper tracks the resource occupancy rate of the target in the football match video which is low.

Table 7: Resource occupancy ratio of different platforms/%.

		Object detection	Feature extraction	Single-target tracking	Multi-target tracking
Algorithm in this paper	CPU occupancy rate/%	29	26	31	34
	Memory usage%	9	7	13	17
CSK algorithm	CPU occupancy rate/%	69	66	64	70
	Memory usage%	39	33	34	41
CT algorithm	CPU occupancy rate/%	65	64	68	72
	Memory usage%	37	29	33	39

4. Discussion

The accuracy and success rate of the algorithm are as high as 0.88 and 0.81, respectively; the average center position deviation index and the average coverage index are 39 and 40 points, respectively; the average frame rate is maintained above 35 Hz, and the tracking time is about 12.5 s. These data show that the proposed algorithm outperforms other algorithms in performing target tracking. The reason is the use of deep learning techniques in this paper. Deep learning is artificial neural network that simulates the human brain's analysis of things. By simulating the human brain to acquire data and parse it, this structure can better learn the essential characteristics of objects. The main ideas of deep learning target tracking are as follows: first, construct a deep learning model to train standard data sets and obtain more accurate target feature information. Then, use this model for target matching and positioning to achieve efficient target tracking. Depth features can more accurately reflect the appearance characteristics of moving objects than traditional features such as scale-invariant features (SIFT). Therefore, the algorithm of this paper greatly improves the accuracy of target tracking. At the same time, it combines the discriminant scale space algorithm and the Markov Monte Carlo algorithm to track the targets in the football video to ensure efficient tracking of single targets while achieving accurate tracking of multiple targets.

5. Conclusions

With the rapid development of computer technology, deep learning has become a big weapon for video target tracking. Deep learning technology has the advantages of high precision, wide application range, and strong stability. Aiming at the traditional target tracking algorithm in the football match video, there is the defect that the target will be lost when the target is severely occluded. A target tracking algorithm based on deep learning football game video is proposed. Combined with deep learning and target tracking technology to track the target, the experimental results show that the tracking success rate, required time, and average frame rate of the proposed algorithm are 0.81, 12.5 s, and 35 Hz, respectively. The average center position deviation index and the average coverage index are 39 and 40 points, respectively, and the resource occupancy rate is low. This shows that the algorithm can well track the targets in the football match video. In the future research, the information technology model is used to further improve the accuracy of football game video target tracking and reduce the defect of losing the target when the target is seriously blocked [41–45].

Data Availability

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that this article is free of conflicts of interest.

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Research Article

An English Diagnostic Intelligence Evaluation Model Based on Organizational Evolutionary Information Entropy

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English is widely used as a universal language in the world, but there are still great limitations in the diagnosis and evaluation of English, which leads to serious errors in the actual use of English. In order to realize the English diagnostic intelligence evaluation, improve the English learning ability, and construct the cognitive framework of English learning, this study proposes an English diagnostic intelligence evaluation model based on the organizational evolution information entropy. Firstly, this study adopts the HRNet text feature extraction model and uses the pretrained model to extract text features from text. Secondly, this study adopts the organizational evolution algorithm to simulate the process of sorting, merging, and cooperating in the evolution of the population and classify and organize the characteristic population. Finally, the information entropy method is used to represent the amount of information contained in each feature for evaluation, and the optimal solution is found. The method proposed in this study has good experimental results in actual testing and comparison and can basically realize the function of English diagnostic intelligence evaluation.

1. Preface

As one of the most common languages in the world, the reception and transmission of information in the process of English learning has a special status in practical applications [1, 2]. The English diagnostic test [3, 4] serves as a learning strategy to detect learners' vocabulary mastery and use [5, 6] and the entire process of English learning [7] and is an effective way to learn English. On the one hand, English diagnostic evaluation helps learners to master their own learning status and timely check and fill in gaps [8, 9]; on the other hand, it can help teachers to grasp students' learning loopholes [10, 11], carry out targeted teaching activities, and improve students' learning ability [12, 13]. English diagnostic evaluation is widely used, including self-study [14, 15], classroom teaching [16, 17], practical communication [18], text reading [19], and other scenarios.

With the continuous development and progress of cognitive diagnostic theory, language cognitive diagnostic testing has gradually become the focus of current research. The production of language cognitive diagnosis is mainly composed of the integration of relevant professions and technologies such as cognitive psychology, measurement psychology, modern statistics, and computer science. With the continuous progress of cognition, people are not satisfied with the macroscopic test results provided, but pay more attention to the process of exploring the whole cognitive test, which is more obvious in English diagnosis. With the continuous progress of cognition, people are not satisfied with the macroscopic test results provided, but pay more attention to the process of exploring the whole cognitive test, which is more obvious in English diagnosis.

According to the research status of English diagnostic research at home and abroad, there are certain deficiencies. (1) There is a lack of theoretical test guidance, and it is not updated in principle, but refurbished. The diagnosis in the field of English testing is still in the stage of exploration and small-scale application, and the testing and verification of large-scale examinations has not yet been carried out. Testing researchers lack specific diagnostic testing principles to guide, lack understanding of the steps and principles of English diagnostics, and are easily limited by current testing

methods and testing conditions. (2) The definitions of diagnostic attributes are different, and there is great controversy. The factors and attributes of diagnosis have a great influence on the accuracy and rationality of the results of English diagnosis, and different attributes ultimately affect the effect of the experiment. The current related research and technology lack the corresponding English proficiency framework and systematic language theory support; it is difficult to select the corresponding attributes correctly, and it is difficult to guide the determination and classification of attributes. There is a considerable controversy among researchers on the definition and quantity of attributes. At the same time, the granularity of attributes is difficult to control, and the granularity of test attributes included in the diagnosis is too simple and rough, resulting in a wide range of attributes, and it is difficult to determine the role of diagnostic information. On the contrary, the granularity of attribute information included in the research process is too fine and the quantity is too large, which affects the classification accuracy and prediction efficiency of English cognitive diagnosis. (3) The diagnosis object is single, and the group cannot be diagnosed. Most of the diagnosis objects of English diagnosis are individuals, and they are more inclined to find problems from individuals and only focus on individual-level diagnosis, which can effectively provide individual diagnosis information. However, the differences between different testers are relatively large, and the diagnostic information is too fragmented to provide test information for the entire group, and it is difficult to timely feedback group information. The current group diagnosis is still under continuous research, and it is still difficult to perform tests by groups and categories. (4) There are few diagnostic reports, which are out of touch with practical applications. The current English diagnosis is mostly a proficiency test, and the results of the test are difficult to link with the actual use, so many researchers do not pay attention to the diagnosis report. The diagnostic information in the score reports of the current research and literature is very one-sided, with less information, mostly descriptive language, and lack of quantitative methods and operability. In general, there are many problems in the field of English diagnostic intelligence evaluation, and there is a lack of scientific and reasonable methods to quantify and deal with the problems.

English diagnostic evaluation has a very important role, but the effect in actual practice is not optimistic. Usually lack of corresponding evaluation knowledge and ability and evaluation time and energy results in the current English evaluation being still dominated by English dictation. Because the evaluation method is single, it is difficult to evaluate the relationship between actual use and vocabulary storage, and the evaluation effect is not obvious. With the development of science and technology, machine learning methods and deep learning methods are gradually applied in life [20, 21]. In terms of text feature extraction and understanding [22], organizational evolution algorithm [23, 24], information entropy method [25, 26], neural network model [27, 28], and other methods [29, 30] are gradually applied to this task [31, 32], and good experiments have been achieved effectively [33, 34]. At the same time, it provides a good experimental basis for the English diagnostic intelligence evaluation task in this study.

Aiming at the problems of lack of theoretical guidance and inconsistent evaluation standards in traditional English evaluation methods, there is an urgent need for a method to improve the single mode of English learning evaluation methods, enrich English diagnosis methods, and improve evaluation effects. This study proposes an English diagnostic intelligence evaluation model based on organizational evolutionary information entropy, which can evaluate English learning ability from multiple perspectives. In addition, it has a high degree of intelligence, reduces the investment of manpower and capital, and has great advantages in improving English learning important practical significance.

2. Related Work

2.1. Organizational Evolution. In 1995, Wilcox introduced the concept of organization into the classifier based on genetic algorithm and proposed a classification algorithm of organizational co-evolution. It puts the characteristic data in each organization, realizes the co-evolution between organizations through methods such as division, merger, and cooperation between organizations, and then extracts rules from the evolution process. In the process of continuous evolution, the population structure can use the searched optimal solution and the information of leaders in the organization to guide the model to continuously explore and converge to the vicinity of the optimal solution. In the algorithm of organizational evolution, the entire population is formed through a certain number of organizations. In the process of evolution, these groups continuously interact with each other to increase the diversity and different characteristics of the organization, avoid the situation of the organization falling into the local optimal solution in the process of continuous evolution, and reduce the probability of falling into the local extreme value. Although organizational evolution methods imitate the phenomenon of actual social evolution and show good performance, they do not make full use of the feature information in the organization when dealing with optimization problems and are still difficult to deal with high-dimensional features. Therefore, it is necessary to use other methods to better extract high-latitude features.

2.2. Information Entropy. Information entropy is one of the main indicators used to measure the dispersion of the set, and it can also reflect the amount of information contained in different data sequences. It is widely used in tasks such as text classification, text extraction, and image segmentation. Using information entropy, a suitable adaptive scale operator can be constructed so that the network model can classify different types of features, adaptively adjust the scale and scale of the organizational structure, and improve the learning effect of the entire model for texts and populations. Since text features are easily affected by context, this study introduces feature functions into information entropy

through references and constructs a new feature information function based on text feature information statistics. Since the main function of the entropy function is to describe the amount of information contained in the organization, it is now introduced into the task of English diagnostic intelligence evaluation to describe the number of text features contained in different organizations, which is equivalent to the evolving organization. Each type of feature value has a corresponding attribute or organization. It can effectively overcome the influence of contextual features, can reduce the influence of irrelevant text feature vectors, noise, and multiword meanings, and has achieved good experimental results in text feature extraction.

2.3. English Diagnostic Method. The traditional diagnostic test intelligently reports the total score of the participants, reflecting the overall level of the subjects and their position in the group [35, 36]. There are big problems in the preface research of English intelligent diagnosis at home and abroad, which are mainly divided into several categories [37, 38]. (1) The field of English diagnostics lacks the guidance of evaluation theory to achieve theory-oriented test development. Although many experts and scholars have been doing innovative work at present, the innovation of theory and method cannot be realized. (2) Different cognitive attributes determine different influencing factors, and the choice of factors has a greater impact on the final result. The selection of attributes and factors is now highly controversial. (3) The object of diagnosis and testing is single, and it is more inclined to diagnosing individuals and cannot diagnose and test organizations and groups. (4) The diagnosis report cannot be quantified and is mostly descriptive language, which is out of touch with the actual use environment. Cognitive diagnosis is a combination of psychology and psychometrics, which reflects the tester's mastery of a certain characteristic knowledge point and can describe the tester's proficiency in language knowledge structure and skills in detail [39]. Compared with the previous method, the English diagnostic intelligence evaluation method is based on the previous basis, using the technology to achieve automation and intelligence to more accurately describe the tester's learning status. At the same time, it can intelligently locate the knowledge point loopholes in learning, which is convenient for teaching and learners to check and fill in the gaps and improve continuously.

2.4. Text Feature Extraction. Turn text data into vector data, and learn more language features from text data in vector data [40, 41]. In other words, the text is not treated as a string, but as a vector that is more convenient to process mathematically, which is the core problem of text feature extraction [42, 43]. The method based on the neural network model is to create a network model, through continuous iterative learning, and finally obtain the conditional probability of each word based on its context [44, 45]. At the same time, during each iteration, the model can evaluate the error and punish those parameters that cause errors according to certain update rules [46]. Text feature extraction based on neural network tends to be mature, which has established a solid foundation for subsequent tasks. In this study, we will use text feature extraction as the basis for the English diagnostic intelligence evaluation task.

3. English Diagnostic Intelligence Evaluation Model

The English diagnostic intelligence assessment is used to diagnose students' reading and writing levels, find their existing problems, provide effective feedback information for students and teachers, and make targeted enhancements and improvements in subsequent learning and teaching. Most of the current studies are mainly English diagnostic tests designed by classification methods, define English assessment methods as English tests under specific conditions, and do not establish a reasonable connection and explanation between the English assessment process and the results. The main problems of English intelligent diagnosis are that the evaluation method is not uniform, the degree of automation and intelligence is low, and it requires a lot of manpower and material resources.

To solve this problem, this study proposes an English diagnostic intelligence evaluation model based on organizational evolutionary information entropy. First, this study introduces the HRNet text feature extraction network and uses the pretrained neural network to extract the feature information corresponding to the English text in Figure 1. Since the HRNet network adopts the fusion of multiscale features and multistage learning, it collects rich text feature information, and at the end of the network, it can output multidimensional text features through multilevel fusion. Secondly, this study inputs the collected text feature information into the organizational evolution module and classifies and organizes different types of feature information through the split operator, merge operator, and cooperation operator. Finally, the difference between the predicted text feature information and the label information is reduced by information entropy, and the entire network model is continuously improved to produce better prediction results. The HRNet text feature extraction network mainly extracts text features, which are multidimensional tensors.

3.1. HRNet Text Feature Extraction Network. The HRNet neural network is widely used in image and text feature extraction and other related tasks, focusing on outputting reliable high-resolution representations. The network model maintains high-resolution representations throughout the process, improving the prediction accuracy of various tasks. In this study, we use the HRNet text feature extraction network to extract the text features in the English test images for the subsequent task of English diagnostic intelligence evaluation. There are many kinds of text extraction networks and a wide range of applications. This study mainly adopts the pretraining model obtained in a large dataset in advance and then fine-tunes it in the dataset collected in this study, which is more suitable for the task of English text feature extraction.

In Figure 2, the HRNet neural network starts from the high-resolution subnetwork as the first stage and gradually

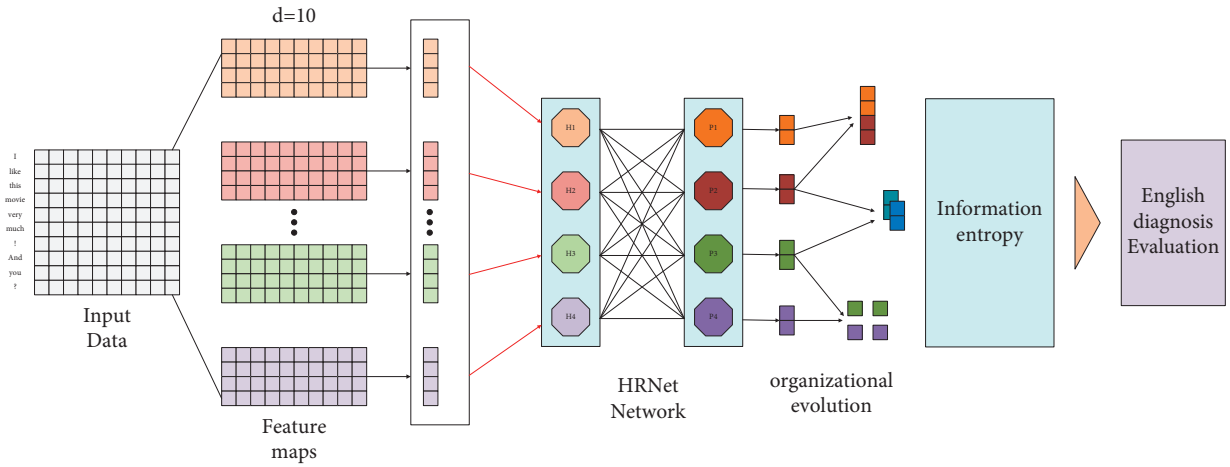

Figure 1: Structure diagram of the English diagnostic intelligence evaluation model.

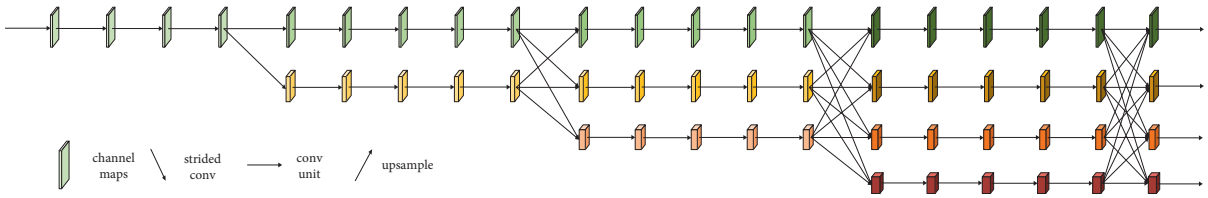

Figure 2: HRNet text feature extraction network.

increases the subnetworks from high resolution to low resolution to form more stages and connects parallel subnetworks of multiple resolutions. In stages 2, 3, and 4 of the network structure, multiple multiscale feature fusion modules are used to fuse multiscale features so that features of each resolution can repeatedly receive feature information from representations of other resolutions. Get rich high-resolution features:

$$N_{11} \longrightarrow N_{22} \longrightarrow N_{33} \longrightarrow N_{44}. \tag{1}$$

The current text feature extraction network in the image is to connect high-resolution to low-resolution self-networks in series. Each subnetwork forms a stage, which is composed of a series of convolution modules. The adjacent self-network modules are downsampling connect. As shown in formula (1), it represents the four stages of HRNet neural network:

$$\begin{array}{ccccccc} C_{31}^{1} & \searrow & \nearrow & 2 & \searrow & \nearrow & C_{31}^{3} \\ C_{32}^{1} & \longrightarrow & \varepsilon_{3}^{1} & \longrightarrow & C_{32}^{2} & \longrightarrow & \varepsilon_{3}^{2} \longrightarrow C_{32}^{3} \longrightarrow \varepsilon_{3}^{3} \\ C_{33}^{1} & \nearrow & \searrow & & C_{33}^{2} & \nearrow & \searrow \quad C_{33}^{3} \quad \nearrow \end{array} \tag{2}$$

A switching unit across parallel subnets is introduced in HRNet neural network so that each subnet repeatedly accepts feature information from other parallel subnets. As shown in equation (2) and Figure 3, we take the third stage as an example. HRNet divides the third stage into several exchange modules, each of which consists of three parallel convolutional units and one exchange unit. The image features of the three parallel subnetworks are fused and learned through the exchange unit module. In the HRNet network, a 3×3 convolution is used for downsampling and a 1×1 convolution is used for upsampling. The images of the same resolution do not perform any operations, and the images are directly fused.

As shown in Figure 4, a represents the feature selection of HRNet V1, and only the feature image with the highest resolution is selected. B shows the feature selection of HRNet V2, which links and fuses feature images of all resolutions, mainly for semantic segmentation and monitoring tasks of key points in images. C represents the feature selection of HRNet V2p. Based on HRNet V2, a feature pyramid is used. In order to get a better effect of the network model on text extraction, we adopt the C network structure to improve the feature extraction ability of the network model.

3.2. Organizational Evolution Model

3.2.1. Split Operator. The main function of the split operator is to classify a large number of organizations into smaller ones in Figure 5. Different types of tiles in Figure 5 represent different types of data features. A threshold is designed in the algorithm. If the size or number of the tissue exceeds the corresponding threshold, it will be decomposed, and the split tissue will be put into the next generation of the population for subsequent tasks. For an organization *orG*, if *orG*> *orG* > max_os, split it into zero child organizations orG_1 and orG_2, where max_os is the threshold. The main function of the split operator is to balance the distribution of individuals in the organization which cannot achieve new solutions. However, it can prevent individuals from tending to the sameness in the organization and avoid the situation that the whole

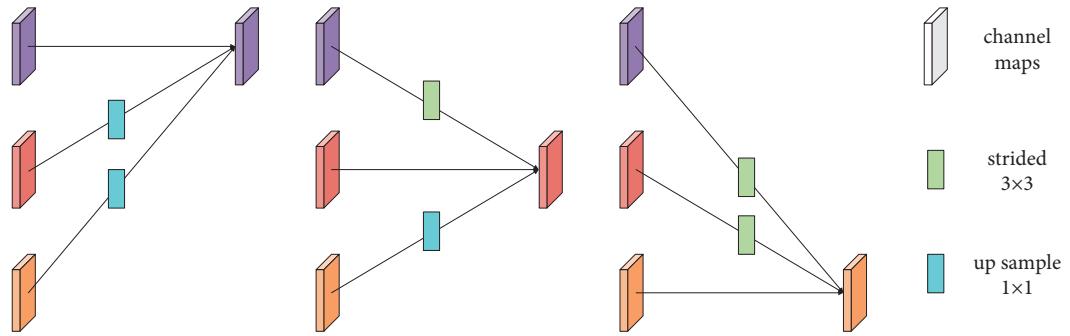

Figure 3: Multiscale text feature fusion.

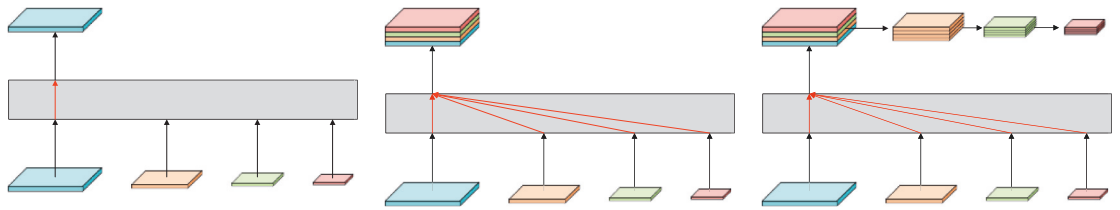

Figure 4: The last layer of the text feature extraction method.

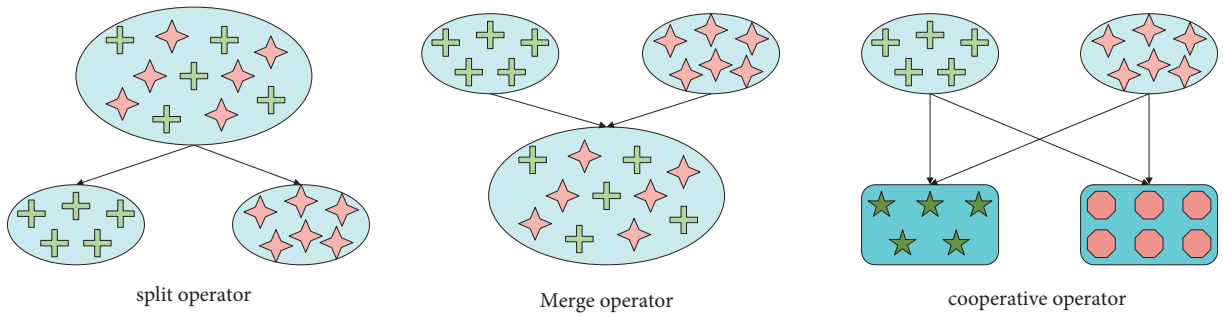

Figure 5: Organization evolution operator.

network model falls into the local optimal solution. Through the effect of the split operator on the entire organization, conditions are provided for the subsequent organizational evolution operator:

$$(|\text{org}| > \max_os)\text{or}\left((|\text{org}| \le \max_os)\text{and}\left(\frac{U(0,1) < |\text{org}|}{N_0}\right)\right). \tag{3}$$

3.2.2. Merge Operator. The merger operator is a method designed to merge two organizations into a larger organization by modelling the relationship between competition and annexation between societies in Figure 5. Through the merger operator, two weaker organizations can be merged to form a larger organization with strength and scale. By continuously increasing its own strength, a better organization can be obtained. Merge the organizations orG_1 and orG_2 into a new organization orG. The essence of the merged organization is that a strong organization swallows a weak organization. The merge operator plays the role of distributing the distribution of individuals in the organization. It can also use the organization with high ability to search for new solutions and merge them into the new organization to further improve the organization's ability:

$$ogG_1 = \left\{\begin{matrix} x_1 \\ x_2 \\ \cdots \\ x_p \end{matrix}\right\}, x_i = (x_{i1}, x_{i2}, \ldots, x_{in}), i = (1, 2, \ldots, p),$$

$$ogG_2 = \left\{\begin{matrix} y_1 \\ y_2 \\ \cdots \\ y_p \end{matrix}\right\}, y_j = (y_{j1}, y_{j2}, \ldots, y_{jn}), j = (1, 2, \ldots, q), \tag{4}$$

$$e_{jk} = \begin{cases} x_k^a, x_k \times U(1 - sR, 1 + sR) < x_k^a \\ x_k^b, x_k \times U(1 - sR, 1 + sR) > x_k^b, k = (1, 2, \ldots, n). \\ x_k \times U(1 - sR, 1 + sR), \text{else} \end{cases}$$

3.2.3. Cooperation Operator. The cooperation operator is to improve their respective strengths through cooperation between two organizations in Figure 5. The essence is that two organizations orG_1 and orG_2 generate two new organizations orG_{n1} and orG_{n2}. The new organization generated by the cooperation operator is added to the next generation group, and the original two organizations orG_1 and orG_2 are deleted at the same time.

$$
\begin{aligned}
ogG_1 &= \left\{ \begin{array}{c} x_1 \\ x_2 \\ \cdots \\ x_p \end{array} \right\}, x_i = (x_{i1}, x_{i2}, \ldots, x_{in}), i = (1, 2, \ldots, p), \\
ogG_2 &= \left\{ \begin{array}{c} y_1 \\ y_2 \\ \cdots \\ y_p \end{array} \right\}, y_j = \left(y_{j1}, y_{j2}, \ldots, y_{jn}\right), j = (1, 2, \ldots, q), \\
ogG_{n1} &= \left\{ \begin{array}{c} r_1 \\ r_2 \\ \cdots \\ r_p \end{array} \right\}, \in r_i = (r_{i1}, r_{i2}, \ldots, r_{in}), i = (1, 2, \ldots, q), \\
ogG_{n2} &= \left\{ \begin{array}{c} s_1 \\ s_2 \\ \cdots \\ s_p \end{array} \right\}, s_j = \left(s_{j1}, s_{j2}, \ldots, s_{jn}\right), j = (1, 2, \ldots, q),
\end{aligned} \tag{5}
$$

$$
r_{ik} = \begin{cases} x_k^a, y_k + U(0,\ 1) \times (y_k - x_{ik}) < x_k^a \\ x_k^b, y_k + U(0,\ 1) \times (y_k - x_{ik}) > x_k^b, k = (1, 2, \ldots, n), \\ y_k + U(0,\ 1) \times (y_k - x_{ik}), \text{else} \end{cases}
$$

$$
s_{jk} = \begin{cases} x_k^a, x_k + U(0,\ 1) \times \left(x_k - y_{jk}\right) < x_k^a \\ x_k^b, x_k + U(0,\ 1) \times \left(x_k - y_{jk}\right) > x_k^b, k = (1, 2, \ldots, n). \\ x_k + U(0,\ 1) \times \left(x_k - y_{jk}\right), \text{else} \end{cases}
$$

The three types of organizations mentioned above have different functions. Although the classification operator does not have the ability to search for new solutions, it can balance the role of organizational scale. The main function of the merge operator and the cooperative operator is to search for new solutions.

3.3. Information Entropy. Information entropy was proposed by the mathematician Shannon. It is one of the main indicators used to measure the dispersion of sets. At the same time, it can also reflect the amount of information contained in different data sequences. It is widely used in text classification and text extraction. In order to realize the task of English diagnostic intelligence evaluation, information entropy is used to determine the change relationship of different organizational structures, so each organizational structure constitutes a sequence, and information entropy is used to calculate the information amount of the features contained in each factor, that is, the weight p_{ij}, where $H(X)$ represents the information entropy value of the sample data X:

$$
p_{ij} = \frac{p_{ij}}{\sum_{j=1}^{n} p_{ij}}, \quad i = 1, 2, 3, \tag{6}
$$

$$
H(x) = E(I(x)) = \sum_{i=1,j=1}^{n} p_{ij} \log \frac{1}{p_{ij}}. \tag{7}
$$

According to Shannon's theorem, when the information entropy of the image $E = 0$, the information amount of the image is 0; when the probability distribution of each gray value in the image is uniform, that is, when the probability of all different pixels is equal, the information entropy of the image is equal. Maximum value can be obtained. For the English language, its language rules are the key elements of the English diagnostic intelligence assessment. According to the probability distribution of language rules, the information content of the language system can be calculated. Because of the amount of information, the system structure is more complex. On the contrary, the system structure is relatively simple. On contrary, the system structure is relatively simple than information entropy function. We use the standard function, which is expressed and explained in detail in equations (6) and (7)

4. Experimental Results and Analysis

4.1. Dataset and Experimental Setup. In the experiment, we use the WikiPeda corpus to train to obtain word vectors and use the Twitter phrase text dataset and the established English diagnostic intelligence evaluation dataset for training and testing. In this study, Adam optimizer is used for network model and fitting and optimization.

4.2. Experimental Results and Analysis. As shown in Figure 6, we use the multimodule test accuracy to represent the effect of English diagnostic intelligence evaluation. In the figure, A, B, C, and D, respectively, represent the spelling of words, the mapping of pronunciation, the grammar rules, and the correspondence between English and Chinese. From the figure, we can see that the accuracy of the test is not directly related to the number of participations, but its English-Chinese corresponding module scores are generally high, and the word spelling needs further improvement.

Figure 7 shows the mapping relationship between the spelling and pronunciation of a word in English, that is, the pronunciation of a word can correspond to the spelling of a word. Through the method of entropy calculation, we can clearly see the mapping rules between the spelling and pronunciation of American English and British English words, green represents British, and yellow represents American, and obviously British English is higher than American English, showing language rules' complexity.

Figure 8 shows the complexity of English grammar rules. In the figure, blue indicates low complexity, red indicates high complexity, and gradually transitions from blue to red. Usually, the independent variable is represented by the past tense of the verb and the degree of grammaticalization (two axes on the bottom), and the height is used to represent the degree of difficulty. We can see that the past tense of verbs

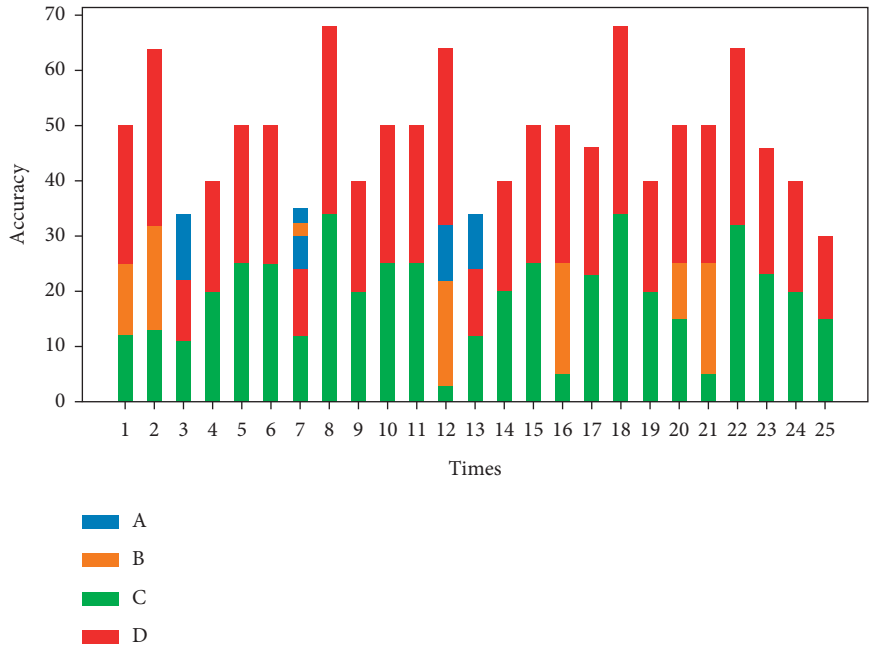

Figure 6: Multimodule test accuracy.

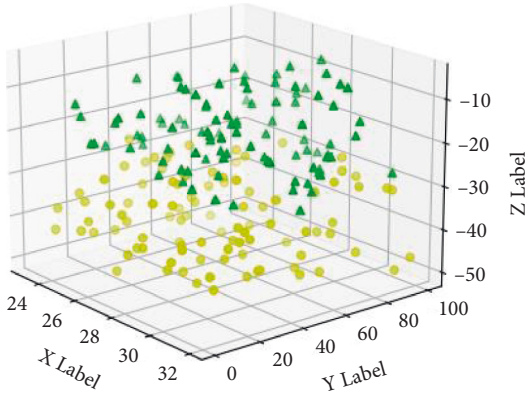

Figure 7: The relationship between word spelling and pronunciation.

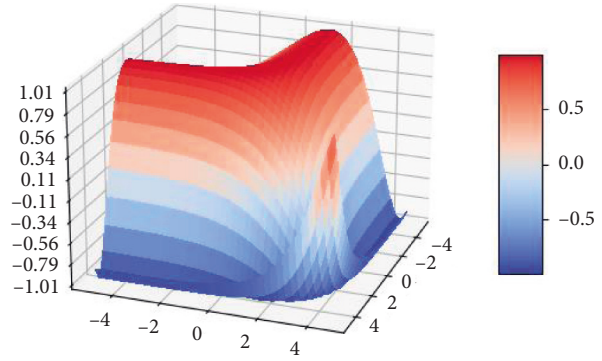

Figure 8: The complexity of grammar rules.

has a higher degree of difficulty and a higher entropy value in a certain area. Therefore, when learners learn such words, they need to use more vocabulary and examples to describe the use of these words completely.

Figure 9 shows the complexity of the semantics. As a symbol system, English has many meanings. Although these words have different meanings, they are generally divided into three types: (1) have the same extended meaning in both variants; (2) have the extended meaning in one variant and change in the other and there is no extended meaning in the body; (3) there are different extended meanings in the two variants. Figure 9 shows the connection between the three situations. From the figure, we can analyze the corresponding connection between each two situations.

Figure 10 shows a comparison of the accuracy of various network models and methods. In the image, the x-axis represents the interval between different test modules, the y-axis represents multiple testing methods, and the z-axis represents the corresponding accuracy of the methods. From the figure, we can see that the green area map of the method in this study has a better accuracy value and has a better fitting effect in the correspondence of multiple modules.

Figure 11 shows the confusion matrix, which corresponds to the comparison between the results predicted by the network model and the results of the label. From red to blue, the prediction effect of the model is shown to be very poor, and the value range is [0, 1]. The abscissa and ordinate represent the corresponding instances and labels. From the figure, we can see that some instances perform poorly, and we need to continue to improve and improve in future experiments.

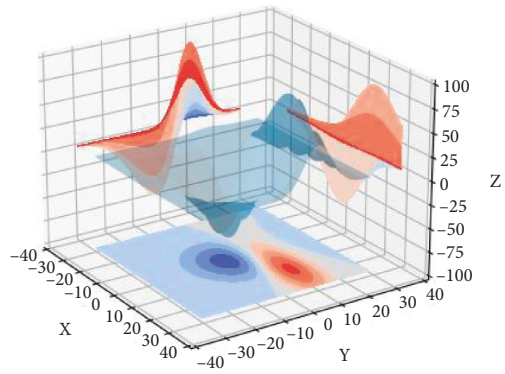

Figure 9: Semantic complexity relationship diagram.

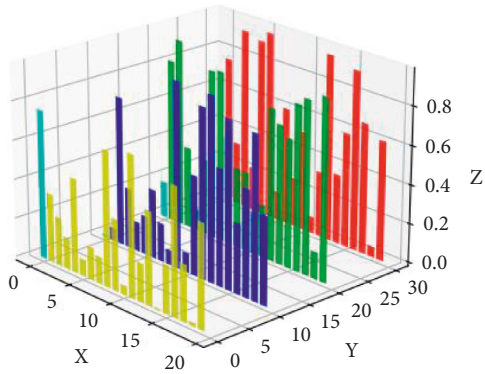

Figure 10: Accuracy comparison of multiple methods.

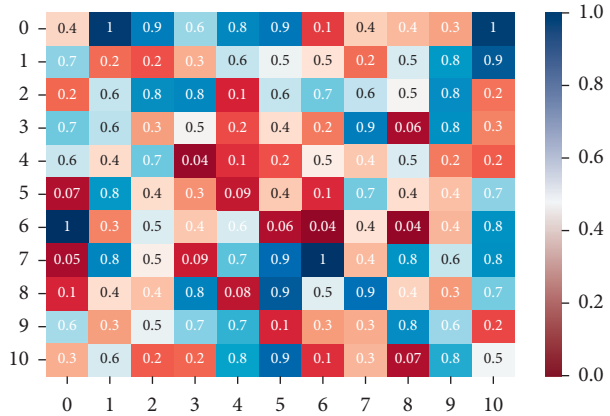

Figure 11: Confusion matrix.

5. Summary

This study proposes an English diagnostic intelligence evaluation model based on organizational evolutionary information entropy. This study firstly uses HRNet neural network to extract text features, then uses the organizational evolution method to simulate the population processing process of feature information, and finally optimizes the entire network model through information entropy to obtain the final optimal solution. Compared with other existing methods, the method in this study has better fitting effect and accuracy and has achieved good results in the evaluation of English diagnostic intelligence. In the follow-up work, we should pay more attention to the establishment and improvement of the network model, simplify the structure and complexity of the network model, and improve the prediction effect of the network model.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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Research Article

Optimal Inspection Scheduling Model for Monitoring Railway Track Grids

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The optimization of railway track inspection schedules is of great significance for the monitoring of railway track conditions and reasonable organization of track maintenance tasks. Here, an optimal inspection scheduling model for monitoring railway tracks is proposed. Railway track inspection activities are divided into equal-length units in the time and spatial location dimensions. The various constraints and objectives on the time and location of different track inspection activities are defined in detail regarding subdivisions of individual management units. The objectives of the model development are to achieve a more optimized equilibrium and robustness of the track inspection schedule. Based on the maximum entropy criterion, entropy is used to measure the distribution equilibrium of the inspection schedule in the time dimension. The proposed model is verified using actual data from the Lanxin railway.

1. Introduction

Following the development of high-speed railways, the safety and continuous operation of trains and comfortable travel of passengers necessitate the reliability, stability, and durability of railway track systems. A railway track is a structure composed of multiple components and is classified into two types: ballasted and ballastless tracks [1]. The ballasted track consists of rails, sleepers, fasteners, and ballast. Slab ballastless tracks and double-block ballastless tracks are mainly used in China's high-speed railways. The slab ballastless track consists of rails, fasteners, slab tracks, cement-emulsified asphalt mortar, and baseplates [2]. The railway track system is a long and large linear asset that is categorized as civil infrastructure and not electrical equipment. Therefore, the achievement of real-time online monitoring of the condition of the entire track system is difficult and costly.

Track inspection comprises both on-track and on-board inspections for track geometry and track component inspection [3]. According to the rules of railway track maintenance [4–6], inspection activities of various inspection methods for railway track systems should be scheduled and organized scientifically and rationally. Ensuring that managers are aware of the condition of railway tracks in time and effectively organize maintenance operations is critical. Common track inspection methods include track geometry cars, track geometry trolleys, cabin-mounted track quality instruments, portable track quality instruments, rail detection trolleys, and manual track walking inspection. On-track inspections include track geometry trolleys and manual track walking inspections among others, whereas on-board inspections include track geometry cars and portable track quality instruments, among others.

Optimizing the equilibrium of the time intervals between adjacent inspection activities and overall robustness are the main challenges experienced in the scheduling of track inspection activities. The equilibrium of the time intervals between adjacent inspection activities indicates that the time intervals of different inspection activities should be as balanced as possible. In addition T_j, T_{j+1}, T_{j+2}, T_{j+3}, and T_{j+4}

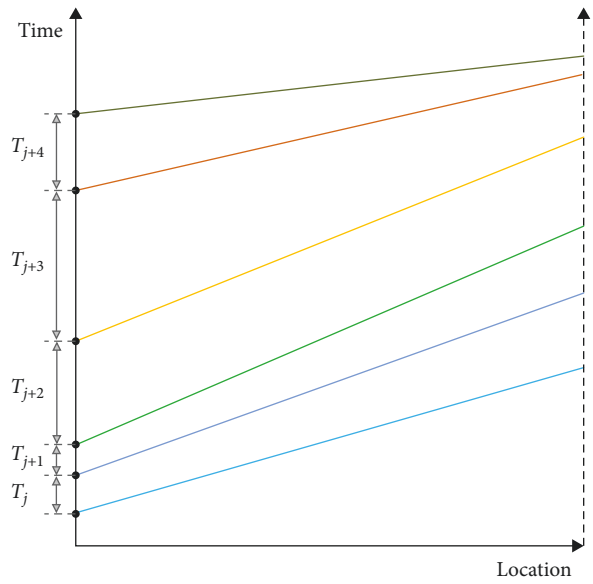

Figure 1: Diagram of adjacent inspection intervals for different inspection activities.

should be as equal as possible, as shown in Figure 1. Improved equilibrium allows for a more optimized distribution of inspections, thereby preventing inspections that are spaced out within too long a period or that are too frequent within a short period. The robustness of the inspection schedule refers to the ability to reduce the effects of various random disturbances (such as severe weather conditions) on the schedule during the execution process. Moreover, $\min(T_j, T_{j+1}, T_{j+2}, T_{j+3}, T_{j+4})$ should be as large as possible. Improved robustness can increase the flexibility of the inspection schedule in the start or end time variation of inspection activities and prevent delays and advances in inspection activities that disrupt the organization of resources such as labor, materials, and machines, as shown in Figure 1. In Figure 1, the horizontal axis represents the location along the railway track, the vertical axis represents the date of inspection activities, and the solid lines with different colors represent different inspection activities.

Currently, research on the optimization of transportation infrastructure inspection schedules mainly focuses on the following two aspects. (1) In a certain scheduling period, the optimal inspection frequency for the transportation infrastructure using the same inspection method and the inspection interval between two adjacent inspection activities are studied [7–17]. These studies assume that the inspection workload and inspection frequency of the transportation infrastructure are not fixed periodically.

Liu [7] aimed to minimize the risk of derailment in the transportation of dangerous goods and proposed a rail inspection frequency optimization model to determine the optimal annual inspection frequency for different railway segments under different risk levels. Soleimanmeigouni et al. [8] proposed a cost-based track geometry inspection interval optimization model to determine the time interval between adjacent inspections of the track geometry in a scheduling cycle. Liu et al. [9] proposed an optimization model for a rail detection trolley inspection schedule with the optimal objectives of optimizing traffic safety, cost, and transportation efficiency. This model determines the number of rail detection inspections in a scheduling period and the detection time interval for two adjacent rail detection inspections with a known number of detection times.

Khouy et al. [10] proposed an optimization model for track geometry inspection intervals, with the minimum cost (including inspection cost, fault repair cost, preventive maintenance cost, and potential risk cost) corresponding to the unit gross tonnage as the optimization objective. Podofillini et al. [11] proposed an optimization model of rail detection schedule using risk-informed approaches and reliability-based approaches and determined the inspection interval of two adjacent rail detection inspections with the optimization objectives of cost and safety. Using the structural reliability theory, Kashima [12] proposed an optimization model for the inspection interval of rail detection inspection based on the life cycle cost. Vatn and Svee [13] proposed a risk-based optimization model for rail detection inspection intervals, and their optimization objective was to minimize cost.

Lam and Banjevic [14] proposed a decision policy for condition-based maintenance that schedules inspections according to the current health of the system, optimized myopically over the subsequent inspection interval. Yan et al. [15] proposed and optimized a nonfixed periodic inspection strategy with a warning degradation threshold, whose optimization objectives were the application of the warning threshold and inspection interval. In the proposed strategy, the above warning threshold is categorized as a degradation process divided into two parts: normal and warning areas, where two different inspection intervals can be used. When the equipment is in normal areas, the corresponding inspection interval is long. When the equipment is in the warning areas, the corresponding inspection interval is short. Kim and Frangopol [16] proposed a cost-based inspection and monitoring optimization model for fatigue-sensitive structures using a probabilistic approach. The inspection schedule is the solution to an optimization problem to minimize the expected total cost (including inspection cost and expected failure cost) and determine the number of inspections and the interval between two adjacent inspections within a planning cycle. Yang and Xie [17] proposed a discrete-time SMDP-based decision-making approach for determining optimal MR&R strategy and inspection intervals for infrastructure facilities, resulting in cost savings and reducing unnecessary waste of resources.

Using the model predictive control (MPC) approach, Su et al. [18] developed a scenario-based chance-constrained approach for railway condition-based maintenance planning, minimizing disruption cost and setup cost of maintenance slots for a finite planning horizon. Further advancing this research, Su et al. [19] proposed a multilevel decision-making approach for both optimal long-term condition-based maintenance planning and optimal short-term maintenance crew scheduling, minimizing condition deterioration and maintenance costs. The MPC and mixed-integer linear programming (MILP) approaches were used.

(2) The optimal selection of different inspection methods for transportation infrastructure at different decision-making stages in a certain planning horizon has been studied [20–22]. These studies assume that the transportation infrastructure manager adopts a fixed periodic inspection strategy. Only one inspection activity was selected from a finite set for each decision-making stage. The finite set consists of different inspection activities wherein different instruments are used. Multiple inspection activities cannot be selected during the same decision-making stage.

Madanat and Ben-Akiva [20] adopted the latent Markov decision process to determine the types of inspection and maintenance activities at different decision-making moments of road surfaces in a long planning cycle, considering the difference in inspection errors and inspection costs of different inspection methods. Durango-Cohen and Samer M [21], considering the uncertainty of road surface state degradation, dynamically adjusted the weight system of the finite known Markov state degradation model using the quasi-Bayes approach to describe the regulation of road surface state degradation. The latent Markov decision process method is used to determine the types of inspection and maintenance activities at different decision moments in a long planning cycle. Mishalani and Gong [22] established the functional relationship between the inspection error of different inspection methods of road surfaces and the uncertainty of their spatial sampling and determined the inspection activity type and maintenance activity type of road surfaces at different decision-making times in a long planning cycle using the hidden Markov decision process method.

In this study, railway track inspection activities were divided into same-length units in the time and spatial location dimensions to consider the influence of various heterogeneous factors (such as geological conditions and climatic conditions). Based on the features of railway track inspection activities, and to optimize the equilibrium and robustness of rail track systems, a time-location grid-based optimal inspection scheduling model for monitoring railway tracks is proposed. The constraint system includes time constraint between activities, fixed duration constraint, spatial constraint between activities, rate constraint of activities, resource constraint, and continuity constraint.

Three fundamental perspectives distinguish our study from previous investigations. (1) This study proposes a method for the definition and division of time-location grids. We divide railway track inspection activities into same-length units in the time and spatial location dimensions. Various constraints and objectives on the time and spatial location of different track inspection activities are defined in great detail with regard to subdivisions of individual management units. (2) A time-location grid-based optimal inspection scheduling model is proposed, with the optimization objectives of attaining equilibrium and robustness. This model enhances the practicability of the inspection schedule, reduces the influence of various factors on the inspection schedule, and guarantees the management of the actual inspection activities on-site. (3) Based on the maximum entropy criterion, entropy is used to measure the distribution equilibrium of adjacent inspection activity intervals in the inspection schedule.

The remainder of this paper is organized as follows. In Section 2, we analyze the features of railway track inspection activities, explain the concept of time-location grids for railway tracks, and present the time-location grid-based optimal inspection scheduling model for monitoring railway tracks. A validation of the proposed model, conducted using actual measurement data, is presented in Section 3. Our conclusions are presented in Section 4.

2. Features of Railway Track Inspection Activities

Although there are many types of railway track inspection methods with varying inspection principles, railway track inspection activities generally have the following characteristics.

(1) Railway track inspection activities are continuous in the horizontal direction. Generally extending from one end of the line segment to the other, track inspection activities are mainly composed of activities with repetitive features. For example, the inspection activity of a track geometry trolley is generally carried out continuously and repeatedly in multiple line segments, which consumes time and advances continuously in accordance with the mileage position.

(2) The inspection items of the different inspection methods are consistent. For example, the inspection items of track geometry cars and track geometry trolleys include surface, alignment, gauge, cross-level, and twist. The rail detection car, rail detection trolley, and manual inspection all inspect rail defects.

(3) To ensure the safety of the operator, the inspection activities of certain inspection methods should be scheduled within the maintenance window, such as the inspection of the track geometry trolley and rail detection trolley. At the same time, certain inspection activities such as the inspection of track geometry cars and rail detection cars do not need to be scheduled within the maintenance window.

(4) There is no logical constraint on the sequence of inspection activities with different inspection methods in the time dimension; that is, the sequence of inspection activities with different inspection methods does not affect the perception of track condition.

(5) There are no multiple inspection activities within a temporal-spatial location. For example, when carrying out inspection activities involving rail detection trolleys, it is not possible to arrange inspection activities involving track geometry trolleys at the same location.

(6) The inspection activities are affected by various temporal-spatial factors, such as the line segment with high risk and hidden danger of equipment

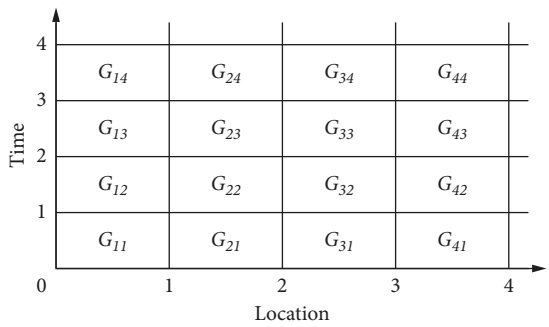

Figure 2: Diagram of railway time-location grid.

quality, and the frequency of inspection activities should be increased. The inspection speed is uncertain owing to a variety of temporal-spatial factors.

3. Subdivision of Railway Track Inspection Activity Based on Time-Location Grid

Railway grid [23] refers to dividing the linear, continuous, and strip-shaped railway lines dividing railway track inspection activities into equal-length "small segments" according to certain rules. The railway time-location grid [24] refers to several small units formed by dividing the entire life cycle process of railway infrastructure based on time and spatial dimensions according to certain rules, as shown in Figure 2. The horizontal axis represents the location and the vertical axis represents time. Each time-location grid is represented by G_{ij}, where i represents the i^{th} railway grid, and j represents the time period when the grid is located. The railway time-location grid is a temporal-spatial-based basic unit and is divided as follows:

(1) Time grid division: According to the actual work requirements of railway infrastructure management, the life cycle process of railway infrastructure can be divided based on minutes, hours, days, weeks, months, and years in the time dimension. In different application scenarios, the administrator can choose the size of the time grid unit based on the actual scenario requirements.

(2) Location grid division: As the smallest unit for dividing linear and continuous railway lines in the spatial dimension, the division of the location grid should take full account of the operation characteristics of inspection activities and the management needs of the railway site, the length of the railway grid in the study is set at 200 m, and the 100 m railway sign is selected as the demarcation point for adjacent grids.

Railway track inspection activities have a clear time span and mileage range information and consume a certain amount of time and resources. Based on the railway time-location grid, the railway track inspection activities are divided into smaller time and spatial units, which can more precisely define various constraints on the time and location of inspection activities, and more accurately illustrate the influence of various time and spatial factors on inspection activities. Therefore, railway infrastructure inspection activities with relatively high temporal and spatial resolutions are manageable, as shown in Figure 3. The horizontal axis represents the location and the vertical axis represents time. The blue line represents the inspection activities of railway infrastructure. The angle between the blue line and the horizontal axis indicates the rate of activity execution. The smaller the angle, the faster the execution rate of the corresponding activities. The red shaded part in Figure 3(b) represents the temporal-spatial constraints between any time and mileage point in the entire execution process of two adjacent activities.

4. Time-Location Grid-Based Optimal Inspection Scheduling Model for Monitoring Railway Track

4.1. Constant. The constants involved in the time-location grid-based optimal inspection scheduling model for monitoring railway track (TGOISM-MRT) are outlined as follows (Table 1):

4.2. Decision Variables. The decision variable of the TGOISM-MRT is t_{ij}^{e}, which indicates whether the track grid G_i performs the inspection activity of the inspection method C_j in the e^{th} unit time, $t_{ij}^{e} \in [0, 1]$, as shown in equation (1). $t_{ij}^{e} = 1$ indicates that the track grid G_i performs the inspection activity of the inspection method C_j in the e^{th} unit time. As $t_{ij}^{e} = 0$, the track grid G_i does not perform the inspection activity of the inspection method C_j in the e^{th} unit time.

$$t_{ij}^{e} = \begin{cases} 1, \text{Inspection activity is performed} \\ 0, \text{Inspection activity is not performed.} \end{cases} \quad (1)$$

For inspection method C_j, the corresponding optimization problem has $N \times E$ Boolean decision variables to be considered, as shown in Figure 4. There are M types of inspection methods for the entire model; therefore, the TGOISM-MRT has a total of $M \times N \times E$ Boolean decision variables that need to be considered.

4.3. Decision Expression. The decision expression involved in the TGOISM-MRT is as follows.

Z_{ij} represents a set of execution times of the previous inspection activities of inspection method C_j of track grid G_i in a scheduling cycle. The number of elements in set Z_{ij} is equal to the inspection time threshold S_{ij} of the C_j is the j^{th} inspection method and G_i the i^{th} track grid. The elements in set Z_{ij} are represented by z_{ij}^{n}, $n \in [1, 2, \ldots, S_{ij}]$, and z_{ij}^{n} indicating that track grid G_i performs the inspection activity of method C_j in the z_{ij}^{n}-th unit time. The functional relationship between z_{ij}^{n} and t_{ij}^{e} $(e \in [1, 2, \ldots, E])$ is illustrated by equation (2). $t_{ij}^{e} \neq 0$ indicates that track grid G_i performs the inspection activity of the inspection method C_j in the e^{th} unit time, and $z_{ij}^{n} = e$.

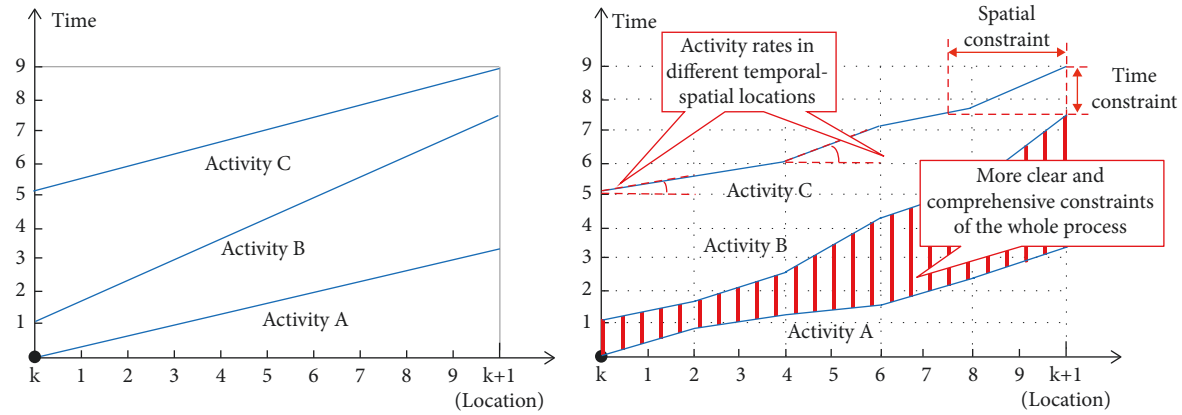

Figure 3: Comparison of the condition before and after subdivision of railway track inspection activities based on the time-location grid. (a) Diagram of railway inspection schedule. (b) Diagram of time-location grid-based railway inspection schedule.

Table 1: Variable denotations.

SD	Starting mileage of the inspection schedule
ED	Ending mileage of the inspection schedule
DR	$= ED - SD$, which represents the mileage length of the inspection activity
LE	Length of the track grid is generally 200 m
N	$= DR/LE$ represents the total number of track grids divided by railway lines
$G_i\,(i \in [1,2,\ldots,N])$	i^{th} track grid
M	Total number of types of track inspection methods
$C_j\,(j \in [1,2,\ldots,M])$	j^{th} inspection method
$C_{ij}\,(i \in [1,2,\ldots,N], j \in [1,2,\ldots,M])$	j^{th} inspection method of track grid G_i
E	Total unit time in a scheduling cycle
S_{ij}	Inspection time threshold of the j^{th} inspection method C_j of the i$^{\text{th}}$ track grid G_i in a scheduling cycle Owing to the influence of various temporal and spatial factors, the inspection frequency values of the same inspection method may differ for different track grids
S_i	$= \sum_{j=1}^{M} S_{ij}$ which represents the inspection time threshold of the total number of inspection methods of track grid G_i in a scheduling cycle
$\min T_{ij}$	Minimum inspection interval threshold of inspection method C_j of track grid G_i in the scheduling cycle
$\max T_{ij}$	Maximum inspection interval threshold C_j of track grid G_i inspection method in a scheduling cycle
$\max L_j$	Threshold of the maximum number of grids inspected in the inspection method C_j per unit time
$\min L_j$	Threshold of the minimum number of grids inspected in the inspection method C_j per unit time
RC_j	Number of workgroups performing inspection activities with an inspection method C_j
RC	Total number of workgroups performing inspection activities

$$z_{ij}^{n} = \text{Inf}\left\{e | t_{ij}^{e} \neq 0, e \in [1,2,\ldots,E]\right\}. \quad (2)$$

U_i represents a set of execution times of the previous inspection activities of all inspection methods of track grid G_i in a scheduling cycle. The number of elements in set U_i is equal to the inspection time threshold S_i of the total number of inspection methods of track grid G_i. The elements in set U_i are represented by u_i^m, $m \in [1,2,\ldots,S_i]$, and u_i^m indicating that the track grid G_i performs the inspection activity of method C_j in the u_i^m-th unit time. The functional relationship between u_i^m and $t_{ij}^e\,(e \in [1,2,\ldots,E])$ is expressed in equation (3). $t_{ij}^e \neq 0$ indicates that track grid G_i performs the inspection activity of inspection method C_j in the e^{th} unit time, and $u_i^m = e$.

$$u_i^m = \text{Inf}\left\{e | t_{ij}^{e} \neq 0, e \in [1,2,\ldots,E], j \in [1,2,\ldots,M]\right\}. \quad (3)$$

Q_{ij} represents the inspection times of inspection method C_j of track grid G_i and is calculated as follows.

$$Q_{ij} = \sum_{e=1}^{E} t_{ij}^{e}. \quad (4)$$

v_j^e represents the number of grids inspected by inspection method C_j in the e^{th} unit time and is calculated as follows.

$$v_j^e = \sum_{i=1}^{N} t_{ij}^{e}. \quad (5)$$

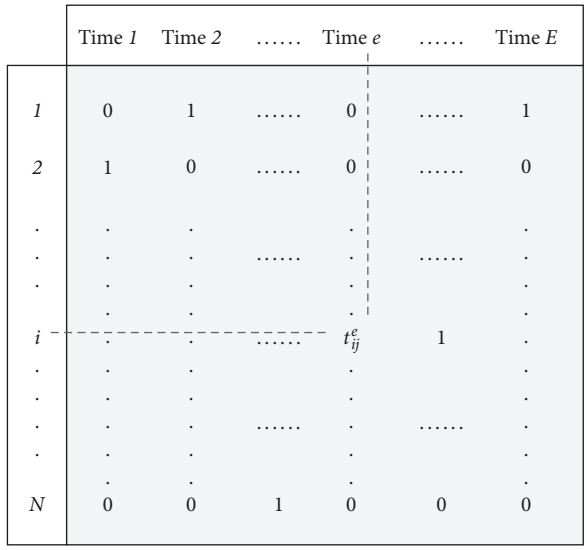

Figure 4: Schematic of decision variable t_{ij}^e.

R_j^e represents the number of workgroups required to perform inspection activities using inspection method C_j in the e^{th} unit time and is calculated as follows. The TGOISM-MRT assumes that there is only one workgroup for the inspection activity using method C_j. If there are multiple workgroups for inspection method C_j, the actual problem is divided into several subproblems of a single workgroup according to the inspection task.

$$R_j^e = \text{Inf}\left(1 \middle| \sum_{i=1}^{N} t_{ij}^e > 0\right). \tag{6}$$

4.4. Objective Functions Based on Time-Location Grid

4.4.1. Equilibrium Objective Function. The TGOISM-MRT uses entropy theory to construct an index called time entropy that measures the equilibrium of the track inspection schedule in the time dimension. The greater the time entropy, the more balanced the inspection schedule in the time dimension.

"Information Entropy" or "Shannon Entropy" [25] was first proposed by Claude Elwood Shannon in 1948 to measure the uncertainty of information. When the state or result of the event is known, information entropy H is equal to 0, where the greater the possibility of states or results of an event, the greater the uncertainty, and the greater the H. The mathematical abstraction of information entropy H is that an event has n possible results $X_i\,(i \in [1, 2, \ldots, n])$, and the probability of each result is p_i. Information entropy H, which measures the uncertainty of the event, is calculated as follows.

$$\begin{gathered} H = -\sum_{i=1}^{n} p_i \ln\, p_i, \\ \sum_{i=1}^{n} p_i = 1,\ i \in [1, 2, \ldots, n], \\ p_i \geq 0,\ i \in [1, 2, \ldots, n]. \end{gathered} \tag{7}$$

Based on the maximum entropy criterion [26], when $p_i\,(i = 1, 2, 3, \ldots, n)$ satisfies the following conditions, H in equation (7) is at its maximum value. Therefore, entropy is a remarkable index for measuring the degree of a group of data, partial to the system mean. The smaller the entropy, the greater the deviation of the set of data from the mean. The greater the entropy, the more concentrated the data is around the mean, and the more balanced the distribution of the data. When a set of data is completely equal, the entropy value reaches its maximum value.

$$p_1 = p_2 = \cdots = p_n = \frac{1}{n}. \tag{8}$$

The TGOISM-MRT replaces variable p_i in equation (8) and redefines entropy as p_i^n determined as the ratio of the time interval b_i^n between two adjacent inspection activities and the total number of unit times $E-1$ in the scheduling cycle. This entropy is called the time entropy, TH_i, of track grid G_i and is used as the equilibrium index to measure the time interval between two adjacent inspection activities of track grid G_i in a scheduling cycle, as shown in equation (11). The larger the value of the time entropy TH_i, the more balanced the time interval between two adjacent inspection activities in the inspection schedule. b_i^n represents the time interval between the $n+1^{\text{th}}$ inspection activity and the n^{th} inspection activity of the track grid G_i, as shown in equation (12). p_i^n represents the ratio of b_i^n to the total number of unit times $E-1$ in the scheduling cycle, as shown in equation (13), where $i \in [1, 2, \ldots, N]$, and $n \in [1, 2, \ldots, S_i - 1]$. $E-1$ is used to define p_i^n because the sum of all $S_i - 1$ time intervals b_i^n in the scheduling cycle of track grid G_i is equal to $E-1$.

$$\begin{gathered} TH_i = -\sum_{n=1}^{S_i-1} p_i^n \ln\, p_i^n, \\ b_i^n = u_i^{n+1} - u_i^n, \\ p_i^n = \frac{b_i^n}{E-1}. \end{gathered} \tag{9}$$

According to the maximum entropy criterion, when the time entropy TH_i of track grid G_i reaches the maximum value, $p_i^n\,(n \in [1, 2, \ldots, S_i - 1])$ values are equal to each other. That is, in a scheduling cycle, the larger the value of time entropy TH_i, the closer the time interval value of two adjacent inspection activities in track grid G_i, and the higher the equilibrium degree of the scheduled inspection of track grid G_i.

The time entropy of all track grids of the railway line is expressed by TH, which is used to measure the equilibrium of all track grids of railway lines in a scheduling cycle, and is calculated as follows.

$$TH = \sum_{i=1}^{N} TH_i = -\sum_{i=1}^{N} \sum_{n=1}^{S_i-1} p_i^n \ln\, p_i^n. \tag{10}$$

When the time entropy TH of the entire railway line reaches the maximum value, the time entropy TH_i of track

grid G_i ($i \in [1, 2, \ldots, N]$) reaches the maximum value, and the inspection schedule equilibrium degree of each track grid in the entire railway line is at its highest.

According to the maximum entropy criterion, the ideal maximum value $TH_{i,\max}$ of time entropy TH_i of track grid G_i without considering the task constraints is expressed as follows.

$$TH_{i,\max} = -\sum_{n=1}^{S_i-1} \frac{(E-1/S_i-1)}{E-1} \ln\left(\frac{(E-1/S_i-1)}{E-1}\right) = -\ln\left(\frac{1}{S_i-1}\right). \tag{11}$$

Accordingly, the ideal maximum value, $TH_{\max}$, of TH of all track grids of the railway line is shown in

$$TH_{\max} = \sum_{i=1}^{N} TH_{i,\max} = -\sum_{i=1}^{N} \ln \frac{1}{S_i - 1}. \tag{12}$$

The ratio of the time entropy TH of all the track grids of the railway line to its ideal maximum value $TH_{\max}$ is expressed by the THR, as shown in

$$THR = \frac{TH}{TH_{\max}}. \tag{13}$$

The equilibrium objective function of TGOISM-MRT is shown in

$$\max THR. \tag{14}$$

4.4.2. Robust Objective Function. The robustness of the inspection schedule refers to the ability to reduce the effects of various random disturbances during the execution process. Owing to the influence of time and spatial factors (such as severe weather and holidays), railway track inspection activities may be delayed or canceled temporarily, which may easily lead to chaos in the entire track inspection schedule. Therefore, the prepared inspection schedule can reduce the influence of various random disturbances.

The TGOISM-MRT defines robust, R, as the ratio of the minimum time interval between two adjacent inspection activities in the track grid to the total unit time E in a scheduling cycle. It is considered to be an important index for measuring the flexibility of the inspection schedule and is calculated as follows.

$$R = \min \frac{b_i^n}{E}, \forall i \in [1, 2, \ldots, N], \forall n \in [1, 2, \ldots, S_i - 1]. \tag{15}$$

The robust objective function of TGOISM-MRT is shown in

$$\max R. \tag{16}$$

4.4.3. Weight-Based Multiobjective Function. The TGOISM-MRT can achieve multiobjective optimization of the equilibrium and robustness of the time interval between adjacent inspection activities of the inspection schedule. Using weighted summation, the multiobjective optimization problem is transformed into a single-objective optimization problem. The optimal objective function after the transformation of TGOISM-MRT is shown in equation (17), where α and β are the weights of the two objective functions. The values of α and β are set by the manager according to the importance of the objectives of equilibrium and are robust in the actual situation.

$$\max \alpha THR + \beta R, \tag{17}$$

where

$$\begin{aligned} \alpha + \beta &= 1, \\ 0 \le \alpha, \beta &\le 1. \end{aligned} \tag{18}$$

4.5. Constraint System Based on Time-Location Grid. This subsection defines the following six types of inspection activity constraints based on the time-location grid of railway track: time constraints between activities, fixed duration constraints, spatial constraints between activities, rate constraints of activities, resource constraints, and continuity constraints, as shown in Figure 5.

4.5.1. Time Constraint between Activities. As shown in Figure 5(a), the time constraints between track inspection activities are as follows. ① In a scheduling cycle, the time interval of inspection method C_j of track grid G_i should be greater than or equal to the minimum inspection interval threshold $\min T_{ij}$, as shown in equation (21). ② In a scheduling cycle, the time interval of inspection method C_j of track grid G_i should be less than or equal to the maximum inspection interval threshold $\max T_{ij}$, as shown in equation (22). In an inspection scheduling cycle, if the inspection time specified by a certain inspection method is 1, the time constraint of the inspection activity corresponding to the inspection method is not considered. In Figure 5(a), the horizontal axis represents the railway mileage, the vertical axis represents the time, and the solid lines of different colors represent different inspection activities. The horizontal axis is divided by the length of the grid, and the vertical axis is divided by the time granularity required for management to form the track time-location grid.

$$\begin{aligned} z_{ij}^{m+1} - z_{ij}^{m} &\ge \min T_{ij} \forall m \in \left[1, 2, \ldots, S_{ij} - 1\right], \\ z_{ij}^{m+1} - z_{ij}^{m} &\le \max T_{ij} \forall m \in \left[1, 2, \ldots, S_{ij} - 1\right]. \end{aligned} \tag{19}$$

The violation of the maximum time constraint hinders the identification of quality-related problems in the track by managers, and violation of the minimum time constraint results in a waste of inspection resources.

4.5.2. Fixed Duration Constraint. The fixed duration constraint for track inspection activities includes two aspects. ① In a scheduling cycle, each type of inspection method needs to complete the specified number of inspections. ② The inspection activities of each type of inspection method involve inspecting all track grids to avoid missing inspections.

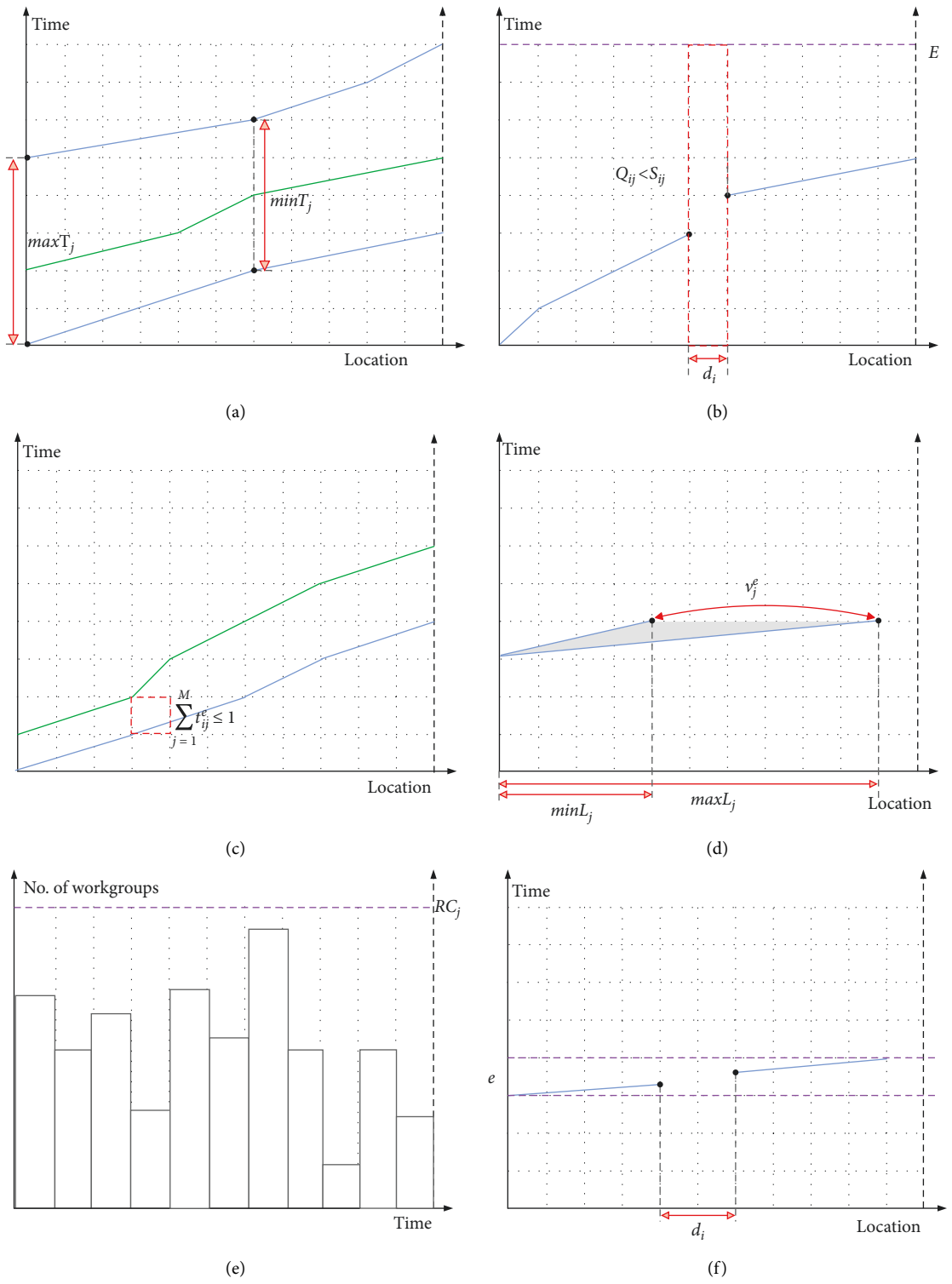

Figure 5: Map of time-location grids based on various constraints of track inspection activities. (a) Time constraint between activities. (b) Fixed duration constraint. (c) Spatial constraint between activities. (d) Rate constraint of activities. (e) Resource constraint. (f) Continuity constraint.

Therefore, in a scheduling cycle, the number of inspection times Q_{ij} of the inspection method C_j of the track grid G_i should be equal to the inspection time threshold S_{ij}. In Figure 5(b), the horizontal axis represents the railway mileage, and the vertical axis represents the time. The horizontal axis is divided by the length of the grid, and the vertical axis is divided by the time granularity required for management to form the track time-location grid. The

purple dotted line indicates the deadline of the inspection schedule. In the figure, owing to the existence of $d_i > 0$, the dotted frame area $Q_{ij} < S_{ij}$, which does not meet the fixed duration constraint.

$$Q_{ij} = S_{ij} \forall i \in [1, 2, \ldots, N], j \in [1, 2, \ldots, M]. \quad (20)$$

The violation of the fixed duration constraint causes the track line without risk to evolve into potential risk, and the original low risk may evolve into a high risk.

4.5.3. Spatial Constraint between Activities. The spatial constraint of track inspection activities means that at most one inspection activity can occur in any time-location grid of the railway track. That is, at most, one inspection activity can occur in track grid G_i per unit time, as shown in equation (21) and Figure 5(c). In Figure 5(c), the horizontal axis represents the railway mileage, the vertical axis represents the time, and the solid lines of different colors represent different inspection activities. The horizontal axis is divided by the length of the grid, and the vertical axis is divided by the time granularity required for management to form the track time-location grid.

$$\sum_{j=1}^{M} t_{ij}^{e} \leq 1 \forall i \in [1, 2, \ldots, N], e \in [1, 2, \ldots, E]. \quad (21)$$

If the above constraints are violated, time-location conflicts between inspection activities occur, affecting the efficiency and safety of inspection activities.

4.5.4. Rate Constraint of Activities. The TGOISM-MRT defines the inspection rate by the number of grids inspected in inspection method C_j per unit time of each type of inspection activity. As shown in Figure 5(d), the rate constraint between track inspection activities is as follows. ①The number of grids inspected v_j^e in inspection method C_j per unit time should be less than or equal to the maximum rate threshold $\max L_j$, as shown in equation (22). ②The number of grids inspected v_j^e in inspection method C_j per unit time should be greater than or equal to the maximum rate threshold $\min L_j$, as shown in equation (23). In Figure 5(d), the horizontal axis represents the railway mileage, and the vertical axis represents the time. The horizontal axis is divided by the length of the grid, and the vertical axis is divided by the time granularity required for management to form the track time-location grid.

$$v_j^e \leq \max L_j \forall e \in [1, 2, \ldots, E], j \in [1, 2, \ldots, M], \quad (22)$$

$$v_j^e \geq \min L_j \forall e \in [1, 2, \ldots, E], j \in [1, 2, \ldots, M]. \quad (23)$$

The maximum rate constraint is used to guarantee inspection quality and prevent false and missed inspections. The minimum rate constraint is used to ensure the efficiency of inspection activities.

4.5.5. Resource Constraint. The resource constraint of track inspection activities means that the number of inspection activities R_j^e with inspection method C_j in unit time is less than or equal to the corresponding number of workgroups RC_j, as shown in equation (24) and Figure 5(e). In Figure 5(e), the horizontal axis represents the railway mileage, and the vertical axis represents the time. The horizontal axis represents the number of workgroups. The purple dotted line indicates the RC_j resource usage threshold.

$$R_j^e \leq RC_j \forall e \in [1, 2, \ldots, E]. \quad (24)$$

Meeting the resource constraints is the basic guarantee of the feasibility of the inspection schedule. If the amount of resources used by the inspection activities exceeds that of the available resources, the organization and arrangement of inspection activities will be unsuccessful.

4.5.6. Continuity Constraint. The continuity constraint of railway track inspection means that the inspection activities performed by each working group with inspection method C_j must be continuous and uninterrupted within a unit time, as shown in equation (25) and Figure 5(f). In Figure 5(f), the horizontal axis represents the railway mileage, and the vertical axis represents the time. The horizontal axis is divided by the length of the grid, and the vertical axis is divided by the time granularity required for management to form the track time-location grid. The purple dotted line indicates the start and end times of the e^{th} unit time. Owing to the existence of $d_i > 0$ in the figure, the continuity constraint is not satisfied.

$$\sum_{i=p}^{p+v_j^e-1} t_{ij}^{e} = v_j^e \forall e \in [1, 2, \ldots E], \exists p \in [1, 2, \ldots N]. \quad (25)$$

If the above constraints are violated, the inspection activities will be discontinuous or interrupted, which will result in a waste of resources, loss of inspection efficiency, and increased management costs.

5. Results and Discussion

5.1. Overview of Empirical Analysis. Actual data regarding the track inspection schedule were collected from December 2016 on a segment in the downward direction of the Lanxin railway between 721 and 765 km. The proposed model was verified using accumulated data.

DR represents the segment length between 721 and 765 km in the downward direction of the Lanxin railway and spans 44 km. This railway segment passed through the Jiayuguan and Heishanhu stations. The center mileage of the Jiayuguan station is 737. 954 km. The center mileage of Heishanhu station was 759.319 km. The Jiayuguan Department is a subsidiary branch under the jurisdiction of the China Railway Lanzhou Group that offers inspection and maintenance services. LE represents the length of the track grid: LE = 200 m. Therefore, the total number of track grids, N, considered in this study is DR/LE = 220.

In this study, an inspection schedule was prepared on a monthly basis. E represents the total number of days in a

Table 2: Workload of track inspection activities for December 2016 in the Lanxin railway.

No.	C_j	j	Direction	SD (km)	ED (km)	Sets of track grid	DR (km)	S_{ij}	$\max T_{ij}$ (day)	$\min T_{ij}$ (day)
1	Track geometry trolley inspection	1	Down	721	765	[1, 2, . . . , 220]	44	1	35	15
2	Rail detection trolley inspection	2	Down	721	765	[1, 2, . . . , 220]	44	1	35	15
3	Manual inspection	3	Down	721	730	[1, 2, . . . , 45]	9	1	35	15
4	Manual inspection	3	Down	730	736	[46, 47, . . . , 75]	6	2	18	7
5	Manual inspection	3	Down	736	765	[76, 77, . . . , 220]	24	1	35	15
6	Track geometry car inspection	4	Down	721	765	[1, 2, . . . , 220]	44	2	18	7

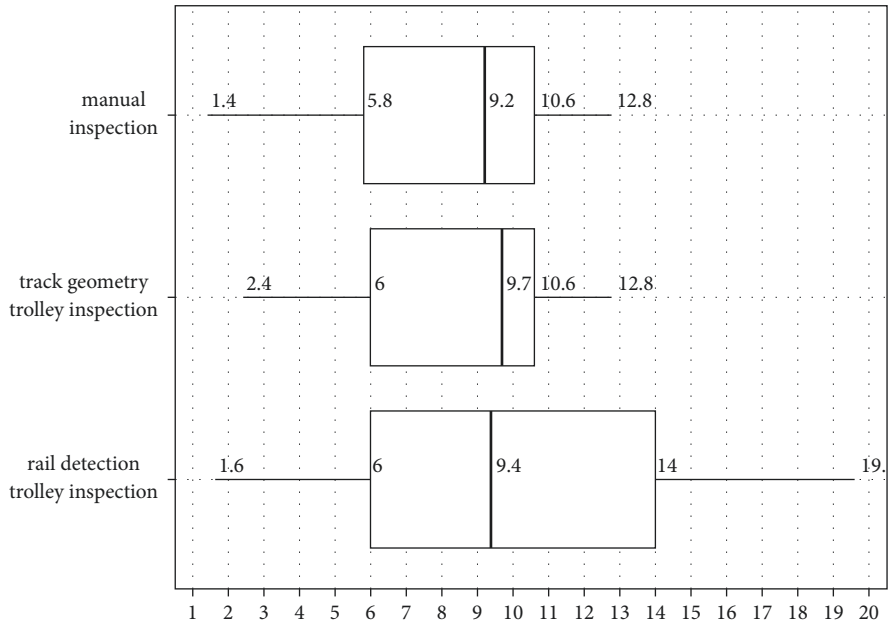

Figure 6: Box plot of activity rates of different inspection methods.

scheduled cycle and is calculated to be 31. Four track inspection methods were considered, including a track geometry trolley, rail detection trolley, manual inspection, and track geometry car. The workload of track inspection activities for the Jiayuguan Department in the downward direction of the Lanxin railway in December 2016 is shown in Table 2. The track quality of the segment between 731 and 736 km in the downward direction of the Lanxin railway is poor. Therefore, the manual inspection frequency of the track grids within the mileage ranging between 731 and 736 km is one more time than the manual inspection frequency of other track grids. The track geometry car inspection was prearranged on December 8th and 21st, respectively, for the first and second inspections in the downward direction of the Lanxin railway.

The Jiayuguan Department has four groups: Workgroup 1 is responsible for track geometry trolley inspections; Workgroup 2 is responsible for rail detection trolley inspections; Workgroup 3 is responsible for manual inspection; Workgroup 4 is responsible for track geometry car inspections.

To obtain the inspection rate for the inspection methods, 581 historical inspection rate data for the four workgroups between January 2015 and December 2017 (three years) were collected. These data were analyzed using box plot methods to observe the overall distribution of these data and identify possible outliers. The first and third quartiles in the historical inspection rate data were selected as the upper and lower thresholds of the inspection rate for the inspection methods.

The inspection rate was defined as the railway line length inspected per unit of maintenance time. The box plot of the activity rates for different inspection methods is shown in Figure 6, where the horizontal axis indicates the inspection activity rate, and the vertical axis indicates the type of inspection method. The rate constraints of the different inspection methods are listed in Table 3.

5.2. Analysis of Results. The First Optimization (1stOpt) software [27] was used to solve the combined optimization problem of the TGOISM-MRT. Parameter α in the objective function was 0.5 and parameter β was 0.5. After the calculation, the corresponding optimal objective function value was 0.570. The equilibrium THR for the track inspection schedule was 0.980. The robust R of track inspection was 0.161. The execution time is approximately two hours, and the statistic was collected using a desktop with an Intel E5-1620 3.50-GHz CPU and 16 GB RAM.

Table 3: Rate constraints of different inspection methods.

No.	Workgroups	C_j	j	$\min L_j$		$\max L_j$	
				km per maintenance window	Number of track grids per maintenance window	km per maintenance window	Number of track grids per maintenance window
1	Workgroup 1	Track geometry trolley inspection	1	6	30	10.6	53
2	Workgroup 2	rail detection trolley inspection	2	6	30	14	70
3	Workgroup 3	Manual inspection	3	5.8	29	10.6	53
4	Workgroup 4	Track geometry car inspection	4	The track geometry car GJ-5 lacks a power source and needs to be hung at the end of the passenger train, to detect track irregularities. Its inspection rate depends on the speed of the passenger train.			

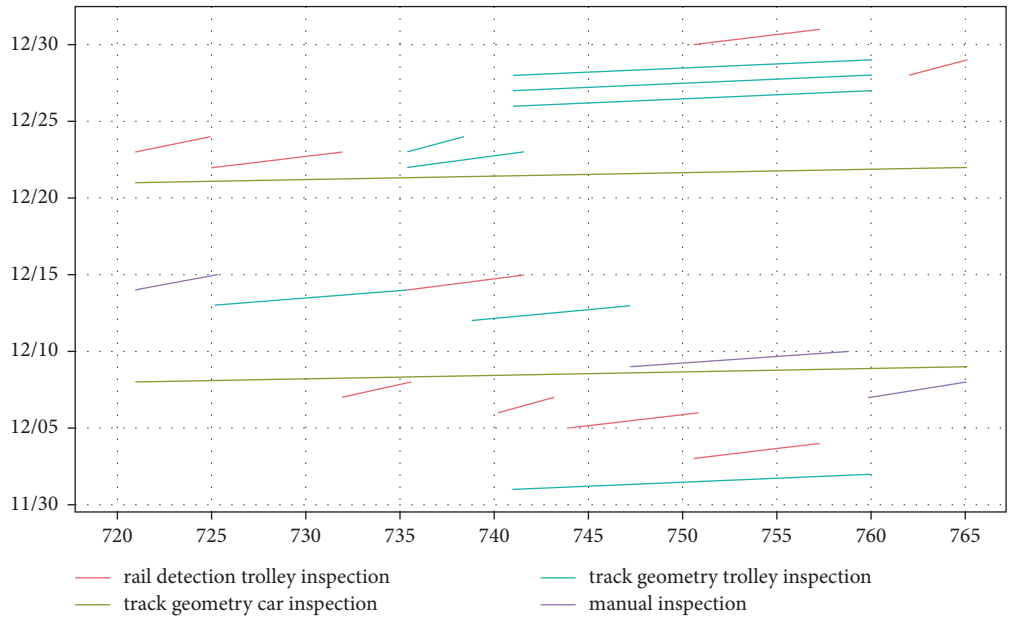

Figure 7: Actual track inspection schedule in the Lanxin railway.

The actual track inspection schedule for the Lanxin railway in December 2016 is shown in Figure 7. The track inspection schedule for December 2016 in the Lanxin railway using the OISM-RTG model is shown in Figure 8. In Figures 7 and 8, the horizontal axis represents the railway mileage, the vertical axis represents the time, and the solid lines of different colors represent different inspection activities. The solid red line indicates the inspection activities of the rail detection trolley. The solid green line indicates the inspection activity of the track geometry car. The solid blue line indicates the inspection activity of the track geometry trolley. The solid purple line indicates manual inspection activities.

A comparison of the pre- and postoptimized track inspection schedules is shown in Table 4. Table 4 shows the following:

(1) Constraints: The actual track inspection schedule in the empirical analysis does not satisfy the fixed duration constraint, space constraint between activities, and rate constraint of activities. This is because the track inspection schedule is mainly based on the management experience of field engineers. It is difficult for these engineers to comprehensively and systematically consider the track inspection activity constraint system established in this study.

(2) Objective function: Compared with the actual track inspection schedule, the track inspection schedule using the TGOISM-MRT improves the equilibrium THR by 22.5%. The robust R increases from 0 to 0.161. The corresponding weighted objective function value was enhanced by 42.5%.

In summary, combined with the visual presentation results of Figures 7 and 8, the track inspection schedule using the TGOISM-MRT is superior to the actual inspection schedule prepared by the field engineer, with a more optimized equilibrium THR and robust R.

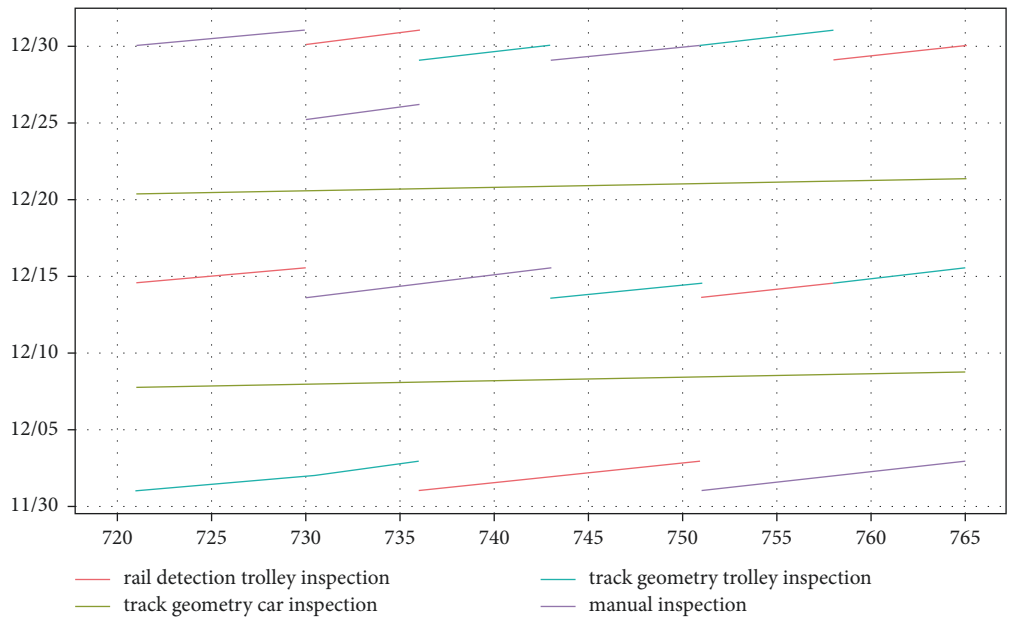

Figure 8: Track inspection schedule in the Lanxin railway using model TGOISM-MRT.

Table 4: Comparison of actual and optimized track inspection schedule.

	Item	Inspection schedule using the OISM-RTG	Actual inspection schedule prepared by the field engineers
Constraint system	Time constraints between activities	Satisfaction	Satisfaction
	Fixed duration constraint	Satisfaction	Violation. For example, the rail detection trolley inspection is not scheduled for track segments between 757.2 and 762 km in the downward direction of the Lanxin railway.
	Space constraints between activities	Satisfaction	Violation. For example, the track geometry trolley inspection and manual inspection are simultaneously scheduled for track segments between 747.2 and 758.8 km in the downward direction of the Lanxin railway.
	Rate constraint of activities	Satisfaction	Violation. For example, on December 26th, the track geometry trolley inspection is scheduled for track segments between 741 and 760 km in the downward direction of the Lanxin railway. The inspection rate is 19 km per maintenance window and is nearly double the upper inspection rate limit (10.6 km per maintenance window).
	Resource constraint	Satisfaction	Satisfaction
	Continuity constraint	Satisfaction	Satisfaction
Objectives	Equilibrium THR	0.980	0.800
	Robust r	0.161	0
	Weighted objective function	0.570	0.400
Visual presentation results		A comparison of Figures 7 and 8 shows that the inspection schedule using the TGOISM-MRT model is superior to the actual inspection schedule prepared by the field engineers.	

6. Conclusions

This study analyzed the features of railway track inspection activities and proposed TGOISM-MRT for optimal inspection scheduling of railway tracks. Track time-location grids were the subject of this study. Time-location grid-based objectives and constraint systems for different track inspection activities are constructed. The TGOISM-MRT is optimized for the equilibrium and robustness of the track inspection schedule to ensure the practicality and guidance of the track inspection schedule. Constraint systems include time constraints between activities, fixed duration constraints, space constraints between activities, rate constraints of activities, resource constraints, and continuity constraints.

The proposed model was verified using actual data for segments ranging between 721 and 765 km in the downward direction of the Lanxin railway. Compared with the actual inspection schedule prepared by the field engineers, the track inspection schedule using the TGOISM-MRT can satisfy the

proposed constraint system and yields more optimized equilibrium and robustness.

The TGOISM-MRT proposed in this paper can also be employed to solve the optimization of the inspection schedule of other linear assets (such as highways and pipelines), with little modification. To improve the TGOISM-MRT and promote the flexibility and practicability of the track inspection schedule, further research will be carried out.

(1) Owing to the assumption limitations of the TGOISM-MRT, the model is suitable for the optimization of the inspection schedule for a single line. Optimizing the track inspection schedule for large-scale railway networks can be a future research direction.

(2) The implementation of the railway track inspection schedule will continue for a period of time. The progress control of the inspection schedule is a process of continuous circular adjustment of the schedule. The optimization of the progress control of the inspection schedule will be explored in future research studies.

Data Availability

Previously reported data are used to support this study and are cited at relevant places within the text as references.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Research Article

Investor Sentiment and Stock Market Reactions to COVID-19: Evidence from China

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This paper treats the outbreak of coronavirus disease 2019 (COVID-19) as a natural experiment that can provide insights into the effects of investor sentiment on stock market reactions. Employing the event study methodology (ESM) and taking the date of the Wuhan lockdown as the event date, we find that average abnormal return (AAR) and cumulative abnormal return (CAR) are significantly negative, and average trading volume excesses far more than before within two days of the outbreak. Further, we establish a difference-in-differences (DID) model to investigate the differences between Hubei and non-Hubei listed companies. The results show that for Hubei listed companies, the change of excessive trading volume (ETV) between pre-event and post-event period is significantly higher than that of non-Hubei listed companies, while there exhibits no relationship between the change of AAR and registration place. Overall, our findings provide new evidence for the interaction of local bias and investor sentiment affecting stock market reactions.

1. Introduction

The sudden outbreak of COVID-19 in Wuhan in early 2020 is a major public health event. From the first case of pneumonia of an unknown cause at the end of December 2019 to the lockdown of Wuhan on 23 January 2020, the number of people with this type of pneumonia across the country increased dramatically every day. In order to control the spread of the COVID-19, the government began to adopt stringent quarantine policies such as closing the borders, restricting air and intercity movement, closing offices, restaurants, and academic institutions [1].

Reports and news related to the COVID-19 on major Internet platforms such as Toutiao, WeChat, and Weibo have quickly risen, affecting investors' attention and sentiment on the stock market to a certain extent. Affected by the COVID-19, the A-share market fell sharply on the first trading day after 2020 Lunar New Year. It is fair to say that the outbreak of COVID-19 created a level of anxiety and fear in Mainland China so strong and so widespread that is incomparable to any public health event the country experienced in the past 20 years. Given the extensive recent literature on the investor sentiment and stock returns, the conditions of the COVID-19 generate a unique opportunity to contribute to the literature by examining investor sentiment in extreme circumstances. The outbreak of COVID-19 in Wuhan also provides an excellent natural experiment to explore the local bias hypothesis by investigating whether Hubei listed companies have a stronger adverse effect on stock returns and trading volume than non-Hubei listed companies.

Our empirical strategy is organized as follows. First, we use the event study methodology, choose Wuhan lockdown as the event date, and then calculate the abnormal return (AR), average abnormal return (AAR), cumulative abnormal return (CAR), and excessive trading volume (ETV) within the event window to analyze the investor sentiment and stock market reactions. Second, we establish a difference-in-

differences (DID) model to investigate whether listed companies registered in Hubei Province behavior differently from non-Hubei listed companies in terms of AAR and ETV since the development of Hubei Province has been the most severely affected by the epidemic.

This study makes contributions to the literature in two aspects. In the first place, we provide evidence through a natural experiment that a large-scale emergent public health event can affect investor sentiment and hence stock returns and trading volume. In the second place, we explore the possibility of local bias on the stock market. The results show that the change of ETV before and after the event date is significantly higher than that of non-Hubei listed companies, while there exhibits no relationship between the change of AAR and registration place. It adds to the research on local bias and expands the perspective of study on the impact of COVID-19 on stock prices.

The remainder of this paper proceeds as follows. Section 2 summarizes the literature review. Section 3 describes research methods and data. Section 4 presents the empirical results and Section 5 concludes.

2. Literature Review

As our paper links to the two lines of studies in existing literature. We first review studies on investor sentiment and stock market reaction. And then we discuss the researches on financial markets and COVID-19.

2.1. Investor Sentiment and Stock Market Reaction. In the field of behavioral finance, the influence of investor sentiment on the stock market has always been the focus of scholars. There are two main methods to conduct the study.

The first one is to construct proxy variables of investor sentiment. Many scholars directly use market trading data, such as the discount of closed-end funds [2] and the trading volume on the day of IPO [3]. And principal component analysis is often used to construct a comprehensive proxy of investor sentiment by market trading data [4]. The data from questionnaire survey are also widely used, such as the consumer sentiment index proposed by the University of Michigan [5]. Recently, with the development of information technology, many scholars extract keywords from media reports and news by the Internet platform and apps to construct investor sentiment variables, such as Facebook [6], Google Trend [7], Baidu index data [8], and so on. Although these proxy variables obtained by the first three methods are essentially related to investor sentiment, there are endogenous problems because online announcements and changes in financial market variables may be the result of trading activities. In addition, the survey participation rate may be insufficient, and participants may be not motivated enough to answer the survey questions truthfully.

The second one focuses on events that cause changes in investor sentiment and affect investment decisions and investors' trading behavior in financial market. Using the impact of major events as the basis for the construction of sentiment can well describe the change of investor sentiment after such events. As a part of the whole, the change of investor sentiment should be consistent with the change of sentiment in the social environment after the event, which has been confirmed by existing studies. For example, Edmans et al. [9] explore the impact of football match results on the stock market and find that the stock prices drop significantly after the loss of the football match. Kaplanksi and Levy [10] investigate the effect of aviation disasters and find that they cause stock market drops that are disproportionately larger than their economic effects and ascribe these to bad moods and anxiety being induced among investors. One study that examines the sentiment of stock returns in the case of extreme circumstances is Shan and Gong [11] who investigate the effect of the Wenchuan earthquake on stock returns. They find that during the 12 months following the earthquake, stock returns are significantly lower for firms near the epicentre of the earthquake and that these results cannot be explained by actual economic losses or by systematic risk.

The second method can avoid endogenous problems and provide more objective results but samples are scarce due to the low frequency [12]. However, the COVID-19 is exactly such kind of event. Therefore, we choose the outbreak of COVID-19 to conduct study, which can avoid the drawbacks of the first method and provide an excellent natural experiment to explore investor sentiment on the stock market.

2.2. Financial Markets and COVID-19. The literature on financial markets and COVID-19 is growing. Baker et al. [13] use textual analysis of news mentions and find that COVID-19 pandemic has resulted in the highest stock market volatility among all recent infectious diseases including the Spanish Flu of 1918. Using 75 countries as research samples, Erdem [14] notes that the pandemic decreases stock returns and increases volatility. Likewise, Zhang et al. [15] find that COVID-19 has led to increase in global financial market risk. But rare research analyzes investor sentiment and the impact of COVID-19 from the perspective of local bias, a financial anomaly, which can be explained by information asymmetry [16–19] or behavioral-based reasons such as familiarity or relative optimism [20–23].

Huang et al. [24] examine local bias in investor attention by analyzing messages posted by investors on China's Internet stock message board and find that individual investors pay more attention to stocks of local companies than to those of nonlocal companies. At the beginning of the COVID-19 outbreak, Wuhan became the focus of the public, and the lockdown of Wuhan pushed the panic and anxiety of the public to the extreme. Thus, after the outbreak of COVID-19, investors may pay more attention to listed companies in Wuhan and Hubei, which may affect investors' decisions. Therefore, we not only apply the event study methodology [25, 26] to analyze the effect of COVID-19 outbreak on the stock market of China by capturing AAR and ETV within the event window but also establish a DID model to analyze local bias in investor attention.

3. Methods and Data

3.1. Event Study Methodology (ESM). This research employs the ESM to analyze investor sentiment and stock market reactions to COVID-19. ESM is mainly used to evaluate whether the occurrence of an event or the release of information will change the decision of investors, thereby affecting the price or trading volume of stocks. Nikkinen et al. [27] study the impact of 9/11 on returns and volatility of global stock markets, finding that the terrorist attack has a short-term negative impact on stock returns, and that the attack significantly increases volatility. Chen et al. [28] explore the impact of severe acute respiratory syndrome (SARS) on the stock price movements of hotels in Taiwan, showing that the SARS outbreak adversely affects their earnings. Tee and Tessema [29] analyze stock market reactions to dividend announcements.

Therefore, we utilize the ESM to conduct our study. First, we should define the event day and determine the event window as well as estimation window.

Although there were confirmed COVID-19 cases in late December 2019, it was not until January 23, 2020, when Wuhan Epidemic Prevention and Control Headquarters released a notice to temporarily close channels leaving the city, COVID-19 came to be widely known by people in China and even around the world, resulting in serious social panic and economic instability. On February 3, 2020, the stock market opened but CSI 300 index fell down 7.88 percent, which was the biggest drop since 2015, as shown in Figure 1. Hence, following to Huang and Liu [30], we set the date of the Wuhan lockdown (January 23, 2020) as the event date ($T_0 = 0$), on which the market reaction can better and timely reflect the unexpected shock of COVID-19 outbreak on stock market. Consistent with Zhang et al. [31], our estimation period include 100 days—from July 23, 2019 to December 17, 2019—while (-25,60) is the event window.

3.2. Difference-in-Differences Model. As the COVID-19 first broke out in Wuhan, the number of confirmed cases in Wuhan, Hubei province far exceeded other provinces, and a series of lockdown measures were stricter there, which further restricted the operation and development of companies in Hubei province, especially in Wuhan. Corporate losses are greater and uncertainty is higher, leading to lower stock returns and higher volatility of listed companies. In addition, when systemic external risks come, market sentiment is complex and noise is high. According to the theory of limited attention [32], investors' attention is scattered and limited, and they may have more pessimistic expectations for listed companies in Hubei Province, which also has a certain impact on investment decisions. Therefore, we establish the DID model based on the event study methodology to further explore whether the registered area has an impact on investors' decision making during the epidemic.

For reliability, we take the following steps to select our sample of the test group. First, we remove all listed firms marked "ST" (special treatment) or "*ST". Second, we exclude all financial firms, all firms whose total debt is greater than their total assets, and all firms with missing data. Third, we pick out all listed firms registered in Hubei province. Our sample of the test group includes 95 firms.

Then, we match the sample of the control group as follows. First, for each stock in the test group, we find a stock from the same industry; second, the stock in the control group is as close as possible to the corresponding stock in the test group in terms of market capitalization, turnover, PE ratio, ROE, net profit per share, and net asset per share in the windows around the event. In particular, we calculate the following matching error for each stock in the test group and the control group.

$$\frac{\mathrm{Cap}_{\mathrm{test}}/\mathrm{Cap}_{\mathrm{control}} + \mathrm{TO}_{\mathrm{test}}/\mathrm{TO}_{\mathrm{control}} + \mathrm{PE}_{\mathrm{test}}/\mathrm{PE}_{\mathrm{control}} + \mathrm{ROE}_{\mathrm{test}}/\mathrm{ROE}_{\mathrm{control}} + \mathrm{EPS}_{\mathrm{test}}/\mathrm{EPS}_{\mathrm{control}} + \mathrm{BPS}_{\mathrm{test}}/\mathrm{BPS}_{\mathrm{control}}}{6}, \quad (1)$$

where Cap is the market capitalization, TO is the turnover, PE is the PE ratio, ROE is the returns on equity, EPS is the net profit per share, and BPS is net asset per share. The definitions of all variables are presented in Appendix. The stock belongs to the potential list of the control group with the lowest matching error is selected as the match for stock in the test group.

Our final sample includes 95 Hubei firms and 95 non-Hubei firms. To avoid the effect of outliers of variables, we winsorize all the continuous variables at the 1st and 99th percentiles.

Table 1 reports the descriptive statistics for the test group and the control group. We can see that the control group displays the similar characteristics as the test group.

3.3. Capital Data. For each sample, we collect the following data from the China Stock Market and Accounting Research (CSMAR) database and Wind database: daily individual return rate, daily trading volume, and the corresponding daily returns of the Chinese Stock Index (CSI) 300. The series period is from July 23, 2019 to April 27, 2020. The rationale for using the CSI 300 Index return as the market return is twofold. First, the CSI 300 Index is the first equity index released by both the Shenzhen Stock Exchange (SZSE) and the Shanghai Stock Exchange (SSE) and aims to reflect the price fluctuation and performance of China stock market. Second, our sample covers the stocks in the Main Board, SME Board, and the ChiNext Board from the two stock exchanges.

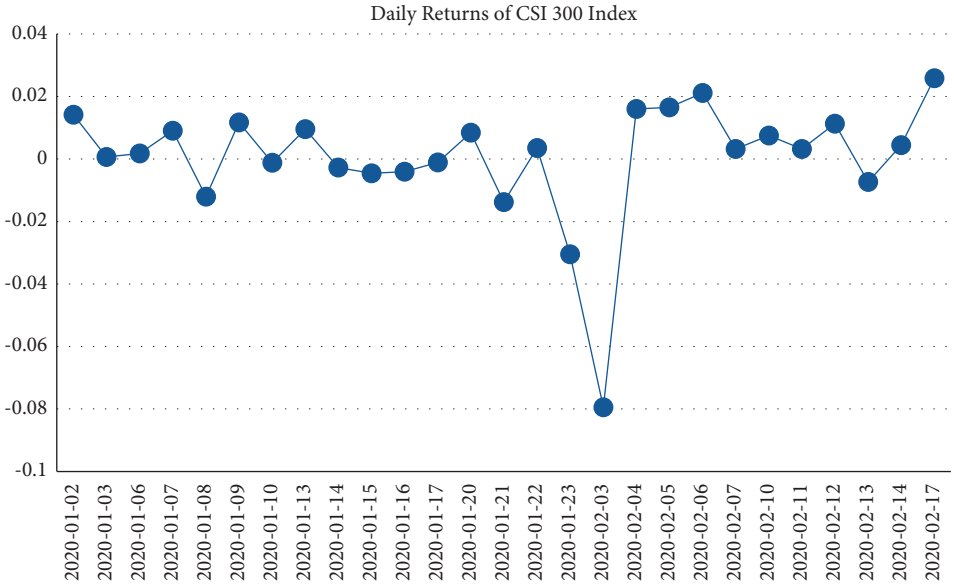

Figure 1: The daily returns of CSI 300 Index from January 2, 2020 to February 17, 2020. *Note.* This figure captures daily returns of CSI 300 Index from January 2, 2020 to February 17, 2020. *X*-axis is the timeline of COVID-19, which sets Wuhan lockdown (January 23, 2020) as the event day ($T_0 = 0$). *Y*-axis refers to daily returns of CSI 300 Index.

Table 1: Descriptive statistics for the test and control groups.

	Capitalization	Turnover	PE ratio	ROE	EPS	BPS
Test group	1.16×10^{10}	2.530	7.209	4.030	0.420	5.682
Control group	1.08×10^{10}	2.676	6.155	3.442	0.428	5.583

Note. This table reports the mean of each variable for the test and the control groups, respectively. The unit of the turnover is %.

4. Model Setup and Empirical Results

4.1. Cumulative Abnormal Return. To empirically investigate the market reaction to the outbreak of COVID-19, we employ the event study methodology with the market model to observe changes in stock returns. Therefore, the abnormal return for stock i on date t, AR_{it} is calculated as follows:

$$\begin{aligned} R_{it} &= \alpha_i + \beta_i R_{mt} + \varepsilon_{it}, \quad t = -125, \ldots, -26, \\ \mathrm{AR}_{it} &= R_{it} - (\alpha_i + \beta_i R_{mt}), \quad t = -25, \ldots, 60, \end{aligned} \tag{2}$$

where R_{it} is the return on stock i for date t, R_{mt} is the return on CSI 300 Index for date t, and α_i and β_i are the ordinary least squares (OLS) estimates for the stock i's market model parameters. α_i and β_i are estimated over a period that extends from125 trading days prior to through 26 trading days prior to the event date and AR_{it} is calculated for the days [−25, 60].

For the test group and the control group, the average abnormal return (AAR_{it}) for date t and the cumulative abnormal return from date t_1 to date t_2 ($\mathrm{CAR}(t_1, t_2)$) are calculated as follows:

$$\begin{aligned} \mathrm{AAR}_t &= \frac{\sum_{i=1}^{N} AR_{it}}{N}, \quad t = -25, \ldots, 60, \\ \mathrm{CAR}(t_1, t_2) &= \sum_{t=t_1}^{t_2} \mathrm{AAR}_t, \quad t_1 = 0,\ t_2 = 60, \end{aligned} \tag{3}$$

where N denotes the number of stocks in the test group and the control group.

Figure 2 depicts the average abnormal returns of the test group and the control group. Each line in the figure is the cross-sectional average value of the event. We find that on the day of the event and the second trading day after the event date, the AAR of the test group and the control group decreased significantly, deviating from 0, and the test group deviated to a greater degree. On the day $t = 2$, and it is found that in the test group and the control group, the AAR is -0.0458 (t-value = -8.507) and -0.0233 (t-value = -3.982), respectively.

Figure 3 captures the CAR of the test group and the control group. We observe that the CAR drops significantly on the day of the event and the two trading days after the event day. As time goes by, the CAR slowly rises, and then slowly decreases. Basically, there is no major and continuous deviation. In addition, the CAR of the test group is generally lower than that of the control group on the day of the event and within 20 trading days after the event date, which preliminarily indicates that the outbreak of COVID-19 may have a greater impact on Hubei listed companies.

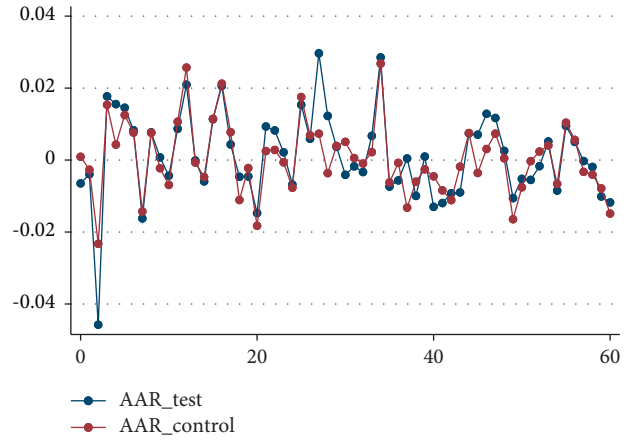

Figure 2: Average abnormal returns of the test group and the control group. *Note.* This figure gives the average abnormal return for the test group and the control group in the subsequent 60 trading days. The red line and blue line represent the average abnormal returns of the test group and the control group, respectively.

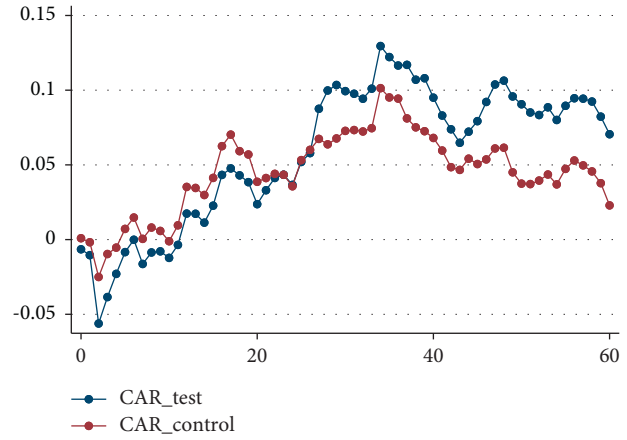

Figure 3: Cumulative abnormal returns of the test group and the control group. *Note.* This figure gives the cumulative abnormal returns for the test group and the control group in the subsequent 60 trading days. The red line and blue line represent the cumulative abnormal returns of the test group and the control group, respectively.

4.2. Excessive Trading Volume. In addition, we also investigate the changes of ETV after the outbreak of COVID-19 since the trading volume also reflects the decisions of investors. Following Barber and Odean [33] and Zhang et al. [31], we calculate for each stock on each trading day the ratio of the stock's trading volume that day to its average trading volume over previous 100 trading days. Thus, the definition of the excessive trading volume is denoted as follows:

$$\overline{V_{it}} = \sum_{t-100}^{t-1} \frac{V_{it}}{100},$$
$$\text{ETV}_{it} = \frac{\overline{V_{it}}}{V_{it}}, \tag{4}$$

where $\overline{V_{it}}$ is the average trading volume over the previous 100 trading days; V_{it} is trading volume of stock i on day t; and ETV_{it} is the excessive trading volume of stock i on day t. If the value of ETV is bigger than 1, then it can be viewed as excessive trading volume on that day.

Figure 4 depicts the ETV of the test group and the control group. We find that on the day of the event and the subsequent 30 trading days, the ETV of the test group and the control group is much greater than 1, fluctuating around the value of 2, and then gradually decreases, fluctuating around the value of 1. And the ETV of the test group is significantly greater than that of the control group, which preliminarily shows that the outbreak of COVID-19 has a significant positive impact on ETV, especially for listed companies in Hubei province.

4.3. Difference-in-Differences Model. In this section, we establish a DID model to analyze the differences between the test group and the control group during the event. In order to avoid holiday effects and seasonal effects and ensure the reliability of sample data, we selected 25 trading days from December 18, 2019, to January 22, 2020, as the pre-event study period and 25 trading days from February 3, 2020, to March 6, 2020, as the post-event study period.

4.3.1. The Setup of DID Model. Referring to Li et al. [34], we run the difference-in-differences regression, which is as follows:

$$\text{AAR}_{j,\text{post}} - \text{AAR}_{j,\text{pre}} = \alpha + \beta^* \text{CDummy}_j + \gamma^* \text{Control}_j + \varepsilon_j, \tag{5}$$

where $\text{AAR}_{j,\text{post}}$ is the post-AAR for stock j and $\text{AAR}_{j,\text{pre}}$ is the pre-AAR for stock j. CDummy_j takes the value of 1 if stock j is from the test group, and 0 if stock j is from the control group. Control_j represents the control variables including the firm size (defined as the natural logarithm of the market value of equity), turnover, PE, ROE, BPS, and EPS during the event period. The definitions of all variables are presented in Appendix. Particularly, we run two regression models for each of the comparison: model (1) with CDummy_j alone; and model and (2) with CDummy_j and Control_j.

4.3.2. Empirical Results. Table 2 reports the result of model (1). T represents the number of trading days before and after the event date. We consider $T = 1$, 5, 10, 15, 20, 25 and run regression, respectively. When $T = 25$, the coefficient of CDummy is 0.0011, and it is not significant, indicating that,

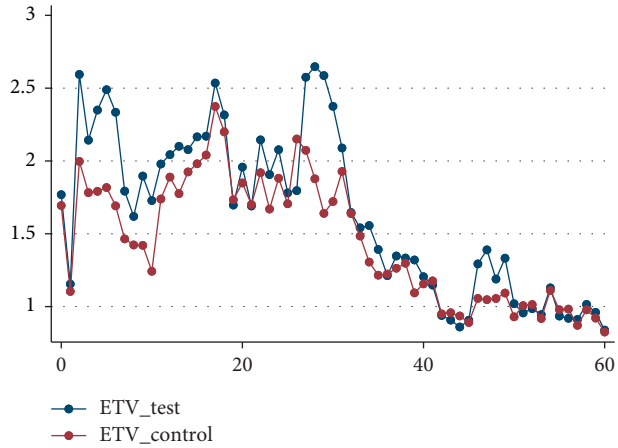

Figure 4: ETV of the test group and the control group. *Note.* This figure gives the excessive trading volume for the test group and the control group in the subsequent 60 trading days. The red line and blue line represent the excessive trading volume of the test group and the control group, respectively.

there is no obvious correlation between $CDummy_j$ and the difference of AAR before and after the event date. When we change the number of trading days before and after the event date, the result is the same. Table 3 reports the result of model (2). The result is consistent with Table 2.

4.3.3. Analysis of the Result. The results show that, regardless of whether control variables are added, there is no obvious correlation between the $CDummy_j$ and the difference of AAR before and after the event date. In other words, under the nationwide impact of the COVID-19, there is no obvious regional difference in the changes of average abnormal return. The reason may be as follows: The Spring Festival holiday started from the first day after Wuhan lockdown on January 24, 2020, and it was not until February 3 that Spring Festival holiday ended and the stock could be traded again. During this long period, people's panic and anxiety have gradually been relieved, and a series of prevention measures taken by the government have also gradually increased the confidence of the people in the victory against the COVID-19. Overall, there is no significant difference in the average abnormal return between Hubei listed companies and non-Hubei listed companies.

4.4. Further Research. In order to further analyze this topic, we change the dependent variable of the DID model from the AAR to ETV, and the control variables and $CDummy_j$ remain unchanged.

The DID model is as follows:

$$ETV_{j,post} - ETV_{j,pre} = \alpha + \beta^* CDummy_j + \gamma^* Control_j + \varepsilon_j, \quad (6)$$

where $ETV_{j,post}$ is the post-ETV for stock j and $ETV_{j,pre}$ is the pre-ETV for stock j. $CDummy_j$ takes the value of 1 if stock j is from the test group, and 0 if stock j is from the control group. $Control_j$ represents the control variables including the firm size (defined as the natural logarithm of the market value of equity), turnover, PE, ROE, BPS, and EPS during the events period. The definitions of all variables are presented in Appendix. Particularly, we run two regression models for each of the comparison: model (3) with $CDummy_j$ alone and model (4) with $CDummy_j$ and $Control_j$.

Table 4 reports the result of model (3). When $T = 25$, the coefficient is significant, indicating that there is an obvious correlation between $CDummy_j$ and the change of ETV before and after the event date. When we change the number of trading days before and after the event date, the result is the same. Table 5 represents the result of model (4). The result is consistent with Table 4.

Regardless of whether the control variables are considered, there is a significant positive correlation between the $CDummy_j$ and the difference of ETV before and after the event date. We think the reasons may be as follows.

On the one hand, the sudden outbreak of COVID-19 has led to a sharp increase in investors' attention to listed companies in Hubei. Investors are generally pessimistic about them because of the impact of the COVID-19 on the economy of the entire country, especially the economic development of Hubei province. Out of pessimistic expectations, investors have dumped the stocks of Hubei listed companies. Thus, for listed companies registered in Hubei, the change of ETV before and after the event date is significantly higher than that of non-Hubei listed companies.

On the other hand, it may also be that after such a long Spring Festival holiday, investors gradually restored confidence in the stock market due to the powerful measures taken by the government. In addition, when the Spring Festival ended, many people were still in a state of being unable to return to work and staying at home. To kill the time, more and more people began to pay attention to the stock market, so the stock trading volume has increased significantly. According the Financial Associated Press on February 21, 2020, the Securities Times reported that according to Baidu index query results, since the opening of the stock market on February 3, the number of searches for "stock account opening" on Baidu surged. What is more

Table 2: Regression result of model (1): average abnormal return and registered place of listed company.

	$T=1$	$T=5$	$T=10$	$T=15$	$T=20$	$T=25$
*C*Dummy	0.0050 (0.643)	0.0014 (0.486)	0.0028 (1.588)	0.0011 (1.018)	0.0009 (0.932)	0.0011 (1.168)
Constant	−0.0act045 (−0.821)	−0.0023 (−1.133)	−0.0038*** (−3.078)	−0.0013 (−1.649)	−0.0006 (−0.837)	0.0001 (0.123)
N	190	190	190	190	190	190
R-squared	0.0022	0.0013	0.0132	0.0055	0.0046	0.0072

Note. This table is based on the following regression: $\mathrm{AAR}_{j,\mathrm{post}} - \mathrm{AAR}_{j,\mathrm{pre}} = \alpha + \beta * C\mathrm{Dummy}_j + \gamma * \mathrm{Control}_j + \varepsilon_j$, and presents the result of the regression without control variables. T is the number of trading days before and after the event date. T statistics are reported in parentheses. Significance at 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Table 3: Regression result of model (2): average abnormal return and registered place of listed company.

	$T=1$	$T=5$	$T=10$	$T=15$	$T=20$	$T=25$
CDummy	0.0047 (0.600)	0.0017 (0.566)	0.0029* (1.688)	0.0012 (1.080)	0.0010 (1.005)	0.0010 (1.119)
Firm size	−0.0043 (−1.061)	−0.0003 (−0.218)	−0.0001 (−0.160)	0.0001 (0.134)	0.0002 (0.347)	−0.0008 (−1.550)
Turnover	0.0011 (0.547)	0.0002 (0.319)	−0.0003 (−0.724)	−0.0001 (−0.106)	0.0003 (1.215)	−0.0001 (−0.453)
PE	−0.0001 (−0.297)	−0.0001 (−1.508)	−0.0001 (−0.471)	−0.0001 (−0.196)	−0.0001 (−0.822)	−0.0001 (−1.434)
ROE	−0.0002 (−0.799)	−0.0001 (−1.563)	−0.0002*** (−3.302)	−0.0001* (−1.721)	−0.0001 (−0.331)	0.0001 (0.258)
BPS	−0.0034 (−0.386)	0.0023 (0.691)	0.0015 (0.779)	0.0002 (0.191)	−0.0018 (−1.638)	−0.0021** (−2.054)
EPS	0.0022 (1.363)	0.0003 (0.458)	−0.0001 (−0.152)	−0.0002 (−0.830)	0.0001 (0.548)	0.0002 (1.005)
Constant	0.0806 (0.858)	0.0035 (0.098)	0.0006 (0.032)	−0.0018 (−0.133)	−0.0052 (−0.429)	0.0175 (1.562)
N	190	190	190	190	190	190
R − squared	0.0380	0.0389	0.1023	0.0502	0.0655	0.0896

Note. This table is based on the following regression: $\mathrm{AAR}_{j,\mathrm{post}} - \mathrm{AAR}_{j,\mathrm{pre}} = \alpha + \beta^{*}\mathrm{CDummy}_j + \gamma^{*}\mathrm{Control}_j + \varepsilon_j$, and presents the result of the regression with control variables. T is the number of trading days before and after the event date. T statistics are reported in parentheses. Significance at 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Table 4: Regression result of model (3): excessive trading volume and registered place of listed company.

	$T=1$	$T=5$	$T=10$	$T=15$	$T=20$	$T=25$
CDummy	0.1017 (0.484)	0.5210*** (2.845)	0.4373*** (2.652)	0.3167** (2.155)	0.2620** (2.005)	0.2146* (1.717)
Constant	−0.3515** (−2.368)	0.3070** (2.371)	0.2380** (2.041)	0.2725*** (2.622)	0.4233*** (4.581)	0.4625*** (5.232)
N	190	190	190	190	190	190
R-squared	0.0012	0.0413	0.0361	0.0241	0.0209	0.0154

Note. This table is based on the following regression: $\mathrm{ETV}_{j,\mathrm{post}} - \mathrm{ETV}_{j,\mathrm{pre}} = \alpha + \beta^{*}\mathrm{CDummy}_j + \gamma^{*}\mathrm{Control}_j + \varepsilon_j$, and presents the result of the regression without control variables. T is the number of trading days before and after the event date. T statistics are reported in parentheses. Significance at 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Table 5: Regression result of model (4): excessive trading volume and registered place of listed company.

	$T=1$	$T=5$	$T=10$	$T=15$	$T=20$	$T=25$
CDummy	0.0923 (0.449)	0.5028*** (2.746)	0.4261** (2.548)	0.3082** (2.065)	0.2566* (1.935)	0.2080 (1.646)
Firm size	−0.0017 (−0.016)	−0.1078 (−1.125)	−0.0667 (−0.762)	−0.0494 (−0.632)	−0.0204 (−0.294)	−0.0332 (−0.503)
Turnover	−0.1641*** (−3.135)	−0.1131** (−2.425)	−0.0398 (−0.934)	−0.0087 (−0.228)	−0.0041 (−0.121)	−0.0172 (−0.536)
PE	−0.0005 (−0.673)	−0.0004 (−0.598)	−0.0003 (−0.455)	−0.0002 (−0.302)	−0.0002 (−0.521)	−0.0004 (−0.873)
ROE	−0.0062 (−1.038)	−0.0025 (−0.469)	0.0011 (0.227)	0.0044 (1.008)	0.0044 (1.152)	0.0051 (1.383)
BPS	0.2559 (1.112)	0.0737 (0.359)	−0.0434 (−0.232)	−0.0816 (−0.489)	−0.1184 (−0.798)	−0.1222 (−0.864)
EPS	0.0152 (0.358)	0.0174 (0.459)	0.0250 (0.724)	0.0152 (0.492)	0.0214 (0.780)	0.0182 (0.696)
Constant	−0.0109 (−0.004)	2.9527 (1.336)	1.7438 (0.864)	1.3566 (0.753)	0.8260 (0.516)	1.2177 (0.799)
N	190	190	190	190	190	190
R − squared	0.0798	0.0753	0.0469	0.0332	0.0316	0.0332

Note. This table is based on the following regression: $\mathrm{ETV}_{j,\mathrm{post}} - \mathrm{ETV}_{j,\mathrm{pre}} = \alpha + \beta^{*}\mathrm{CDummy}_j + \gamma^{*}\mathrm{Control}_j + \varepsilon_j$, and presents the result of the regression with control variables. T is the number of trading days before and after the event date. T statistics are reported in parentheses. Significance at 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

worth mentioning was that people in Wuhan who searched for "stock account opening" ranked first in the country during the week from February 9th to February 16th. Investors said it was mainly due to their confidence in COVID-19 prevention and control and the sudden increase of free time. Therefore, after the outbreak, the ETV is significantly greater than 1 for a period, and after the event date, the ETV of Hubei listed companies increased much more than that of non-Hubei listed companies.

5. Conclusions

This study investigates investor sentiment and stock market reactions to COVID-19 outbreak in Wuhan. Our research employs an ESM to calculate the AAR, CAR, and ETV of the event window and finds that the sudden outbreak of COVID-19 has a negative effect on the stock returns and a positive effect on the trading volume.

On this basis, by establishing a DID model, we further investigate whether listed companies registered in Hubei Province behave differently from non-Hubei listed companies in terms of AAR and ETV since the development of Hubei Province has been most severely affected by the epidemic. The results show that for listed companies registered in Hubei, the change of ETV before and after the event date is significantly higher than that of non-Hubei listed companies, while there exhibits no relationship between the change of AAR and registration place. There are two possible reasons. First, the impact of the COVID-19 is nationwide, and during the Spring

Festival holiday, with the implementation of prevention and control measures, investor sentiment gradually changed from pessimism to optimism. Therefore, there is no obvious regional differences in AAR. Second, due to the long holiday after the event day and the fact that people cannot return to work in the short time, more people especially Hubei investors have turned their attention to the stock market and the number of stock account openings has increased, leading to a more significant increase in the ETV of Hubei listed companies.

Our study provides new insights into the impact of a large-scale emergent public health event on investor sentiment and stock market reactions. Moreover, it complements the works studying on local bias and expands the perspective of study on the impact of COVID-19 on stock prices. Our findings can enable policymakers to evaluate and implement effective policies to stabilize the stock markets and help investors to make appropriate investment strategies.

The limitation of this paper is as it is difficult to match the sample using all the stock trading data, we select the stock with the lowest matching error calculated from the six market trading data as the match for stock in the test group, which may have deviations in reflecting the entire sample in the market (Table 6).

Appendix

Table 6: Variables.

Variables	Definition
CAR	Cumulative average return, which is measured by model (3).
ETV	Excessive trading volume, which is measured by model (4).
CDummy	Takes the value of 1 if stock is from the test group, and 0 if stock is from the control group.
Cap	Market capitalization, the sum of the market value of tradable shares.
TO	Turnover, the trading volume scaled by the total number of shares outstanding.
PE	PE ratio, the ratio of market value per share to earnings per share, which is divided by 10.
ROE	Return on equity, net profits divided by the net assets.
EPS	Net profit per share, the ratio of net profit to general capital.
BPS	Net asset per share, the ratio of net asset to general capital.
Firm size	The natural logarithm of the market value of equity.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Lin Sun and Wei Shi are co-first authors of this work and have equal contribution to this paper.

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Research Article

Efficiency Analysis of the Crop Production in China in 2019 and 2020: Role of Uncertainty Perceptions in COVID-19

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This paper employs data envelopment analysis (DEA) to determine crop production efficiency in 15 major provinces of China during 2019-2020. The total power of agricultural machinery, the application amount of chemical fertilizer, the irrigation area of cultivated land, the area of grain sowing, and the total capacity of reservoirs in each province are defined as the input items. The production of food, production of oil plants, and production of fruits are considered output items. According to the findings from the DEA, the most efficient crop production is observed in Shandong and Xinjiang provinces. We also discuss the role of farmers' uncertainty perceptions in COVID-19. By cluster analysis, the provinces with large grain sown area and high grain yield are Henan and Heilongjiang, the provinces with moderate grain production in the grain sown area are Hunan, Hubei, Jiangxi, Guizhou, and Yunnan, and Xinjiang, Shandong, Hebei, Anhui, Sichuan, Jiangsu, Inner Mongolia, and Jilin are the provinces with low grain production.

1. Introduction

China is a large developing agricultural country, and its total crop output ranks among the top in the world. Every year, China exports a large number of crops. With the increase of our country's population, the demands for all kinds of agricultural products increase rapidly. However, economic growth has also brought many environmental problems and ecological crises, such as climate change, land desertification, water pollution, the spread of acid rain, and so on. All these issues will lead to a decrease in crop yield in our country. The increasing demand for agricultural products and the decreasing supply are bound to affect people's living standards. Therefore, it is of great significance to analyze the yield efficiency of the major crop-producing provinces in China in the past three years and explore how to improve the resource utilization rate, so as to improve the crop production efficiency and expand China's crop yield.

Currently, most people use the DEA model to study agricultural production efficiency. Farrell [1] first put forward the prototype of DEA, and then Charnes et al. [2] formally proposed the DEA model. Vollrath [3] and Restuccia et al. [4] studied the agricultural production efficiency of many countries with the help of this model. For instance, Jiang et al. [5] studied the utilization efficiency of agricultural resources in 16 sample areas of prefecture-level cities in Anhui Province using the super-efficiency-DEA model. Dong et al. [6] adopted DEA efficiency to evaluate the agricultural production of Zhejiang Province and put forward the corresponding countermeasures. They found an overall low level of agricultural production efficiency in Zhejiang Province. The poor efficiency of resource utilization and the improper scale of input was the main elements affecting the agricultural efficiency, and the production technology level is the secondary one. Based on the C2R model of DEA, Mingyue [7] evaluated the grain production efficiency of 13 major grain-producing provinces in 2018, including Heilongjiang, Henan, Shandong, Jilin, Jiangsu, Anhui, Sichuan, Hebei, Hunan, Inner Mongolia, Hubei, Jiangxi, and Liaoning. Based on the previous research, our paper takes the crop yield of 15 provinces in 2019 and 2020 as the research object. It takes the total power of agricultural machinery, fertilizer application amount, cultivated land irrigation area, grain sowing area, and total reservoir

capacity of each province as input items. Grain yield, oil yield, and fruit yield are output items. This paper employs the data envelopment analysis method to evaluate and analyze China's crop-producing provinces' yield efficiency.

This paper is organized as follows. Section 1 includes the research background of China's main crop yield efficiency analysis and literature review. Section 2 briefly introduces the research method of this paper, that is, the super-efficiency-DEA model. Section 3 uses the super-efficiency-DEA method to analyze the crop yield efficiency of 15 provinces: Shandong, Henan, Hebei, Anhui, Hunan, Heilongjiang, Sichuan, Jiangsu, Hubei, Inner Mongolia, Jilin, Jiangxi, Guizhou, Yunnan, and Xinjiang in 2019 and 2020. At the same time, the cluster analysis method is also used in the study and analysis. Section 4 analyzes the research results, draws conclusions, and puts forward corresponding suggestions.

2. Research Methods

2.1. Super-Efficiency-DEA Model. In calculating the efficiency value of the CCR model, there are often multiple effective decision units (efficiency value is one), making it impossible to compare and analyze between effective decision units. In order to achieve the order of decision-making units, Anderson and Pearson [8] eliminated the evaluated decision-making units from the efficiency boundary and utilized the remaining decision-making units to form a new efficiency boundary, thus calculating the distance between the eliminated decision-making units and the new efficiency boundary. Since the efficiency boundary does not surround the excluded decision-making units, the new efficiency value calculated by the excluded decision-making units is bigger than one for the effective decision-making units. In contrast, for the invalid decision-making units, the efficiency value obtained by the excluded decision-making units remains unchanged. It is still less than one so that all decision-making units can be sorted completely. Since the effective decision unit efficiency is greater than one, the concept of super-efficiency is invented.

Super-Efficiency Master Mold. When evaluating the efficiency of the decision-making unit, the fractional programming model is

$$\max h_{j_0} = \frac{u^T Y_{j_0}}{u^T X_{j_0}},$$

$$S.t. \begin{cases} h_j = \dfrac{u^T Y_j}{v^T X_j} \le 1 \quad (j = 1, 2, \ldots, n; j \ne j_0) \\ v \ge 0, u \ge 0 \end{cases} \tag{1}$$

In this formula, the variables of the model are v and u.

It can be transformed into a linear programming problem model.

$$\max h_{j0} = \mu^T Y_{j0},$$

$$S.t. \begin{cases} \omega^T X_j - u^T Y_j \ge 0 \quad (j = 1, 2, \ldots, n; j \ne j_0) \\ \omega^T X_0 = 1 \\ \omega \ge 0, u \ge 0 \end{cases} \tag{2}$$

Its dual linear rule can be expressed as

$$\min \theta - \varepsilon \left(\sum_{i-1}^{m} S_i^- + \sum_{r-1}^{s} S_r^+ \right),$$

$$s.t \begin{cases} \sum_{\substack{j=1 \\ j \ne j_0}}^{n} X_j \lambda_j + s^- = \theta X_{j_0} \sum_{\substack{j=1 \\ j \ne j_0}}^{n} Y_j \lambda_j + s^- = Y_{j_0} \lambda_j \ge 0 \, (j = 1, 2, \ldots, n) s^+ \ge 0, s^+ \ge 0 \end{cases} \tag{3}$$

In this model, θ represents the super-efficiency value of the j_0th decision unit, ε is the non-Archimedean infinitesimal quantity, n is the number of DMUs, each DMU includes m input variables and s output variables, s_i^- are s_r^+ are input and output slack variables, respectively, X_{ij} represents the value of the jth decision-making unit on the ith input indicator, Y_{rj} represents the value of the jth decision-making unit on the rth output (output) indicator, λ_j is the weight coefficient of input and output indicators, and θ, λ_j, s_i^-, s_r^+ represent unknown parameters, which the model can solve. Assume that the optimal solutions of the model equation of the planning problem are as follows:

(1) If $\theta \ge 1$ and $s^{-0} = s^{+0}$, j_0th DM U_0 represents that DEA is efficient.

(2) If $\theta \ge 1$ and $s_i^- \ne 0$ or $s_r^+ \ne 0$, j_0th DM U_0 represents that DEA is weakly efficient.

(3) If $\theta \ge 1$ and $s_i^- \ne 0$ or $s_r^+ \ne 0$, j_0th DM U_0 represents that DEA is invalid.

2.2. Cluster Analysis. Clustering analysis is based on the principle of similarity. The training data with high similarity are included in the same cluster, and those with a high difference are divided into different clusters. K-means

clustering algorithm is unsupervised learning and a classical algorithm in clustering analysis. K-means algorithm takes distance as the standard of similarity measurement between training data. This means that the smaller the gap between the training data is, the higher the similarity is, and the more likely the training data is to be included in the same cluster. K-means algorithm usually uses the Euclidean distance to calculate the distance between training data.

The mapping method of Sammon [9] is used to find N points in q-dimensional space, where the original data come from higher N-dimensional space.

The measured $d_{ij} = d(x_i, x_j)$ point distance in N-dimensional space is similar to $d^*_{ij} = (d^*(y_i, y_j))$.

Corresponding q-dimensional space: this evidence is achieved by minimizing the error standard E, also called the Sammon pressure.

$$E = \frac{1}{\lambda} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{\left(d_{ij} - d^*_{ij}\right)^2}{d_{ij}}, \tag{4}$$

where $\lambda = \sum_{i<j} d_{ij} = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} d_{ij}$, and it is not necessary to maintain λ to successfully solve the optimization problem because, as a constant, it will not change the optimization problem.

3. Empirical Analysis

3.1. Sample Data and Variables. This part analyzes the yield efficiency evaluation of 15 major agricultural production provinces in China in 2019 and 2020. In this paper, the total power of agricultural machinery, the application amount of chemical fertilizer, the irrigated area of cultivated land, the sown area of grain, and the total reservoir capacity are taken as input items, and grain, oil plant, and fruit output are output items. The data are selected from China Statistical Yearbook. The specific index data are shown in Table 1.

The output indicators of super-efficiency-DEA are described as follows. Technical efficiency (TE) reflects the effective degree of existing technology utilization in production, that is, the ability of the evaluated object to obtain the maximum output under the given input. Scale effect (SE) reflects the effectiveness of production scale, that is, whether each decision unit is operating under the most appropriate investment scale. Synthesis technical efficiency (STE) includes technical efficiency and scale efficiency, also called scale technical efficiency. When the observed decision-making unit achieves technical efficiency and scale efficiency, it is called scale technical efficiency.

STE Effectiveness. CCR model evaluates both scale effectiveness and technical effectiveness, namely, total efficiency. The total efficiency value satisfies $0 \le \theta \le 1$ when the efficiency value $\theta = 1$, and the evaluated decision-making unit is scale technology effective. Otherwise, it is scale technology invalid.

TE effectiveness is the BCC model used to evaluate the technical effectiveness of decision-making units. Technical efficiency satisfies $0 \le \theta \le 1$. When $\theta = 1$, the evaluated object is in a state of technical effectiveness. Otherwise, it is technically invalid.

SE effectiveness is determined by total efficiency and technical efficiency, and its formula is SE = STE/TE.

Super-Efficiency-DEA Effectiveness. The efficiency value θ is no longer limited in the range of 0 ~ 1 but allows an efficiency value of more than 1. If $\theta \ge 1$, the scale is more technical. Otherwise, it is invalid in scale or technology. This method can be used to compare and sort each decision-making unit effectively. Using the λj CCR model, the returns to the scale of the decision unit $DM\ U j0$ can be analyzed. When $\sum_{j=1}^{n} \lambda_1^0 = 1$, $DM\ U j0$ is economies of scale not changed, when $\sum_{j=1}^{n} \lambda_1^0 < 1$, $DM\ U j0$ is economies of scale increased, when $\sum_{j=1}^{n} \lambda_1^0 > 1$, $DM\ U j0$ is economies of scale reduced.

3.2. Findings of Super-Efficiency-DEA. When the DEA method is used to measure performance, the effectiveness of the results largely depends on the input and output indicators used in the evaluation process. The calculation results of grain production efficiency of major grain-producing provinces in China in 2019 and 2020 are shown in Tables 2 and 3.

From Table 2, we can get that among the 15 major crop-producing provinces in 2019, Shandong, Henan, Hunan, Heilongjiang, Sichuan, Jiangsu, Hubei, Inner Mongolia, Jilin, Jiangxi, Yunnan, and Xinjiang are 12 provinces with effective output, and the remaining provinces are not. The output efficiency of 15 provinces is statistically analyzed. The minimum value is 0.8606, and the average value is 0.9755. The output efficiency of Hebei, Anhui, and Guizhou did not reach the average value. Shandong, Henan, Hunan, Heilongjiang, Sichuan, Jiangsu, Hubei, Inner Mongolia, Jilin, Jiangxi, Yunnan, and Xinjiang are effective. In addition to the above provinces, Guizhou is still effective in technical efficiency. Except that the returns to scale of provinces with STE effectiveness remain unchanged, the returns to scale of other provinces increase. By sorting the super-efficiency-DEA value, it can be found that the benefit rankings of Henan, Hebei, Sichuan, and Jiangxi are greatly decreased, and the benefit ranking of Xinjiang is unchanged.

Table 3 shows the results in 2020. Effective output is Shandong, Henan, Hunan, Heilongjiang, Sichuan, Jiangsu, Hubei, Inner Mongolia, Jilin, Jiangxi, Yunnan, and Xinjiang twelve provinces; the remaining provinces have not reached the maximum output. The output efficiency of the15 provinces is statistically analyzed. The minimum value is 0.8791, and the average value is 0.9789. The output efficiency of Hebei, Anhui, and Guizhou does not reach the average value. Shandong, Henan, Hunan, Heilongjiang, Sichuan, Jiangsu, Hubei, Inner Mongolia, Jilin, Jiangxi, Yunnan, and Xinjiang are effective. In addition to the above provinces, Guizhou is still effective in technical efficiency. Except that the returns to scale of provinces with STE effectiveness remain unchanged, the returns to scale of other provinces increase. By sorting the super-efficiency-DEA value, it can be seen that the benefit rankings of Sichuan, Jiangsu, Hubei, Jiangxi, and Yunnan are greatly decreased, and the benefit ranking of Xinjiang is unchanged. In summary, those

Table 1: Input and output indicators of major agricultural provinces in China in 2020.

Province	Input					Output		
	Total power of agricultural machinery (10 MW)	Fertilizer application rate (10 kt)	Cultivated land irrigation area (1k hectares)	Grain-planting area (1 k hectares)	Total reservoir capacity (100 m cubic metres)	Grain output (10 kt)	Oil plant production (10 kt)	Fruit yield (10 kt)
Shandong	102758.3	395.3	5271.4	8312.8	220.3	5357.0	289.0	2840.2
Henan	10679.8	666.7	5328.9	10734.5	432.9	6695.4	645.5	2589.7
Hebei	10357.0	297.3	4482.2	6469.2	206.3	3739.2	119.5	1391.5
Anhui	7830.7	298.0	4580.8	7287.0	203.8	4054.0	161.4	706.3
Hunan	6650.5	229.0	3176.1	4616.4	514.0	2974.8	239.2	062.0
Heilongjiang	6471.8	223.3	6177.6	14338.1	267.7	7503.0	11.5	165.0
Sichuan	4682.3	222.8	2954.1	6279.3	523.2	3498.5	367.4	1136.7
Jiangsu	5112.0	286.2	4205.4	5381.5	35.3	3706.2	94.3	983.6
Hubei	4515.7	273.9	2969.0	4608.6	1263.8	2725.0	313.9	1010.2
Inner Mongolia	3866.4	218.4	3199.2	6827.5	1097	3652.5	228.7	280.4
Jilin	3653.7	227.1	1909.5	5644.9	334.3	3877.9	81.8	153.9
Jiangxi	2470.7	115.6	2036.1	3665.1	327.9	2157.5	120.8	693.3
Guizhou	2486.6	83.2	1154.0	2709.4	445.5	1051.2	103.0	442.0
Yunnan	2714.4	204.0	1922.5	4165.8	763.1	1870.0	62.5	860.3
Xinjiang	2789.0	257.8	4959.9	2203.6	210.8	1527.1	66.4	1604.8
Average	11802.6	266.6	3621.8	6216.2	456.4	3626.0	193.7	994.7
Max	102758.3	666.7	6177.6	14338.1	1263.8	7503.0	645.5	2840.2
Min	2470.7	83.2	1154.0	2203.6	35.3	1051.2	11.5	62.0
Standard deviation	24444.1	128.7	1452.2	3029.2	331.8	1736.7	157.1	807.2

Table 2: Efficiency evaluation of major agricultural provinces in China in 2019.

Provinces	Synthesis technical efficiency (STE)/ CCR	Ranking of STE	Technical efficiency (TE)/BBC	Scale efficiency (SE)	Scale benefits (R)/CCR	Scale benefits	Super-efficiency-DEA	Ranking of super-efficiency-DEA
Shandong	1.0000	1	1.0000	1.0000	1.0000	Constant	1.63757521	2
Henan	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00002878	12
Hebei	0.8845	3	0.8863	0.9981	0.8149	Increasing	0.00000072	15
Anhui	0.8881	2	0.8904	0.9975	0.8814	Increasing	0.00265337	8
Hunan	1.0000	1	1.0000	1.0000	1.0000	Constant	0.15126099	4
Heilongjiang	1.0000	1	1.0000	1.000	1.0000	Constant	0.04179591	6
Sichuan	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00004657	11
Jiangsu	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00017372	9
Hubei	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00770955	7
Inner Mongolia	1.0000	1	1.0000	1.0000	1.0000	Constant	0.15943523	3
Jilin	1.0000	1	1.0000	1.0000	1.0000	Constant	0.10305273	5
Jiangxi	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00000744	14
Guizhou	0.8606	4	1.0000	0.8606	0.3132	Increasing	0.00000959	13
Yunnan	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00007938	10
Xinjiang	1.0000	1	1.0000	1.0000	1.0000	Constant	2.04570101	1

provinces need to make more efficient use of the resources to improve the output because of the output efficiency differences and uneven distribution of resources.

3.3. Results of Cluster Analysis. The K-means algorithm clusters the grain production and grain-planting area of the main grain-producing provinces in China in 2020. According to the actual situation, the provinces are divided into three grades: large grain production of grain-planting area, medium grain production of grain-planting area, and small grain production of grain-planting area. The distinction between the three grades is obvious. The clustering analysis results of grain production evaluation grades in 2020 are shown in Table 4, and the clustering graph of each province is shown in Figure 1.

The provinces with high grain yield in large grain-planting areas are Henan and Heilongjiang, accounting for 13.33%. The provinces with moderate grain yield in medium grain-planting areas are Hunan, Hubei, Jiangxi, Guizhou,

Table 3: Efficiency evaluation of major agricultural provinces in China in 2020.

Provinces	Synthesis technical efficiency (STE)/CCR	Ranking of STE	Technical efficiency (TE)/BBC	Scale efficiency (SE)	Scale benefits (R)/CCR	Scale benefits	Super-efficiency-DEA	Ranking of super-efficiency-DEA
Shandong	1.0000	1	1.0000	1.0000	1.0000	Constant	1.60010865	2
Henan	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00021696	9
Hebei	0.8791	4	0.8896	0.9882	0.7974	Increasing	0.00007220	10
Anhui	0.8868	3	0.8885	0.9981	0.8948	Increasing	0.00025323	8
Hunan	1.0000	1	1.0000	1.0000	1.0000	Constant	0.11059507	4
Heilongjiang	1.0000	1	1.0000	1.0000	1.0000	Constant	0.05266353	6
Sichuan	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00000001	15
Jiangsu	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00000185	12
Hubei	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00000079	14
Inner Mongolia	1.0000	1	1.0000	1.0000	1.0000	Constant	0.172401297	3
Jilin	1.0000	1	1.0000	1.0000	1.0000	Constant	0.10112767	5
Jiangxi	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00000812	11
Guizhou	0.9183	2	1.0000	0.9183	0.2939	Increasing	0.00349393	7
Yunnan	1.0000	1	1.0000	1.0000	1.0000	Constant	0.00000137	13
Xinjiang	1.0000	1	1.0000	1.0000	1.0000	Constant	2.15722821	1

Table 4: Cluster analysis results of grain yield evaluation grades of provinces in 2020.

Evaluation level	Provinces	Number	Proportion (%)
Large grain sown area and high grain yield	Henan, Heilongjiang	2	13.33
Medium grain sown area and moderate yield	Hunan, Hubei, Jiangxi, Guizhou, Yunnan, Xinjiang	6	40
Small grain sown area and low grain yield	Shandong, Hebei, Anhui, Sichuan, Jiangsu, Inner Mongolia, Jilin	7	46.67

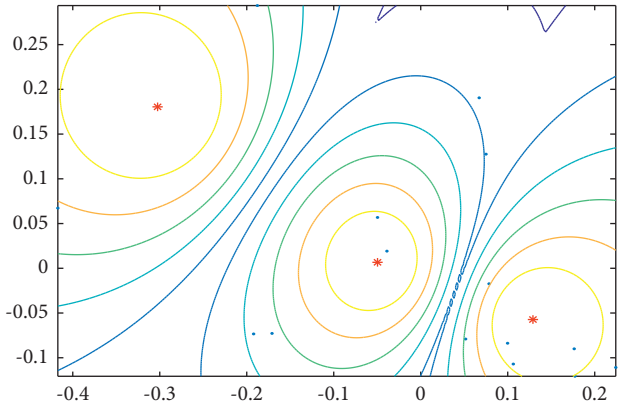

Figure 1: K-means clustering of three clustering centers.

Yunnan, and Xinjiang, accounting for 40%. The provinces with low small grain yield in small grain-planting areas are Shandong, Hebei, Anhui, Sichuan, Jiangsu, Inner Mongolia, and Jilin, accounting for 46.67%. The large grain yield in large grain-planting areas will also increase. These 15 provinces are major grain-producing provinces in China. However, the proportion of provinces with low small grain yield in small grain-planting areas reaches 46.67%. Therefore, expanding grain-planting areas is of great significance to improve grain yield.

4. Conclusions

In this paper, the super-efficiency-DEA method is employed to study the crop yields of 15 provinces in 2019 and 2020, which includes Shandong, Henan, Hebei, Anhui, Hunan, Heilongjiang, Sichuan, Jiangsu, Hubei, Inner Mongolia, Jilin, Jiangxi, Guizhou, Yunnan, and Xinjiang. The total power of agricultural machinery, the amount of chemical fertilizer application, the irrigation area of cultivated land, the grain sowing area, and each province's total reservoir capacity are used as input items. The grain output, oil output, and fruit output are taken as output items to analyze the output efficiency of the main crop-producing provinces in China. The empirical analysis results show that compared with other provinces and cities, Shandong, Henan, Heilongjiang, Sichuan, Jiangsu, Hubei, Inner Mongolia, Jilin, Jiangxi, and Xinjiang are always in the forefront of grain output in 2019 and 2020. They should lead other provinces to improve the level of crop production. In the ranking of super-efficiency-DEA values in 2019 and 2020, Henan and Hebei are declining for two consecutive years. In the ranking of super-efficiency-DEA values in 2019-2020, Sichuan and Jiangxi are also declining. Overall, the ranking of most provinces fluctuates year by year.

We should fully understand the importance and urgency of preventing cultivated land from "non-grain" to stabilize

grain production and improve and mend a series of laws and regulations related to cultivated land. Sufficient grain production is an important guarantee for national food security. Insufficient grain sowing area will lead to a sharp decline in China's grain production. At present, because of the ecological damage, China's cultivated land area is being reduced, and the cultivated land area in China is decreasing. If this situation continues, it will affect China's food security. Therefore, a series of laws and regulations related to cultivated land should be improved, and laws and regulations should be strictly implemented to prevent the "non-grain" of cultivated land.

It is also necessary to adhere to arable land resources' scientific and rational use and clear priority of arable land use. Cultivated land is the foundation of grain production, but the area of cultivated land is limited. To take full advantage of the existing cultivated land resources, under the premise of preventing the "non-grain" of cultivated land, we should adhere to the scientific and rational use of cultivated land resources and properly deal with the relationship between the development of grain production and the development of comparative benefits. We should not simply determine the use of cultivated land by economic benefits but implement strict cultivated land protection measures, strictly control the conversion of cultivated land to forest land, garden land and other types of agricultural land, and ensure sufficient food production to ensure people's daily life needs and reserves.

This paper compares the crop production efficiency in 15 major provinces of China during 2019-2020. We found a significant decline in crop production efficiency in 2020 compared to 2019. We suggest that this difference comes from the risk perceptions in COVID-19. Most small businesses and producers have been shut down due to COVID-19, and the uncertainty has risen in the markets. Therefore, we suggest that producers, especially small-size farmers, should be strengthened by grain-planting incentive mechanisms. It is necessary to implement the reward policy of grain-producing across provinces and give grain growers certain subsidies every year to mobilize farmers' enthusiasm to plant food. We should vigorously promote mechanized production to improve grain-planting scale efficiency. Food-planting professionals can be sent to the countryside to give farmers technical support to help them solve some technical bottlenecks, thereby increasing food production. Through cluster analysis, we can know that expanding grain-planting area is of great significance to improving grain output.

Data Availability

The data used to support the findings of this study are obtained from http://www.stats.gov.cn/tjsj/ndsj/2021/indexch.htm.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

The Performance Evaluation of IEE in Colleges and Universities Based on AHP Model

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At present, the country strongly encourages all walks of life to innovate, especially in the field of education. China's major colleges and universities have increased the encouragement of innovation and entrepreneurship education (IEE) projects in keeping with the pace of the times, so it is particularly important to reasonably evaluate the actual benefits of the project. On the one hand, it can greatly improve the recognition of all walks of life for emerging education projects. On the other hand, it can realize the timely and accurate application of the financial funds of the project. Based on this background, through the analysis and summary of existing theories and comprehensive consideration at all levels, this paper studies the new education projects from the aspects of teaching environment, conditions, quality, satisfaction, and financial capital and then constructs a set of performance evaluation index system for IEE in major colleges and universities. At the same time, this paper analyzes the actual education environment in China and evaluates the IEE in all kinds of colleges and universities by using analytic hierarchy process (AHP). Judging from the assessment results, the current teaching conditions and the quality of teachers in Chinese universities are very good. But the conclusion from the perspective of students is opposite, and the investment ratio of their financial capital is not optimistic. Therefore, this paper puts forward the optimization suggestions.

1. Introduction

At present, China's economic development environment has entered a new era that is different from any previous stage. The emphasis on education has also reached a new level and even shoulders the important task of an important engine [1]. In the mid-1990s, China's major universities gradually launched the research on IEE [2] and make the humanities accomplishment of college students achieve a new leap by gradually cultivating their innovation, entrepreneurship, and practical ability [3–5]. But in recent years for the popularity of IE is still far from enough, it is difficult to deal with the major universities setting a series of innovative talent training objectives [6–8]. The reason for this phenomenon is that there are still many problems in the current IEE in universities, such as the pursuit of short-term achievements while ignoring long-term effects, the unified and rigid supply mode, the single and rigid supply mode, the failure of entrepreneurship education curriculum to integrate into the teaching system, and the shortage of IE practice teaching [9–11].

However, domestic colleges and universities are actively studying how to construct a teaching quality monitoring system suitable for their own situation at present [12–14], but there are few theoretical studies and practical explorations on the teaching level monitoring mechanism specifically for IEE [15]. Therefore, it is necessary to construct an IEE evaluation system from the perspective of performance, so as to scientifically evaluate the IEE ability of schools and the entrepreneurial quality of students [16]. It helps really improve students' innovative ability and the key qualities needed for entrepreneurship [17]. And we can provide effective decision-making reference for the government and universities to improve the IEE reform according to the performance evaluation results of IEE [18].

Based on the above analysis, this paper analyzes the actual education environment in China and evaluates the implementation performance of IEE projects in Chinese

universities, so as to analyze the current actual situation and the parts that need to be improved. It is conducive to providing theoretical basis and practical guidance for optimizing the level of IEE in colleges. There are two main contributions of this paper. On the one hand, this paper designs the performance evaluation target system of IEE in universities from the three aspects of teaching input quality, teaching operation quality, and teaching output quality and confirms the evaluation target. Then the performance evaluation index system of IEE in universities is constructed from five aspects. On the other hand, this paper proposes a comprehensive evaluation method of IEE performance in universities by using analytic hierarchy process (AHP) and puts forward the measures to improve the performance of the government and schools in the future according to the evaluation results.

This paper mainly analyzes from the following six aspects. The first part comprehensively analyzes the current domestic and international realistic background and the expected goals of this study. The second part analyzes and summarizes the previous studies. The third part constructs the performance evaluation index system of IEE in colleges and universities from five aspects: teaching environment, teaching condition, financial capital, teaching quality, and teaching satisfaction. The fourth part expounds the reasons for choosing AHP and the process evaluation. The fifth part takes China as an example to empirically test the constructed index system. The sixth part puts forward the IEE performance improvement suggestions according to the research conclusion.

2. Related Work

At present, many scholars have realized that the evaluation of IEE is very important. For example, Zhou and Zhou [19] took the quality of IEE as the research content, constructed a complete set of evaluation index system for the quality of IEE of college students, and then evaluated it by using extenics. The index system included the existing educational conditions and channels, reasonable educational curriculum and activities, and the actual results achieved. Finally, taking eight universities as an example, the empirical research was carried out, and the corresponding improvement suggestions were put forward. In addition, Wang et al. [20] also proposed an advanced method to evaluate the quality of IEE in colleges. On the basis of traditional fault tree analysis (FTA), they proposed fuzzy fault tree analysis (FFTA) to evaluate the reliability of IEE for teachers and students. In order to further improve the performance of entrepreneurship education in all kinds of colleges and universities, Mao and Zhang [21] constructed the evaluation index system of IEE in colleges and universities and defined and analyzed various indicators. They also improved the traditional decision tree algorithm and then took several universities as examples to verify the rationality of the index system.

When this project is applied to higher vocational colleges, Zhou [22] designed a set of reasonable evaluation system from the aspects of investment proportion, development process, and accurate operation. Then the weight of each was analyzed and compared by AHP. Byun et al. [23] believed that universities not only shoulder the responsibility of traditional education and research, but also need to communicate with the region, so as to make more contributions to social development. Therefore, they established an indicator system for evaluating universities, hoping to improve sustainability by increasing innovative activities with local stakeholders. Gao [24] proposed that the foundation of college students' entrepreneurial success is a good entrepreneurial ecological environment. Based on the above analysis, this paper constructed a set of college students' entrepreneurial ecological environment evaluation index system and used AHP-fuzzy comprehensive evaluation method to evaluate and analyze in Shandong Province. From the results, multiparty cooperation is necessary and plays a decisive role in improving college students' entrepreneurship.

3. Design of Performance Evaluation Index System of IEE

3.1. Characteristics of the Index System. Based on the research and analysis of previous scholars, this paper conducts a comprehensive analysis from the perspectives of the training objectives of entrepreneurial talents, the practical needs of society, and the domestic and foreign environment, so as to determine the final evaluation goal and then designate a reasonable evaluation and assessment system. The main features are as follows.

3.1.1. Evaluation Content Diversity. There are many contents of innovation and entrepreneurship (IE) assessment, including IE rate of students in colleges, employment rate and entrepreneurship rate of graduates, the quantity and quality of scientific research achievements, guidance of teachers on IE of students, curriculum construction, IE base development, IE project construction, and IE fund investment. Through multiperspective evaluation, the quality of IEE in universities can be fully reflected.

3.1.2. Evaluation Process Persistence. IEE in colleges and universities is a dynamic cycle, progressive, and continuous improvement process. The performance evaluation of IEE aims to monitor and control the whole process and operation results of IEE, so as to form effective feedback and continuously optimize the IEE system. This requires the institutionalization, standardization, and specialization of the performance evaluation process of IEE and the use of scientific methods and modern information technology to promote the sustainable development of the performance evaluation of IEE in all colleges and universities.

3.1.3. Comprehensiveness of Evaluation Objects. In the evaluation process, a comprehensive evaluation is carried out around the following objects, including full-time IE tutors, part-time IE teachers, innovation and

entrepreneurship disciplines, IE curriculum and teaching material development, IE of students, and IE project incubation.

Therefore, this paper follows the characteristics of the above three innovation and entrepreneurship development evaluation systems and establishes the performance evaluation target system of IEE in all kinds of colleges and universities as shown in Figure 1.

3.2. Index System Establishment. Based on the analysis of previous scholars, this paper has a preliminary understanding of the performance evaluation of IEE in all kinds of colleges and universities. At the same time, it comprehensively considers the AHP and analyzes the correlation between various elements. Finally, according to the specified evaluation objectives and the evaluation of expert professors, the performance evaluation index system of IEE in all kinds of colleges and universities is established (Table 1).

4. Performance Evaluation of IEE

4.1. Research Method Selection. Analytic Hierarchy Process (AHP): The various factors that affect decision-making are decomposed, and qualitative and quantitative research and analysis are carried out from the dimensions of objectives, criteria, and schemes to make decisions. This method is mainly applicable to the decision-making of projects with problems on criteria or without structure. Firstly, AHP will decompose complex problems according to different levels and different factors. Secondly, it compares the importance of indicators and then establishes a judgment matrix to calculate λ and corresponding feature vectors. Finally, it will calculate their importance [25]. The index system studied in this paper has a relatively clear hierarchical structure, but the index system is relatively complex. Therefore, after comprehensive consideration, AHP is selected to study the subject, and the proportion of each index is calculated based on the established system, and the targeted suggestions are put forward by experts.

4.2. Evaluation Process

4.2.1. Construct Judgment Matrix. In the AHP, the matrix judgment scale is used to make the elements in the matrix quantitatively show their importance. Judgment matrix refers to the degree of importance obtained by comparing different factors with correlation between the two adjacent levels [26]. In the past, there are some subjective factors in the construction of the matrix, which greatly reduces the authenticity of the performance evaluation results. In order to ensure the objectivity of judgment, this paper takes 1–9 as a scale. Then we compare and empower the first-level index and the second-level index on the basis of consulting experts. Assuming that the comparison score between indicator X and indicator Y is α, the comparison score between indicator Y and indicator X is $1/\alpha$. Table 2 shows the definition diagram of judgment matrix.

4.2.2. Calculate Weight Vector. Firstly, the eigenvector and the maximum eigenvalue of matrix A are defined, which are substituted into formula (1), and finally the weight vector is obtained by normalization.

$$A \cdot W = \lambda_{\max} \cdot W. \tag{1}$$

In the formula, A is the original judgment matrix, W is the weight, and λ max is the maximum feature vector.

4.2.3. Consistency Test of Judgment Matrix. When carrying out the analytic hierarchy process, it is necessary to analyze the consistency of the matrix and understand the specific value of the maximum feature root, so that the judgment matrix is logically reasonable. The steps for consistency checking are as follows:

$$\begin{aligned} \mathrm{CI} &= \frac{\lambda_{\max} - n}{n-1}, \\ \mathrm{CR} &= \frac{\mathrm{CI}}{\mathrm{RI}}. \end{aligned} \tag{2}$$

In the formula, n denotes the order of the judgment matrix. CI is the consistency index. CR is the consistency ratio. RI is a random index introduced in the formula. The specific value of RI comes from the average value calculated by judging the consistency of the matrix in random sampling, as shown in Figure 2.

In the process of judgment, when $\mathrm{CR} < 0.1$, the consistency of judgment matrix is acceptable. When $\mathrm{CR} > 0.1$, it is considered that the judgment matrix does not meet the consistency requirement and needs to correct the judgment matrix.

4.2.4. Calculate Weight. According to formula (3) and expert scoring results, final weights of indicators are calculated.

$$W = W_i W_{ij}. \tag{3}$$

In the formula, W is the total weight of the index, W_i is the first-level index weight, and W_{ij} is the second-level index weight.

In summary, the university IEE performance evaluation process is shown in Figure 3.

5. Example Analysis

5.1. Determination of Index Weight

5.1.1. Construct Hierarchical Model. According to the hierarchical model and data collection results, as well as the specific conditions of the five evaluation indexes of teaching environment, teaching condition, financial capital, teaching quality, and teaching satisfaction, the first-level indicators are set as $R = (R1, R2, R3, R4, R5)$. The second-level indicators are set as $R1 = (R11, R12, R13, R14)$, $R2 = (R21, R22, R23, R24)$, $R3 = (R31, R32, R33, R34)$, $R4 = (R41, R42, R43, R44)$, $R5 = (R51, R52, R53, R54)$.

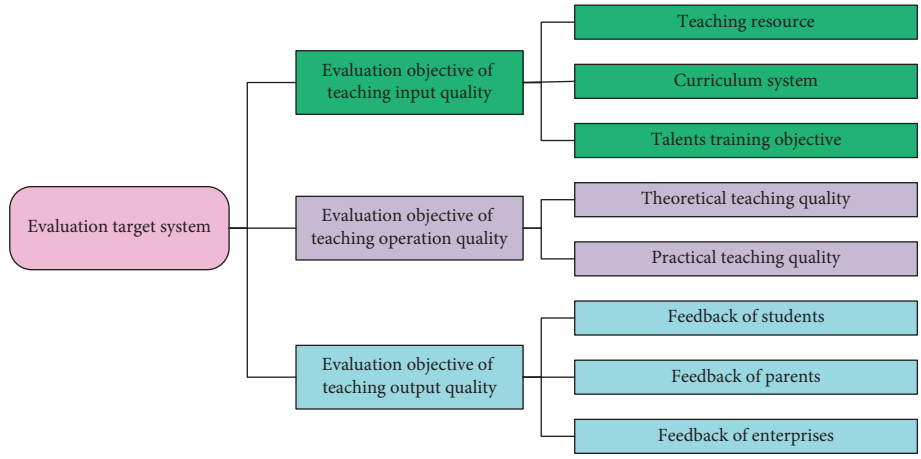

Figure 1: Performance evaluation target system of IEE in all kinds of colleges and universities.

Table 1: Performance evaluation index system of IEE in all kinds of colleges and universities.

Total index	First-level indicator	Second-level indicator
IEE performance	Teaching environment	IE platform construction
		IE information release and publicity
		Quality, decision-making, and ability of leader
		Management system construction
	Teaching condition	Number of IE disciplines
		Number of IE courses
		Number of IEE practice bases
		Number of IE practices
	Financial capital	The proportion of IEE funds to total teaching funds
		Annual growth rate of investment in IEE
		The proportion of students' self-financing in total venture capital
		Annual return on student entrepreneurship projects
	Teaching quality	The proportion of teachers with entrepreneurial experience in all entrepreneurial education teachers
		The proportion of teachers with entrepreneurial trainer qualification in all entrepreneurial education teachers
		The proportion of off-campus entrepreneurial tutors in all entrepreneurial education teachers
		Number of entrepreneurship education teachers conducting entrepreneurship training each year
	Teaching satisfaction	Entrepreneurial rate of students
		Support rate of parents for entrepreneurship of students
		Enterprise satisfaction with IE projects
		Adoption rate of enterprises of innovative and entrepreneurial projects

Table 2: Definition diagram of judgment matrix.

Comparison of importance between two elements	Weight
X and Y are equally important	1
X is a little more important than Y	3
X is clearly more important than Y	5
X is very more important than Y	7
X is extremely more important than Y	9
Intermediate value of two adjacent judgments	2, 4, 6, 8

5.1.2. Construct Judgment Matrix. The experts and professors construct judgment matrix based on index score, so as to calculate the weight of evaluation indicators. Then according to the results of matrix operation, we obtain the feature vector and feature root and finally calculate the index weight. Accordingly, the index weights of the first level are $W = (W1, W2, W3, W4, W5)$ and $\sum Wi = 1$.

5.1.3. Consistency Test and Weight Calculation. In order to ensure the true reliability of the data source of the judgment matrix, we issued a quantitative indicator table to five experts and 100 college students. On the basis of explaining the filling method in detail, all the respondents filled out the questionnaire seriously and practically, of which 87 were valid. The experts filled in the questionnaire based on their own practical experience, and the students filled in the questionnaire according to their own learning experience and harvest. Finally, we get the judgment matrix by analyzing the questionnaire data and making effective trade-offs based on Delphi method (Tables 3–8).

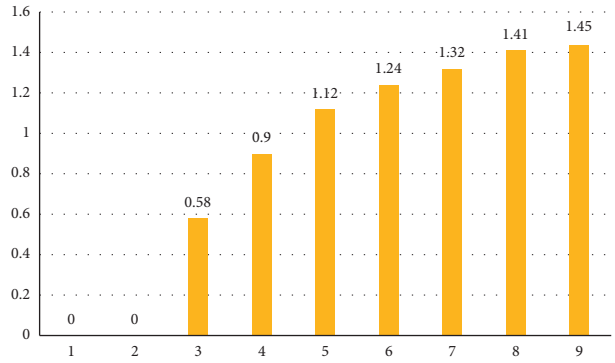

Figure 2: Random consistency index.

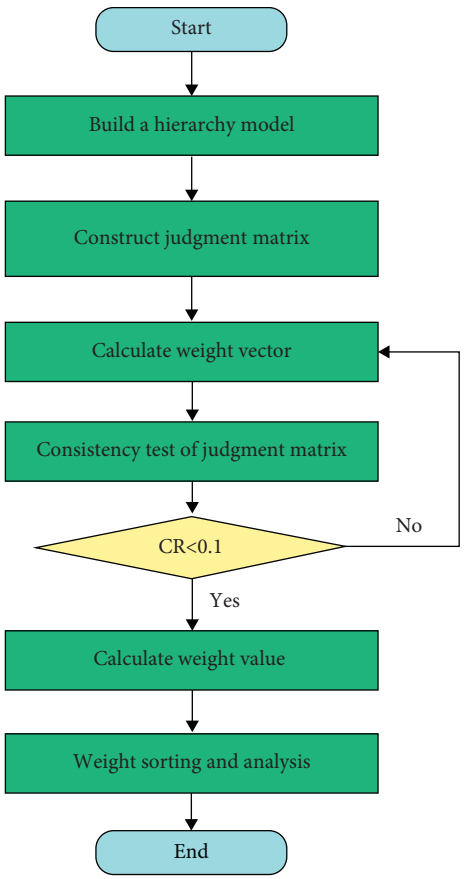

Figure 3: Performance evaluation flowchart of IEE in all kinds of colleges and universities.

Table 3: Weight of the first-level indicators.

U	R_1	R_2	R_3	R_4	R_5	W_i
R_1	1	1/4	4	1/2	2	0.161
R_2	4	1	7	2	6	0.415
R_3	1/4	1/7	1	1/7	1/2	0.042
R_4	2	1/2	7	1	4	0.301
R_5	1/2	1/6	2	1/4	1	0.081
Total						1

Table 4: Weight of teaching environment in second-level indicators.

R_1	R_{11}	R_{12}	R_{13}	R_{14}	W_i
R_{11}	1	1/6	1/2	1/5	0.067
R_{12}	6	1	4	2	0.465
R_{13}	2	1/4	1	1/3	0.128
R_{14}	5	1/2	3	1	0.340
Total					1

Table 5: Weight of teaching condition in second-level indicators.

R_1	R_{21}	R_{22}	R_{23}	R_{24}	W_i
R_{21}	1	1/3	2	5	0.279
R_{22}	3	1	5	7	0.536
R_{23}	1/2	1/5	1	2	0.124
R_{24}	1/5	1/7	1/2	1	0.062
Total					1

Table 6: Weight of financial capital in second-level indicators.

R_1	R_{31}	R_{32}	R_{33}	R_{34}	W_i
R_{31}	1	3	5	6	0.521
R_{32}	1/3	1	3	4	0.290
R_{33}	1/5	1/3	1	2	0.123
R_{34}	1/6	1/4	1/2	1	0.067
Total					1

Table 7: Weight of teaching quality in second-level indicators.

R_1	R_{41}	R_{42}	R_{43}	R_{44}	W_i
R_{41}	1	1/5	1/2	2	0.132
R_{42}	5	1	3	6	0.537
R_{43}	2	1/3	1	4	0.262
R_{44}	1/2	1/6	1/4	1	0.069
Total					1

Table 8: Weight of teaching satisfaction in second-level indicators.

R_1	R_{51}	R_{52}	R_{53}	R_{54}	W_i
R_{51}	1	6	2	5	0.501
R_{52}	1/6	1	1/4	1/2	0.069
R_{53}	1/2	4	1	3	0.304
R_{54}	1/5	2	1/3	1	0.126
Total					1

$$\lambda_{\max} = 5.134, \quad \text{CI} = 0.033, \text{CR} = 0.030. \tag{4}$$

$$\lambda_{\max} = 4.066, \quad \text{CI} = 0.022, \text{CR} = 0.024. \tag{5}$$

$$\lambda_{\max} = 4.099, \quad \text{CI} = 0.033, \text{CR} = 0.037. \tag{6}$$

Table 9: Performance evaluation indicator weight of IEE.

First-level indicator	Weight	Second-level indicator	Weight	Total weight
B1	0.161	C1	0.067	0.011
		C2	0.465	0.075
		C3	0.128	0.021
		C4	0.340	0.055
B2	0.415	C5	0.279	0.116
		C6	0.536	0.222
		C7	0.124	0.051
		C8	0.062	0.026
B3	0.042	C9	0.521	0.022
		C10	0.290	0.012
		C11	0.123	0.005
		C12	0.067	0.003
B4	0.301	C13	0.132	0.040
		C14	0.537	0.161
		C15	0.262	0.079
		C16	0.069	0.021
B5	0.081	C17	0.501	0.041
		C18	0.069	0.006
		C19	0.304	0.025
		C20	0.126	0.010

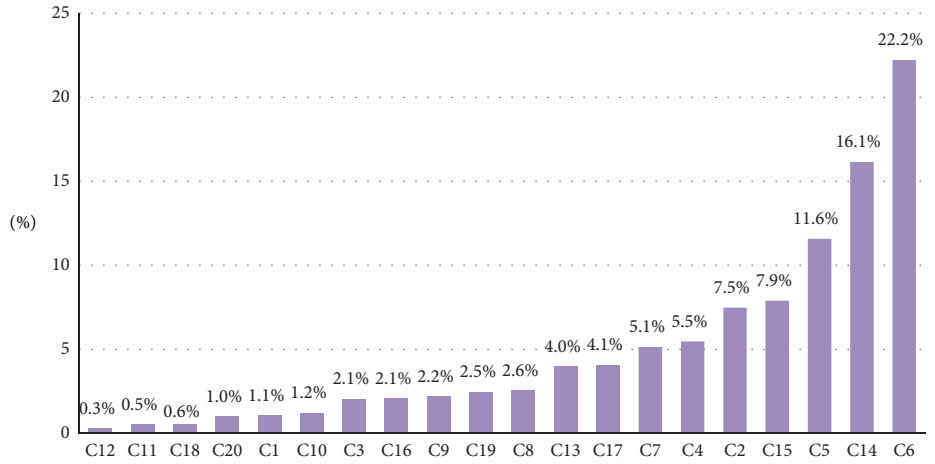

Figure 4: Total ranking of indicator weights of IEE performance evaluation.

$$\lambda_{\max} = 4.162, \quad \text{CI} = 0.054, \text{CR} = 0.060. \tag{7}$$

$$\lambda_{\max} = 4.102, \quad \text{CI} = 0.034, \text{CR} = 0.038. \tag{8}$$

$$\lambda_{\max} = 4.059, \quad \text{CI} = 0.020, \text{CR} = 0.022. \tag{9}$$

6. Results and Discussion

Through the above calculation results, it is not difficult to see that the judgment matrix CR given by experts is less than 0.1; that is, the results are effective by calculating the matrix, and the index weight is as Table 9. From the overall analysis of the performance of IEE in all kinds of colleges and universities, we find that the evaluation value of IEE performance indicators is high, indicating that the overall IEE in the school is in good condition and has long-term stable development ability.

It can be seen from Table 9 that teaching condition and quality account for 72.5% in the first-level indicators, which is good in the performance evaluation of IEE in universities. However, the teaching environment, financial capital, and teaching satisfaction are poor in the performance evaluation of IEE in universities, especially the financial funds, which is only 0.035. It shows that the key to improve the level of IEE in all kinds of colleges and universities is to improve the teaching environment, increase financial investment, and improve social satisfaction with IE teaching.

Figure 4 can be drawn by calculating and sorting the proportion of each secondary index. It can be seen from the chart that the number of IE courses accounts for the highest

proportion, followed by the number of IE disciplines and the proportion of teachers with entrepreneurship training qualification to all entrepreneurship education teachers. However, the support rate of parents for entrepreneurship of students and the proportion of students' self-financing in total venture capital are relatively weak; in particular the weight of the annual return on student entrepreneurship projects is only 0.003. It shows that, in the development process of IEE in all kinds of colleges and universities, more attention is paid to teaching conditions and teachers, and the importance of capital investment and teaching feedback needs to be improved.

7. Conclusions and Suggestions

At present, the country vigorously promotes innovation in major industries including education, and the evaluation requirements of its innovation performance are more stringent. However, the existing performance evaluation of IEE in all kinds of colleges and universities generally lacks objectivity, which has great limitations. Therefore, based on the connotation of IEE, this study establishes the performance evaluation system of IEE in all kinds of colleges and universities. Then this paper uses the advanced AHP to determine the index weight and takes China as an example to verify the rationality of the index system. The evaluation results show that the teaching environment, financial capital, and teaching satisfaction are the key factors to improve the level of IEE in all kinds of colleges and universities in the future. However, the development level of IEE in universities is not high, and the support rate of parents and enterprises for students' entrepreneurship is low. And the annual return rate of students' entrepreneurial projects is far from enough. It shows that the road of IEE in major colleges and universities has a long way to go.

In the future, the evaluation index system for the performance of IEE in all kinds of colleges and universities can be constructed from more aspects, and the combination weight can be determined by the weight calculation method combining qualitative and quantitative methods, so as to evaluate the performance of IEE in all kinds of colleges and universities more scientifically.

According to the theory of performance management, performance improvement should be carried out according to the actual situation after performance evaluation. Therefore, based on the evaluation and analysis of the performance of IEE in all kinds of colleges and universities, this paper puts forward suggestions to promote the project to be truly implemented from the theoretical level to the practical application. Specifically, the level of IEE can be improved from the following three aspects.

7.1. Building a Multichannel IEE Platform. The factors affecting students' learning effect are multilevel and multiangle. The adaptability of teaching methods and the integrity of teaching platform play a fundamental role in students' learning effect. However, the construction of IEE platform is insufficient, and there is still room for improvement and optimization. In view of this, the IEE platform can be optimized from the following two aspects in the future. First, under the existing resources of colleges and universities, schools can use new media technology to combine modern teaching methods with traditional education contents and methods to build a curriculum system that is more closely related to entrepreneurial practice. When developing students' innovation and entrepreneurship, we invite elites in various fields or authoritative experts in corresponding fields to share in order to achieve the desired results. Second, it is conducive to promoting close communication among many universities by using the Internet to build a national entrepreneurship education platform. The current Internet has been rapidly popularized. We make full use of this platform to develop application software and share high-quality video courses in major universities to students. It can not only realize students' fragmented learning of IE knowledge, but also realize the general education of IE.

7.2. Encouraging and Supporting Policies for Entrepreneurship of College Students. At present, the supporting mechanism for university entrepreneurship is not perfect. For this situation, the government should formulate policies according to the results of the investigation and study and increase the project support of college students' IE, so as to stimulate the enthusiasm of college students' IE. At the same time, universities should actively cooperate with the government. Specifically, governments and schools can improve the supporting capacity of safeguards from the following three aspects. First, the government's policies are cleverly combined with the current thriving new media to promote policy popularity, so as to improve the success rate of the implementation of IEE projects in all kinds of colleges and universities. Second, the government should pay more attention to the stimulation of college students' enthusiasm for IE and the support of projects, rather than staying in the theoretical teaching. It should enable entrepreneurial students to obtain practical benefits, such as tax deductions, loan guarantees, guiding services, and subsidies for corresponding start-up funds. In addition, certain financial rewards should be given to enterprises that have achieved certain success. Third, universities should take the initiative to strengthen the contact and docking with relevant government departments, including education, industry and commerce, tax, labor and employment departments. At the same time, universities should also strengthen ties with regional IEE institutions.

7.3. Increasing Resources Investment to Improve the Quality of IEE Projects. There are many factors affecting the implementation of IEE projects in all kinds of colleges and universities. The construction of curriculum system and the ability of teachers play a key role. Therefore, educational authorities at all levels and universities should increase investment in resources. On the one hand, universities should invite teachers with rich internal experience or practical business experience of enterprises and professional forces from professional training institutions, so as to systematically discuss the training scheme, curriculum design,

teaching content design, teaching material compilation, and teaching form. At the same time, major colleges and universities should strengthen the investigation and communication of students by listening to students' voice. It is beneficial to promote the goal of education project formulation and the curriculum content is also the condition of students' actual needs. On the other hand, universities should provide more opportunities for full-time teachers to participate in professional practice in off-campus institutions, so that more teachers can truly participate in the whole process of enterprise operation. And universities can encourage teachers to participate in the entrepreneurial practice of enterprises, so that they can understand the actual needs of students and improve the performance of education projects.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Research on the Construction of Accounting Informatics System and Risk Assessment Method in Big Data's Era

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The traditional financial informatics administration system risk assessment method in the evaluation of system risk can deal with less data throughput, and the system risk assessment effect is not good, so the study of the financial informatics administration system of the risk assessment method under the background of big data is a necessity. The method sets logical nodes according to system modules and builds risk estimation models by finding logical relationships between data. Based on the big data background, according to the utility theory and the risk preference function estimation, choose the big data batch calculation and streaming calculation methods to calculate the system programme risk index and financial data faithless risk index. According to the risk residual value, the probability of a system function failure in the main module and submodule of the system is adjusted, and the risk level is defined by the exponential function to realize the system risk estimation under the background of big data. Experimental results show that compared with the two traditional system risk estimation methods, the proposed method has a larger data throughput and a wider range of risk indicators. It can be seen that the proposed method meets the risk estimation requirements of the enterprise financial informatics administration system.

1. Introduction

The growth of informatics technology and the advent of the big data's era provide a more convenient informatics resource sharing platform for accounting informatization, promote the growth of accounting informatization, reduce the cost of accounting informatization construction, and greatly enhance the efficiency of accounting work [1–3]. However, accounting informatization involves not only technical content but also administration and other aspects. Especially in big data's era, with the rapid growth of accounting informatization, there are also many risks. Through the evaluation of accounting informatization big data's era, the main risks of accounting informatization can be identified, and then targeted countermeasures can be taken to enhance the success rate and application effect of accounting informatization [4]. In big data's era, accounting informatization has become a hot issue for scholars. The financial administration system is the growth direction of the financial field. The system uses advanced data entry, data processing, and data storage methods to realize the real-time synchronous processing of various financial data of enterprises [5, 6]. With the continuous improvement of the national economic system, the economic benefits of various types of enterprises in society are improved, and the industrial results have made a qualitative leap, which makes the volume of financial data huge.

There are many kinds of data, resulting in the formation of the current big data model in the financial field. Big data are a new concept that has attracted much attention in recent years. By discovering a large number of data features with complex sources, we can capture the correlation between data and analyze various data indicators [7].

Facing the new characteristics of the current financial data, when assessing the risk safety of the enterprise's financial informatics administration system, abandon the original traditional random sampling analysis and investigation method to process the data and process all the financial data and informatics of the enterprise in a large number, high-speed, diverse, and low-density value in a

diversified form, so as to accurately grasp the system risk and timely maintain the security of risk module to ensure the security of enterprise financial informatics [8]. The emergence of this estimation method reduces the pressure of risk administration and control of enterprise financial managers and provides a reference for other informatics administration departments.

2. Overview of Financial Informatics Administration System and Big Data Era

2.1. Financial Informatics Administration System. A financial informatics administration system is an organized and modular operation of data analysis, prediction, planning, monitoring, and other links in financial administration with the help of modern informatics and network technology [9–11]. According to the program structure widely used in current society, it can be divided into five parts: organization interconnection, accounting transaction processing, financial administration, financial decision-making, and financial supervisor. In the actual operation process, the financial informatics administration system is to implement the statistical regulation of financial informatics according to the general process of financial data manipulation.

2.2. Big Data Era. Big data refer to the confluence of huge amount of data. That is, an informatics transportation system with real-time characteristics is constructed in the form of multiple forms and the collection of informatics sources from many channels [12]. The era of big data is an effective quantitative communication environment built under the social background of expanding social informatics demand structure. Taking the enterprise financial informatics system as an example, the characteristics of the current big data era can be summarized as follows. (1) Large amounts of data: the financial informatics system big data's era contains informatics resources in the early, middle, and late stages of the enterprise with rich informatics content. (2) Low-value density and fast renewal: the informatics in the enterprise financial data administration system is updated almost all the time, and the data between the new data and old data are covered and connected at the same time. In other words, the arrival of the big data era provides a good informatics environment for the long-term growth of industry resources.

3. Risk Assessment of Financial Informatics Administration System under the Background of Big Data

Although the financial informatics administration system has been widely used in the growth of contemporary enterprises, there are many risks in program manipulation under the background of big data. Putting forward countermeasures for hidden dangers is a condition to reflect the value of resource administration in the big data's era.

3.1. Organization Interconnection Risk Assessment. The organization interconnection link in the financial administration informatics system is mainly used for informatics transmission and interaction between internal organizations and enterprises. It is a channel to ensure the interconnection of informatics in various fields of enterprise financial administration. With the gradual increase of informatics big data's era, strengthening the discrimination between true and false informatics connectivity links in the system has become the main aspect of effective risk prevention.

Figure 1 shows the curve distribution of the accounting risk coefficient under different flows of big data's era [13]. For example, in the process of using the financial informatics administration system for statistics, in order to ensure the long-term promotion of financial administration, the methods implemented by financial managers in the organization interconnection module are as follows. (1) Always adhere to the financial data administration arrangement, which is based on the current business state of the enterprise, to ensure the mutual regulation and arrangement of internal informatics of enterprise financial administration. (2) For asset operation-related informatics from the same industry and market environment, the method of multiparty comparison and confirmation is adopted to evaluate the financial informatics administration. (3) Form a big data informatics filtering structure, do a good job in the overall administration of financial informatics administration informatics in various fields in an orderly manner, and realize the coordinated undertaking of the two parts of financial informatics reception and integration based on reasonable resource administration methods.

When the financial administration informatics system is applied in the big data environment, the risk protection of informatics interconnection and communication links can avoid the imbalance of financial capital arrangement caused by the confusion of true and false informatics. It protects the security problems from the interactive channel of financial administration informatics.

3.2. Accounting Transaction Risk Assessment. Accounting transaction processing is mainly to provide enterprises with accurate and timely financial informatics to ensure the efficiency of financial administration [14–16]. During the practical operation of financial informatics administration system in the big data's era, on the one hand, the system operation should skillfully give play to the role of big data technical means to sort out and process financial data so as to ensure the optimal arrangement of internal capital of enterprises; on the other hand, it is to adjust the process of accounting transaction processing to avoid the confusion of data programme informatics manipulation process, so as to avoid the risk of financial informatics administration. The mathematical form of the weight of each correlation function is as follows, where λ is the characteristic root of A and W represents the vector:

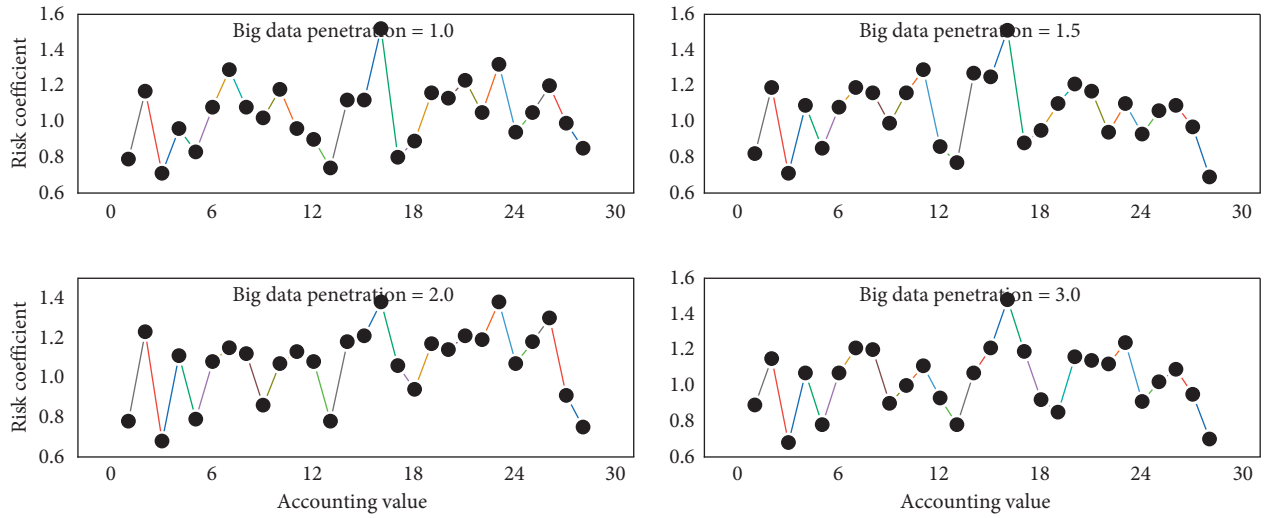

Figure 1: The curve distribution of accounting risk coefficient under different flows' big data's era.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \text{ or } A = \left[a_{ij}\right], i, j = 1, 2, \dots, n,$$

$$AW = \lambda W,$$

$$W = (W_1, W_2, \dots, W_n),$$

$$\lambda_{\max} = \sum_{1}^{n} \frac{(AW)^i}{nW_i}. \tag{1}$$

For example, in the process of an enterprise using the financial informatics administration system for capital administration, in order to meet the needs of contemporary social growth, the system application personnel summarized the key points of risk prevention in the system application as follows. (1) When operating the financial informatics administration system every day, start the program backup system at the same time to back up the daily enterprise financial update informatics and analyze the risk control mode from the application data link of the program. (2) Six per compartment, 12 months: update the financial informatics administration system applied in the enterprise and clean up the program garbage independently to ensure the internal informatics extraction rate of the program.

The risk prevention of the processing module of the financial informatics administration system is to analyze the manipulation from the perspective of the external factors of the manipulation program. The proper arrangement of the work of this link can reduce the hidden dangers in the field of external manipulation and reflects the safe application form of contemporary financial informatics administration system.

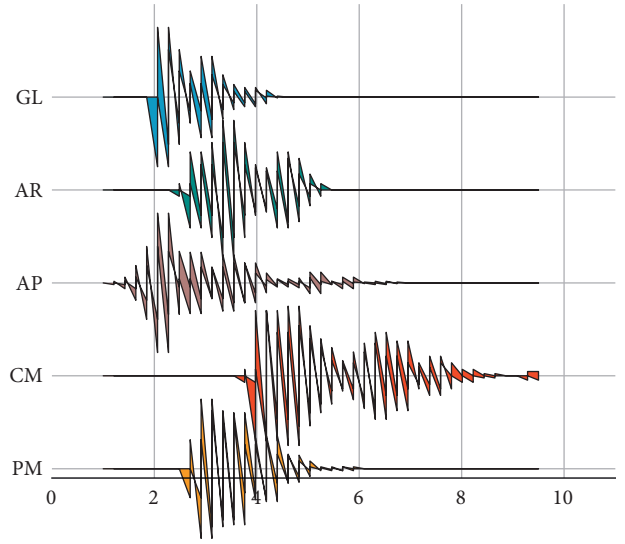

Figure 2: The curve distribution of VaRin different accounting departments.

3.3. Financial Administration Module Risk Assessment. The financial administration module is to record and analyze various account fields in enterprise finance in detail. Therefore, during the subsequent risk assessment of the financial administration module, it is necessary to conduct a detailed risk adjustment of the financial administration module from the aspects of general ledger [15], receivable and payable accounts [16], cash administration [17], project administration, employee salary, fixed asset administration, etc. The curve distribution of VaR in different accounting departments is illustrated in Figure 2. For example, when an enterprise uses the financial informatics administration system for internal asset administration, in order to reduce the hidden dangers in the field of enterprise asset administration under the big data environment, the risk

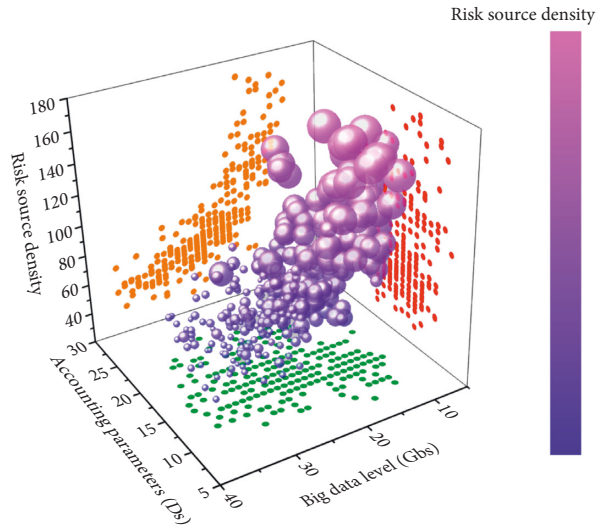

Figure 3: Three-dimensional scatter diagram between the density of accounting risk sources, accounting and financial parameters, and the big data level.

assessment of the financial administration module is carried out in combination with the specific application status of the system. (1) Do a good job in the general ledger administration of financial informatics. General ledger informatics includes accounts receivable, cash flow changes, fixed asset structure, and other aspects and uses the big data virtual analysis framework to track all data for informatics statistics and implement risk prevention in the fields of the integrity of financial informatics administration [18]. (2) The accounts receivable part mainly focuses on the risk protection of enterprise arrears, paid accounts, and customer informatics accounts; in the part of cash administration, the enterprise focuses on judging the changes of daily cash flow and project cash flow; fixed assets' administration is to analyze the operation of real estate, equipment, and other funds in the operation of enterprises. The mathematical form of the weight of each U correlation function is as follows:

$$U = \{U_1, U_2, U_3, U_4, U_5\}. \tag{2}$$

In the context of big data, the scope and form of enterprise financial resource administration are gradually increasing. Enterprises must comply with the basic practice trend of procedural manipulation in the big data environment [19–21]. However, in order to reduce the problems in the application of the financial informatics administration system, it is necessary to implement a targeted response to risk problems for each financial administration link. This process can solve the operation problems of the financial administration module in time, so as to reduce the crisis index in enterprise financial informatics administration.

3.4. Financial Decision Support Risk Control. The risk control of the financial decision support link is also the leading strategy of risk regulation in the application of financial informatics administration system under the big data environment. The financial decision support link is mainly the enterprise financial data analysis based on the enterprise financial statement data. It can use the financial capital data decision-making using + VBA, lightship, and other tools based on the finance, business, and external data of each link. The financial informatics administration system of this part has well realized the factor control of enterprise long-term operation analysis. The mathematical form of the weight of each U correlation function is as follows:

$$\begin{aligned} \mathrm{CR} &= \frac{\mathrm{CI}}{\mathrm{RI}}, \\ \mathrm{CI} &= \frac{\lambda_{\max} - n}{n - 1}, \\ \sum_{1}^{n} \sum_{1}^{m} W_j b_{ij} &= 1. \end{aligned} \tag{3}$$

Figure 3 shows a three-dimensional scatter diagram between the density of accounting risk sources, accounting and financial parameters, and big data level [22]. For example, in big data's era, an enterprise carries out capital administration with the help of financial informatics administration system. In order to reduce the problems in program administration, it not only controls the elements from the financial program informatics administration part but also analyzes the key points from the field of financial decision support control. (1) Create a program automation connection between the financial data decision-making risk prevention and control system. Whenever the project, structure, and other aspects of the enterprise need fund application or analysis, the technicians need to formulate the financial administration plan in the early stage and implement the tracking analysis of the content of financial decision-making according to the preliminarily evaluated risk prevention and control needs. (2) When all data links of the financial decision-making part are subject to risk control, the financial decision support risk control part needs to test the accuracy of the data in the statement. Once there are errors in the data in the statement, the risk prevention and adjustment of financial data should be carried out immediately.

In the big data's era, the control of financial informatics administration system lies in risk prevention from the application and supervision of enterprise financial informatics administration data in combination with the actual situation of the enterprise operation, and then a good job is done in risk control in the planning and evaluation stage of the financial informatics administration system [23].

3.5. Finance Officer Risk Assessment. The chief financial officer's informatics risk assessment is mainly to prevent risks from the perspective of financial informatics administration system operators in the big data environment. First, strengthen the attention of enterprise financial managers to the prevention of program application risk and then create a new financial supervisor informatics system with multiple aspects of regulation and control by improving the ability of individual program manipulation and standardization, actively upgrading the equipment of financial informatics

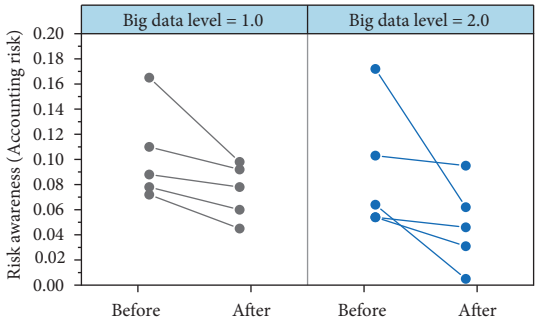

Figure 4: Relationship curve between risk awareness and accounting meaning ratio under different big data.

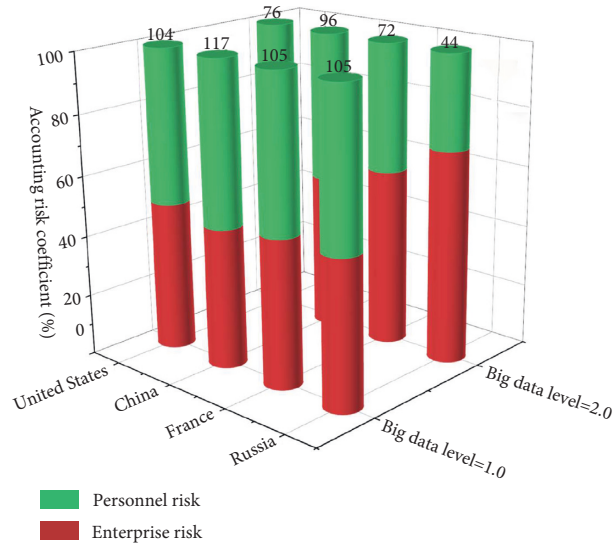

Figure 5: Relationship curve between risk awareness and accounting meaning ratio under different big data.

administration system and introducing the concept of modern financial informatics administration [24]. Second, the financial supervisor's informatics risk control link is to do a good job in the supervision of each link of the financial informatics administration system in the enterprise in combination with the specific situation of the enterprise's operation. For example, during the period when enterprises implement the risk prevention of financial informatics administration system in the big data environment, on the one hand, enterprises carry out risk prevention by formulating the informatics supervision system of a financial supervisor. On the other hand, they realize the effect of risk supervision in the application of the financial informatics administration system by setting program control standards and irregularly sampling and checking various parts of financial administration informatics.

3.6. Dynamic Transformation of Financial Informatics Risk Awareness. The growth of operational risk assessment of financial informatics administration system under the big data environment should also be reflected in that managers and should form a dynamic risk awareness. On the one hand, in the big data's era, informatics changes rapidly, and the correlation, linkage, and coordination between informatics are relatively high. If enterprises/individuals simply grasp the key points from the perspective of the financial informatics administration structure, there will be risk assessment work, which cannot achieve the practical state of prevention [25–27]. On the other hand, in the systematic arrangement of the work of the financial informatics administration system under the big data environment, it is necessary to convert the planar risk assessment into a flat risk control form. Otherwise, during the operation of the financial informatics administration system, it is naturally unable to achieve the analysis trend of controlling the financial informatics risk assessment.

Figure 4 illustrates relationship curve between risk awareness and accounting meaning ratio under different big data. For example, in order to evaluate the risk of the financial informatics administration system in the big data environment, an enterprise mainly carries out the dynamic transformation of administration elements from the level of financial risk awareness. (1) During the operation of the financial informatics administration system, make full use of Excel financial statements and other data resources to build the personnel production raw materials. The widespread application of financial statement data structure in many aspects such as operation cost provides a basis for exploring good information system supervision. (2) The risk assessment structure of the financial informatics administration system in a big data environment needs continuous real-time online update processing, so as to realize the effect of multidimensional risk prevention of the financial informatics administration system. In the big data environment, it is an orderly risk assessment scheme to adjust the interrelated financial risk assessment methods of the financial informatics administration system.

4. Construction of Accounting Informatization Risk Index System in Big Data's Era

This study mainly measures the risk factors of accounting informatization big data's era from the following aspects:

(1) Risk of accounting informatization sharing platform: in the big data's era, the focus of accounting informatization is the sharing of relevant informatics. However, at present, the growth of accounting informatization in China is slow, and insufficient attention is paid to the construction of the accounting informatization platform [28]. The accounting informatization sharing platform cannot meet the requirements of flexibility, adaptability, and expansibility of informatics sharing platform. It also causes the construction risk of the accounting informatics sharing platform.

(2) There are risks in the accounting informatics system software itself: compared with the growth level of foreign accounting informatics, the construction of accounting informatics in China started late and developed slowly, resulting in many internal risks in

the accounting informatics system software. In big data's era, software upgrading is fast, but the R & D cycle is long and the cost is high, which will also cause risks in the accounting informatics system software itself.

(3) Security risk of accounting informatics system: the growth of network technology provides an opportunity for some hackers and criminals to use system vulnerabilities to attack the informatics system. Figure 5 shows the relationship curve between risk awareness and accounting meaning ratio under construction of the accounting informatization risk index system in the big data's era. Especially, in big data's era, with the deepening of accounting informatization, more and more accounting businesses rely on informatization means, which further increases the security risk of the accounting informatics system.

(4) Risk of imperfect accounting informatization standards and regulations: the XBRL series of national standards and expandable business reporting language based on accounting standards issued by the Ministry of Finance (XBRL) general classification standard is deficient in publicity and practice. Moreover, at present, the accounting informatics law has not yet been issued, and the imperfection of relevant laws and regulations is also an important factor causing the risk of accounting informatization.

(5) Risk of cloud accounting service providers: in big data's era, due to the huge amount of data, for enterprises, a large part of the construction of accounting informatization depends on the services provided by cloud accounting service providers. Once the professional level or after-sales service quality of cloud accounting service providers fails, it will bring great risks to the construction of enterprise informatization.

(6) Enterprise personnel risk: the quality of accounting operators is very important in the process of enterprise accounting informatization construction, but at present, the level of accounting operators is low, and enterprises lack compound talents proficient in technology and professional knowledge. Especially in big data's era, the requirements for accounting operators are higher, which further increases the growth risk of accounting informatization.

(7) Accounting informatics risk: in big data's era, the magnetic medium mainly relied on for data storage in the accounting informatics system which is very vulnerable to the external environment (such as external magnetic field) [29], and there is informatics that is not controlled by the enterprise, which will cause the risk of data distortion and loss. In this case, employees' attention to accounting informatics and enterprises' audit of accounting informatics will also affect the size of accounting informatics risk.

(8) Enterprise administration risk: in big data's era, there are a large amount of data, fast change speed, and many formats, which makes the current informatics processing technology unable to effectively manage data, increasing the difficulty and risk of enterprise administration. In addition, some enterprises, especially small- and medium-sized enterprises, due to insufficient funds and other reasons, pay insufficient attention to the construction of accounting informatization, lack of maintenance funds, and maintenance technology, which will also cause the risk of accounting informatization.

(9) New informatics island risk: it mainly refers to the risk that informatics cannot be shared and exchanged [30]. However, in big data's era, the problem of nonsharing and exchange of informatics will be solved, and the corresponding risk is the risk of new informatics island, that is, the phenomenon that the accounting informatics system cannot be effectively integrated with other informatics systems of the enterprise.

(10) Industry competition risk: the convenience of the big data's era makes the competition in the accounting informatics industry generally exist in the process of market growth. Unfair industry competition, such as hiring network hackers and other illegal intrusions into the competitor's informatics system, stealing and spreading the competitor's accounting informatics on the network, and disclosure of secrets by employees within the enterprise, will be a great blow to the competitor. Therefore, the insufficient internal control of enterprises can easily lead to the risk of industry competition.

5. Influencing Factors of Enterprise Accounting Informatization in Risk Big Data's Era

In the growth of accounting informatization, the stability of the platform, data encryption loopholes, authentication defects, and other problems will bring certain risks to accounting informatization.

5.1. Self-Construction of Informatics Platform Construction and Growth of Accounting Informatization. A large amount of public resource informatics sharing platform support is needed. For example, the growth of cloud accounting needs the support of a cloud computing platform. Cloud computing has strong scalability. A large number of users provide resource convenience for cloud computing providers. At the same time, the scale effect also reduces the cost of software services. Traditional software only needs to investigate and analyze the needs of customers and finally provide a set of financial software according to the

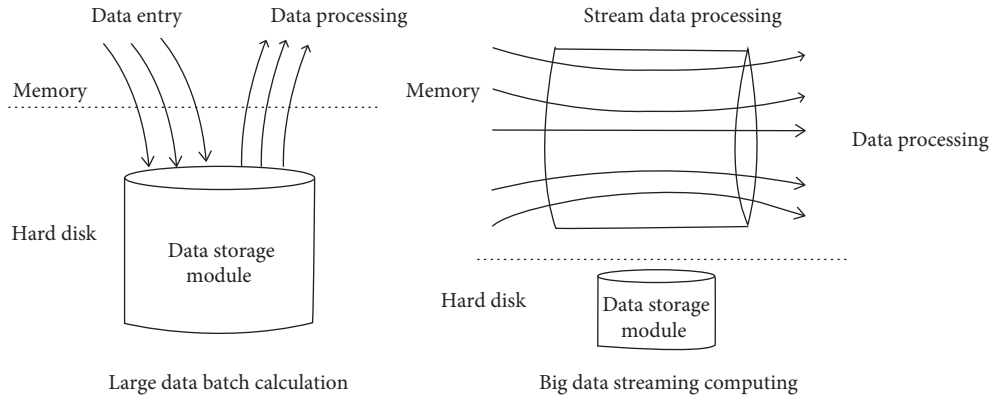

Figure 6: Calculation model of the accounting risk index.

requirements of customers. However, cloud computing faces different industries and businesses, so it is more difficult to build than traditional software. It has stronger adaptability, higher flexibility, wider scalability, and stricter technical standards. Therefore, the construction process of a cloud computing platform takes a long time, costs a lot of money, requires high skilled technicians, may be developed for a long time, and finally declares failure. At present, foreign cloud computing platforms are more advanced than domestic ones. The cloud computing platforms of companies such as Google are already in the lead, and Microsoft and other companies also have their own cloud computing platforms. The cloud computing platform just developed in China is based on accounting informatization. Many technological processes are not mature, some small problems will appear in the operation process, and the promotion effect is not very good. The cloud computing technology is more advanced abroad than at home, but domestic enterprises are unwilling to store all kinds of informatics on foreign cloud computing platforms. The research and growth of cloud computing platforms in China lag behind, which also directly affects the growth of cloud accounting in accounting informatization.

5.2. Informatics Data Use Security. Many enterprises are reluctant to store accounting data on the public cloud platform, mainly because they are worried about the security of data. When building the cloud accounting informatics system, we should consider the security factors from the following an aspect. One is the identity authentication during login. The informatics system is set manually. He only recognizes the login mode set in the program, so the problem of identity authentication is related to the security of the whole informatics system [31, 32]. The accounting informatics system is a part of informatics system. It also needs identity authentication to ensure the security of informatics. At present, the authentication methods used in the informatics system mainly include user name and password, key, dynamic password board, and fingerprint or face recognition system. However, the authentication method adopted by the accounting informatics system, especially the cloud accounting informatics system, is user name and password. This authentication method is simple to use, but the security factor is too low, and it is easy to be intercepted by Trojan horse programs. Figure 6 illustrates the calculation model of the accounting risk index for informatics data use security.

In addition, because some operators do not pay enough attention to identity authentication, they often use their birthdays or telephone numbers as the operation password. These two simple numbers are easy to be cracked. Some operators do not change the operation password all the year round and do not pay attention to avoiding the surrounding personnel when entering the operation password, which is easy to cause password leakage. The second is the problem of data encryption. In accounting informatization, cloud accounting data are transmitted through computer network. In the transmission process, the carrier of data is no longer paper, but other media.

There are many ways to confirm data. In this case, the security of cloud accounting is particularly important. The growth of accounting informatization in China has lagged behind, and the network accounting data encryption technology is also very immature. When developers develop network software, the setting of data encryption module is simple, and the focus of encryption is on software itself to prevent other manufacturers from stealing the software, while little investment is made in data encryption technology. Although the accounting personnel will be required to enter the user name and password when logging in the accounting software, this is only the setting of the operation authority of the software, not the setting of the data encryption program. When accounting data are transmitted in the network, there must be a certain encryption method to ensure the safe transmission of accounting data. If the data are not encrypted, it is easy to be intercepted by network hackers or competitors during network transmission, stealing the enterprise's financial data or changing the enterprise's financial data through specific virus software programs, so that the receiving department makes wrong decisions.

5.3. National Industrial Policy Standards. The arrival of big data makes many enterprises pay more and more attention to the growth of informatization. The administration mode

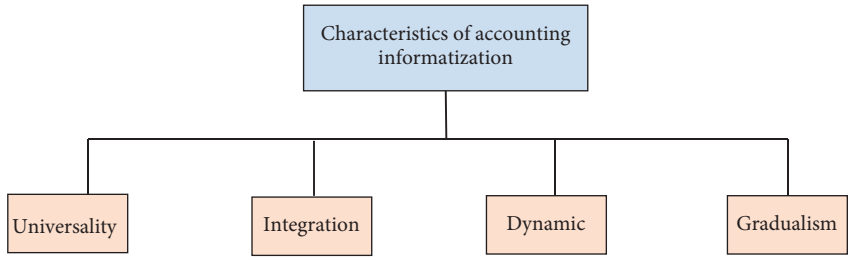

Figure 7: Characteristics of accounting informatization in policy standards.

of enterprises is gradually connected with informatization, and accountants also begin to accept cloud accounting, which is inseparable from the growth of the Internet. The rapid growth of the Internet is due to the use of unified standards all over the world. Accounting informatization is based on the Internet, and its growth should also follow the growth law of the Internet, so we must unify the technical standards of informatization construction [33]. The standards are unified, and the construction of accounting informatization will continue to develop with the growth of big data. If the standards cannot be unified, the construction of accounting informatization will be diversified, which will affect the growth of the whole industry and even disrupt the whole industry. In order to further standardize accounting informatization standards and promote the rapid growth of accounting informatization, the Ministry of Finance issued the extensible business reporting language (XBRL) general classification standard based on enterprise accounting standards five years ago.

Figure 7 shows characteristics of accounting informatization in policy standards. The promulgation of the standard has made the growth of accounting informatization a step further towards standardization. According to the arrangement of relevant national departments, the general classification standard of accounting standards will be first implemented in some enterprises. These enterprises are mainly some large- and medium-sized enterprises listed abroad and some accounting firms involved in securities and futures. At the same time, domestic listed companies and large- and medium-sized enterprises are also encouraged. However, this is a long process. If all enterprises want to implement XBRL, it needs to be further popularized and used. In addition to the accounting informatization standard is still in its infancy, China's legislation on informatics security has not been carried out. In big data's era, data are growing rapidly all the time. Enterprises transmit data informatics and financial informatics through the network, but it still lags behind in network financial supervision. Up to now, China has not promulgated any laws on informatics security, which makes enterprises unable to find appropriate laws to protect their legitimate rights and interests once they encounter informatics security violations.

6. Conclusion

To sum up, the risk estimation of financial informatics administration system under the background of big data is a theoretical induction of the integration of digital means in the enterprise capital administration structure. On this basis, this study explores the risk estimation method of the financial informatics administration system through the aspects of organization interconnection risk assessment, accounting transaction risk assessment, financial administration module risk assessment, financial decision support risk control, financial supervisor informatics risk assessment, and so on. Therefore, the research results of this study provide a new idea for the scientific regulation of domestic enterprise capital. In short, this study reveals the business and industrial economics of data economy in the era of big data. The development law of economic business integration is also a reference of the humanistic economic development view. One of the products of guiding the development of sharing economy is also to promote industrial economy and the digital economy. The integrated development of the Chinese economy provides a new accounting model.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Python-Based Visual Classification Algorithm for Economic Text Big Data

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In order to improve the classification accuracy and reduce the classification time of the economic text big data visualization classification algorithm, one based on the Pitton algorithm is proposed. The economic text big data are preprocessed by filtering out useless symbols, word segmentation processing, and removing stop words. According to the processing results, the most relevant features of the economic text big data classification process are selected, including Gini index, information gain, mutual information, etc., and the TF-IDF weighting algorithm is used to weight the economic text data features. Based on feature weighting, using Naive Bayesian algorithm, combining classification probability distribution and text probability distribution, Naive Bayesian classifier is constructed to obtain the optimal classification result through input vector, and the visual classification of economic text big data is completed through Python software programming. The simulation results show that the classification accuracy of the algorithm for the visual classification of economic text big data can reach 100%, and the classification time is less than 5 seconds. It has high accuracy and fast efficiency.

1. Introduction

With the rapid development and widespread application of information technology and the Internet, the Internet has gradually become an important channel for people to obtain information. The amount of various information data has exploded, and people have gradually moved from an era of lack of information to an era of information overload. Hundreds of millions of web text data are generated every second in the world. Internet users are often unable to quickly and effectively obtain the valuable content they need in the face of such massive text big data. In order to quickly obtain valuable text big data, these texts need to be classified. Therefore, the research and implementation of the text classification system are of great significance [1, 2]. Economic text is an important part of text big data, and it is also an important way for people to obtain information. The original text classification technology is done manually. Facing the exponentially increasing text information on the Internet, manual information extraction can no longer meet people's needs. This requires the use of the computer's ability to process information automatically, quickly, and in a large amount to provide users with quick and accurate access to valuable information [3, 4]. With the growing development of the Internet today, economic textual big data are no longer limited by the layout and length of paper media but present a huge amount of information and a wide variety of characteristics. Using computers to effectively filter and classify these economic data can quickly and efficiently obtain valuable information content, reduce human resource investment, and improve information use efficiency. The text classification technology can filter economic data in advance, classify the collected economic data, and generate a category economic database, which can facilitate users to browse the category information of interest and improve user experience. In short, text classification technology can help people filter and filter big data, which has more important research significance in real life [5].

Therefore, many experts and scholars have conducted a lot of research in the field of economic text processing,

forming a relatively mature technical system of economic text classification. The continuous development of economic text classification technology has become a branch of natural language processing. This technology is widely used in research fields such as information retrieval, information screening, and automatic abstract generation. Using these research results, users can quickly obtain the information they need from a large amount of complex economic text data and, at the same time, can eliminate information. In addition, in this fast-paced era, users need to quickly understand the main content of information, and economic text classification technology can refine this information to generate a summary. Literature [6] proposed a Chinese multilabel text classification method based on big data technology. First, the semantic information fusion method and fuzzy block fusion method were used to extract the semantic similarity features of Chinese multilabel text big data, and a big data analysis model of Chinese multilabel text was established. Second, the feature detection of Chinese multilabel text is carried out by using the statistical data feature extraction method. The semantic feature extraction model of Chinese multilabel text big data is built. The fuzzy C clustering analysis method is used to establish a fuzzy clustering model of Chinese multilabel text big data, and the multilevel feature information reorganization method is used to reconstruct the fuzzy feature of Chinese multilabel text big data. It is based on the semantic attribute characteristics of Chinese multilabel text. Feature reconstruction realizes Chinese multilabel text classification and big data fusion processing. However, this method has low accuracy in the visualization and classification of economic text big data, resulting in poor classification results. Literature [7] proposed a large data text classification method based on distributed NBC under the Spark framework. This method explores the Naive Bayes classifier (NBC) by studying the adaptability of the MapReduce and Apache Spark frameworks and studies the existing aspects. In the big data computing framework, the training sample data set is divided into m categories based on the Naive Bayes text classification model. In the training phase, the output of the previous MapReduce is used as the input of the next MapReduce, and four MapReduce jobs are used. The design process makes full use of the parallel advantages of MapReduce [8–10]. Finally, the class label value of the maximum value is taken out during the classifier test, and the experiment is performed on the Newgroups data set. The proposed method has higher classification accuracy than the comparison algorithm. However, the economical text big data visualization classification time of this method is relatively long, resulting in low classification efficiency [11, 12].

Aiming at the problems of the above methods, this study proposes a Python-based economic text big data visualization classification algorithm and verifies the effectiveness of the method through simulation experiments. The innovation point of this study is to use TF-IDF weighting algorithm to determine the feature weight of economic text data, which can accurately express text information, solve the problem of low classification accuracy of existing literature results, introduce Naive Bayes algorithm to classify big data of economic text, and improve the classification efficiency.

2. Python-Based Visual Classification of Economic Text Big Data

2.1. Python Software. Since all the processes of visual classification of economic text big data in this article are completed by Python software programming, the brief introduction of Python software is provided below.

The original meaning of Python is python. It was proposed by Guido van Rossum in 1989. It is an object-oriented, interpreted computer programming language. After its public release, it has been popular among program enthusiasts. Python is characterized by concise and clear syntax, is easy to read, has good scalability, and is an open-source software. Programmers do not need to have a deep programming foundation. The programming language is easy to understand and is very suitable for learning primary programming [13–15]. At present, many institutions at home and abroad, including schools, have gradually developed training and courses related to Python programming. Python can implement rich APIs and various scientific computing tools, so that even programmers who are accustomed to using C language, C++, and JAVA can easily get started and operate, and integrate their written packages in other languages into the python platform. In addition, the Python compiler itself can also be integrated into programs in other languages, hence the name "glue language" [16–20]. The scientific computing extension library dedicated to Python has also received a lot of praise, especially its 3 very useful extension libraries: Num Py, Sci Py, and matplotlib. Num Py is generally used to process arrays, and its processing speed is very fast; Sci Py can easily perform numerical operations; matplotlib can provide rich drawing functions [21–23]. More and more researchers are using python and its extension libraries to process experimental data, draw beautiful charts, and even develop some applications. In order to improve the visual classification efficiency of economic text big data, this study applies Python software, which processes data array and calculates the numerical value very fast [24].

2.2. Economical Text Big Data Preprocessing. For the obtained economic text, it needs to be preprocessed, and the initial economic text is expressed as a word sequence related to classification only. Different economic texts will undergo different preprocessing steps in the preprocessing process. The steps and methods of text preprocessing are as follows [25]:

2.2.1. Filter Out Useless Symbols. Usually, a complete economic text consists of basic content, symbols, numbers, letters, etc. According to the characteristics of the original economic text data, regular expressions are used to obtain

the text content, and only information useful for economic text classification is retained.

2.2.2. Word Segmentation. After processing the original economic text with useless symbols, the text needs to be processed by word segmentation. Chinese word segmentation refers to the division of a sentence into independent words or words [26]. Word segmentation is the process of recombining consecutive words or words into word sequences according to certain rules. Text segmentation is one of the important steps in the process of text classification. It has attracted a large number of researchers to study word segmentation algorithms and has achieved some good results in the field of word segmentation. The commonly used word segmentation algorithms are as follows:

Segmentation Based on String Matching. The segmentation dictionary is the basic condition for string segmentation, and then the entries in the dictionary are compared with the strings in the text. If the result of the comparison is true, it means that the string can be divided from other content and can be used as a word or phrase in the text. If the result of the comparison is false, it cannot be used as a word or phrase in an economic text and cannot be divided. The word segmentation has low time complexity and is easy to understand, but if there is no corresponding word or phrase in the word segmentation dictionary, it cannot be segmented [27, 28].

Statistics-Based Word Segmentation. If the word segmentation is to realize the model construction of Chinese, it needs the part-of-speech and statistical characteristics of manual annotation as the basic conditions. When the model is built, the next word segmentation operation is performed, and the probability of each word can be calculated by the constructed model, and the word with the highest probability value is used as the final word segmentation result. The advantage of this word segmentation is that it overcomes the shortcomings of word segmentation for string matching, whereas the disadvantage is that it requires manual labeling for the construction of the model, which limits the use of the word segmentation and requires relatively high time complexity.

Word Segmentation Based on Comprehension. The principle is to analyze the grammar and semantics of words simultaneously during the word segmentation operation, and it is indispensable for the syntactic and semantic information to eliminate the phenomenon of word ambiguity. Three interrelated subsystems constitute the whole part of the word segmentation system. To determine whether a word segmentation is ambiguous, it needs to be based on the syntactic and semantic information of words and sentences obtained by the word segmentation subsystem under the coordination of the general control part. When the generality and complexity of language knowledge have not been solved, the technology of word segmentation based on understanding is currently at an immature stage [29].

The word segmentation tool in this article is the ICTCLA word segmentation system developed by the Chinese Academy of Sciences through which the text segmentation operation is performed. This is because ictcla word segmentation system can automatically find new feature languages from the text content based on information cross entropy and then adaptively test the language probability distribution model of corpus to realize adaptive word segmentation. The word segmentation system has a high accuracy of word segmentation and high applicability of word segmentation. Even if the word segmentation dictionary does not correspond to this sentence, it can segment words according to the characteristics of words and sentences, and the time complexity of word segmentation is low and easy to understand. Therefore, it solves the limitations of the above word segmentation methods.

2.2.3. Get Rid of Stop Words. The content of an economic text is generally composed of verbs, nouns, adjectives, and other words, but it also contains many functional words, also called stop words, which do not contain textual information. Stop words can be divided into two categories: (1) this type of word is widely distributed and often appears in all types of text, resulting in the word's inability to distinguish text categories. For example, the word "we" exists in many types of texts, so this type of word cannot be used as an information word representing related categories. (2) Some function words such as prepositions, adverbs, conjunctions, and modal particles, such as "ah" and "being" are included. Filtering out these words with no actual meaning will improve the accuracy of the later text classification. In order to improve the accuracy, the feature words participating in the economic text classification cannot contain stop words, so it is necessary to delete the stop words. By comparing the words in the stop vocabulary list with the words in the text vocabulary set after word segmentation, if the word does not exist in the stop vocabulary list, then the word is regarded as the text content; otherwise, it is deleted [30].

2.3. Text Feature Processing

2.3.1. Text Feature Selection. Feature selection of economical text data refers to the process of constructing the minimum and best feature sets that can represent the original text through specific methods without changing the original spatial attributes. In feature selection, we need to try to identify the features that are most relevant to the classification process, because some words are more likely to be related to category distribution than others. Therefore, it is necessary to determine the most important features in the classification and define the category contribution function of feature words, including Gini index, information gain, mutual information, etc. [31].

(1) Gini Index. One of the most commonly used methods to quantify the level of feature recognition is to use a measurement method called the Gini index. $p_1(w), p_2(w), \ldots, p_k(w)$ represent the percentage of class tags of k different classes of word w. In other words, $p_k(w)$ is the conditional probability that the document belongs to the

i th category, provided that the document contains the word w. Therefore, there is

$$\sum_{i=1}^{k} p_i(w) = 1. \tag{1}$$

Then, $G(w)$ represents the Gini index of word w is defined as follows:

$$G(w) = \sum_{i=1}^{k} p_i(w)^2. \tag{2}$$

The value of Gini coefficient $G(w)$ is always in the range of $(1/k, 1)$. The greater the value of the Gini coefficient $G(w)$ is, the greater the recognition power of w is. For example, when all documents containing the word w belong to a particular class, the value of $G(w)$ is 1. On the other hand, when documents containing word w are evenly distributed among k different classes, the value of $G(w)$ is $1/k$. One comment of this method is that the global class distribution may be biased from the beginning, so the above-mentioned metrics may sometimes not accurately reflect the discriminative ability of the underlying attributes. Therefore, in order to reflect the discriminative ability of attributes more accurately, a normalized Gini index can be constructed. $p_1(w), p_2(w), \ldots, p_k(w)$ represent the global distribution of documents in different classes, and then the normalized probability value $p_i'(w)$ is determined as follows:

$$p_i'(w) = \frac{p_i(w)/P_i}{\sum_{j=1}^{k} p_j(w)/P_j}. \tag{3}$$

In the formula, P_j represents the Gini coefficient with j. These normalized probability values are used to calculate the Gini coefficient as follows:

$$G(w) = \sum_{i=1}^{k} p_i'(w)^2. \tag{4}$$

The use of the global probability P_i ensures that the Gini index more accurately reflects the difference between the classes when there is a deviation of the class distribution in the entire text collection. For a text corpus containing n texts, d words, and k classes, the information gain calculation complexity is $O(n \cdot d \cdot k)$, because it takes $O(n \cdot d \cdot k)$ time to calculate $p_i(w)$ for all different words and classes.

(2) Information Gain. Another commonly used text feature selection method is information gain or entropy. Suppose the document contains the word w, then let p_i be the global probability of class i, and $p_i(w)$ be the probability of class i. Let $F(w)$ be the score of the text containing w:

$$\begin{aligned} \mathrm{IG}(W) = &-\sum_{i=1}^{m} P(C_i)\log P(C_i) + P(W)\sum_{i=1}^{m} P(C_i|W)\log P(C_i|W) \\ &+ P(W)\sum_{i=1}^{m} P(C_i|\overline{W})\log P(C_i|\overline{W}). \end{aligned} \tag{5}$$

Among them, $\mathrm{IG}(W)$ represents the information gain IG value, m represents the total number of categories, C_i represents the i category, $P(C_i)$ represents the probability that the sample belongs to the C_i category in the sample set, $P(W)$ represents the probability that the text contains the noun W, $P(C_i|W)$ represents the probability that the noun W appears in the C_i category, and $P(C_i|\overline{W})$ represents the conditional probability that the sample belongs to the C_i category under the premise that the noun W does not appear. In the information gain, the larger the IG value is, the more important the feature item is, the more it can reflect the category information, and the more conducive it is to the classification. By setting the threshold, when the Ig of the feature item is greater than the preset threshold, the feature words are retained; otherwise, the feature words are eliminated. That is to say, when the new text comes in, the feature words and weight of the new text are determined, so as to reduce the dimension of the text vector.

(3) Mutual Information. Mutual information measurement is derived from information theory and provides a formal method for modeling mutual information between features and classes. According to the degree of co-occurrence of class i and word w, the pointwise mutual information $M_i(w)$ between word w and class i is defined. The expected co-occurrence of category i and word w on the basis of mutual independence is given by $P_iF(w)$, and the true co-occurrence is given by $F(w) \cdot P_i(w)$. In practice, the value of $F(w) \cdot P_i(w)$ may be much larger than $P_i \cdot F(w)$, or it may be much smaller, depending on the degree of correlation between the class i and the word w. There are two ways to determine the correlation of words. One is to determine the correlation by the ratio of the word and the class, and its calculation formula is as follows:

$$M_i(w) = \log\left(\frac{F(w)P_i(w)}{F(w)P_i}\right) = \log\left(\frac{P_i(w)}{P_i}\right). \tag{6}$$

The second method from the point of $M_i(w) > 0$ view, word w is positively correlated with i type, when $M_i(w) < 0$, word w is negatively correlated with i type. Note that $M_i(w)$ is specific to a particular class i. The overall mutual information needs to be calculated as a function of the mutual information of different types of words w. These are defined by using the average and maximum values of $M_i(w)$ on different classes:

$$\begin{aligned} M_{\mathrm{avg}}(w) &= \sum_{i=1}^{k} P_i \cdot M_i(w), \\ M_{\max}(w) &= \max_i\{M_i(w)\}. \end{aligned} \tag{7}$$

To determine the relevance of word w, you can use either of these two methods. However, the second measurement method is more effective in determining the positive correlation between word w and category. This is because it expands the type of words, calculates the mean and maximum values, and makes the measurement results more accurate.

2.3.2. Text Feature Weighting. This study uses the TF-IDF weighting algorithm to weight the features of economic text data. The term frequency-inverse document frequency (TF-IDF) is one of the most commonly used weighting algorithms. This method is usually used to measure the importance of words or words contained in a text to text. The main idea of TF-IDF is as follows: if a word or phrase appears more frequently than other words or phrases in the same text, but the word or phrase rarely appears in other texts, then the word or phrase is, it is believed to have a good ability to distinguish text categories. Its calculation formula is as follows:

$$tfidf_{i,j} = tf_{i,j} \times idf_i. \tag{8}$$

Among them, idf_i represents the probability that the feature item appears in the entire text set and $tf_{i,j}$ represents the number of times a word appears in the text, which is used to measure the ability of the word to express the text content. For a word in the text, its importance is expressed as follows:

$$tf_{i,j} = \frac{n_{i,j}}{\sum_k n_{k,j}}. \tag{9}$$

Among them, $n_{i,j}$ represents the number of occurrences of a specified feature item in the text, and the denominator represents the sum of the number of occurrences of each word or phrase in the text. The inverse document frequency is the inverse ratio of the frequency of the feature item in the text set, also called the inverse document frequency, which is used to measure the ability of the word to distinguish documents. The frequency of the reverse document of a specified feature item is related to the number of all texts and the number of documents containing the feature item. Based on the eigenvalues $G(W)$ and mutual information measures of the new text $M_i(w)$ obtained in the previous section, the IDF calculation formula for the feature item is as follows:

$$idf_i = \log \frac{|D|M_i(w)}{\left|IG(W)\left\{j\colon t_i \in d_j\right\}\right|}. \tag{10}$$

Among them, $|D|$ represents the total number of texts in corpus D, $\left\{j\colon t_i \in d_j\right\}$ represents the number of texts containing the word, t_i represents the i-th feature item, and d_j represents the j-th text.

2.4. Visual Classification Based on Naive Bayes Algorithm. This study uses the Naive Bayes algorithm to visually classify the economic text big data, because the main advantages of the Naive Bayes classifier are short training calculation time and high calculation accuracy, thereby improving the accuracy of the economic text big data visualization classification effectiveness. The Naive Bayes algorithm is a modular classifier under the known prior probability and class conditional probability. Its basic idea is to calculate the probability that document X belongs to class H. In Bayesian classifiers (also called generative classifiers), a probabilistic classifier based on the modeling of word features of different classes needs to be established. Then, the text is classified according to the posterior probability of the words appearing in the economic text and the text belonging to different categories. Naive Bayes is easy to implement and calculate. Its Bayes theorem formula is as follows:

$$P(H|X) = \frac{P(H|X)P(H)}{P(X)}. \tag{11}$$

Among them, $P(H|X)$ is the posterior probability where the feature term appears in the entire text set, which means the prior probability of reversing the document when H appears under condition X. $P(H)$ is the prior probability, which represents the prior probability of hypothesis H. The posterior probabilities in the text set contain more information than the prior probability household $P(H|X)$ that contains more information than $P(H)$

Naive Bayes is a statistical method in the form of probability. It is an estimation of a set of probability parameters. Its purpose is to combine the probability distribution of classification and text. It is based on Bayesian rules and relies on simple document representation. The best visual classification is selected through the input vector, and a Naive Bayes classifier is constructed to select the most likely category. It calculates the conditional probability of each category S_i of word w, where f_j is a feature in the context. The Naive Bayes classifier finds the class that maximizes the formula by choosing S as the most suitable class in the context:

$$\begin{aligned} S &= atg\max P\left(S_i|f_i, \ldots, f_m\right), \\ &= atg\max \frac{P\left(f_i, \ldots, f_m|S_i\right)}{P\left(f_i, \ldots, f_m\right)}. \end{aligned} \tag{12}$$

3. Simulation Experiment Analysis

In order to verify the performance of the Python-based economic text big data visualization classification algorithm proposed in this study in practical applications, through Python software programming, in the Win 10 operating system, in the python 2.7 development environment, the 2.7 ghz Intel Core i5 CPU and 8gb1867mhz DDR3 memory are simulated and analyzed.

This study selects several types of economic data that are familiar to people daily as the corpus. The content is the Sohu economic data training set provided by Sogou Lab. Seven types of data are selected to form their own corpus for analysis. Each category has 2000 documents. The basic information of the corpus is listed in Table 1.

The classification accuracy is based on the test results, and its expression is as follows:

$$P = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}}. \tag{13}$$

In the formula, TP represents the number of samples that correctly classify samples belonging to the positive class into the positive class, and FP represents the number of samples incorrectly classify the samples that belong to the negative class into the positive class.

Table 1: Basic information of the original corpus.

Document category	Number of documents
Agriculture	2000
Finance	2000
Consumption	2000
Output value	2000
Price	2000
Financial	2000
Currency	2000

Using classification accuracy as an experimental indicator, we adopt the Python-based economic text big data visualization classification algorithm proposed in this study, the Chinese multilabel text classification algorithm based on big data technology proposed in reference [6], and the distributed Chinese text classification algorithm proposed in reference [7], and NBC's big data text classification algorithm classifies the above-mentioned document categories and verifies the classification accuracy of the three algorithms. The comparison results are shown in Figure 1.

According to Figure 1, the document classification accuracy of the Python-based economic text big data visualization classification algorithm proposed in this study can reach up to 100%, while reference [6] proposed a Chinese multilabel text classification algorithm based on big data technology and literature [7] The document category classification accuracy of the proposed distributed NBC-based big data text classification algorithm is only 80% and 70%, which shows that the document category classification effect of the Python-based economic text big data visualization classification algorithm is better than that of the literature. Reference [6] proposed a Chinese multilabel text classification algorithm based on big data technology and the reference [7] proposed a distributed NBC-based large data text classification algorithm for document classification.

In order to further verify the effectiveness of the algorithm in this study, we adopt the Python-based economic text big data visualization classification algorithm proposed in this study, the Chinese multilabel text classification algorithm based on big data technology proposed in reference [6] and the Chinese multilabel text classification algorithm based on big data technology proposed in reference [7]. The document category classification time of the distributed NBC big data text classification algorithm is compared and analyzed, and the comparison result is shown in Figure 2.

According to Figure 2, the document category classification time of the Python-based economic text big data visualization classification algorithm proposed in this study is within 5 s. Reference [6] proposed a Chinese multilabel text classification algorithm based on big data technology, and the classification time of the proposed distributed NBC-based big data text classification algorithm is within 9 s [7]. The document category classification time of the Python-based economic text big data visualization classification algorithm proposed in this study is longer than that of the Chinese multilabel text classification algorithm based on big data technology proposed in reference [6] and the distributed NBC-based algorithm proposed in reference [7]. The document category classification time of the data text classification algorithm is short.

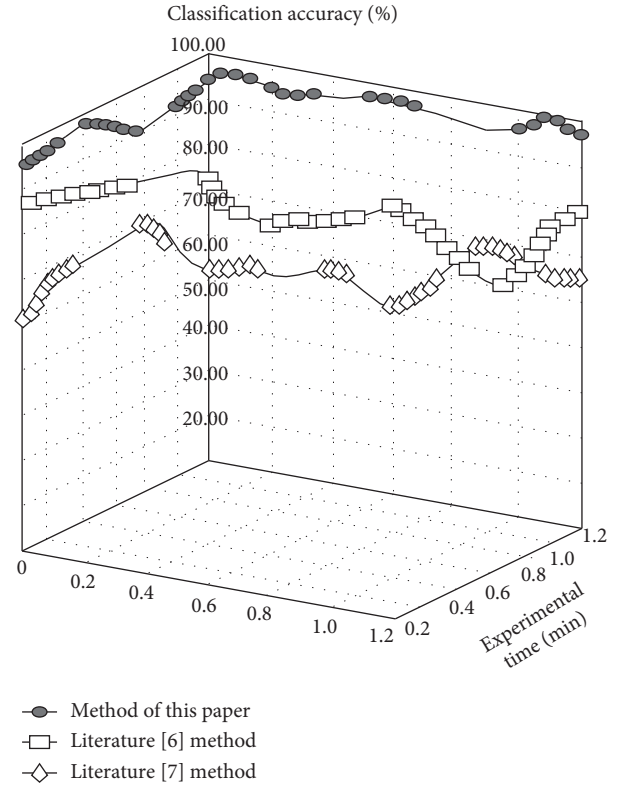

Figure 1: Comparison results of classification accuracy of the three algorithms.

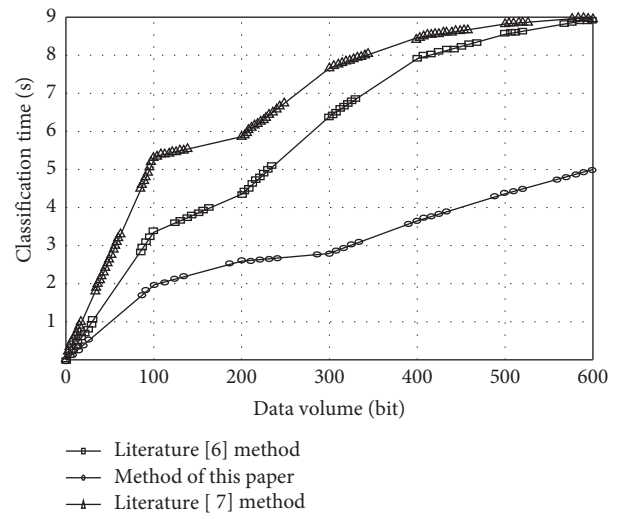

Figure 2: Comparison results of classification time of the three algorithms.

4. Discussion

This study significantly improves the visual classification accuracy of big data in economic texts. This is because this study first preprocesses the big data of economic text, thereby

eliminating useless symbols, performing word processing, and eliminating stop words, and lays a concise and accurate data foundation for the later text classification. The TF-IDF weighted algorithm is used to weight the characteristics of economic text data, and the Naive Bayesian algorithm is used to complete the visual classification of economic text big data, which improves the overall classification accuracy. This study significantly improves the efficiency of big data in economic text. This is because the method of this study preprocesses the big data of economic text, it eliminates useless symbols, performs word processing, and eliminates stop words, which facilitates the further classification of text and saves the processing time. At the same time, according to the processing results, the most relevant features in the process of economic text big data classification are selected for classification, which improves the classification efficiency.

5. Conclusion

With the rapid spread of the Internet and the rapid development of digital media technology, a large amount of data information has appeared on the Internet. As more and more information is stored in electronic form, the amount of text is growing rapidly. This information is mainly stored in text databases and repositories, which contain a large amount of text belonging to various sources, such as e-mail messages, business, news articles, entertainment, government, art, literature, military, economics, and digital books Pavilion. The text stored in the database has an inherent unstructured or semi-structured format. The increasing size and complexity of this unstructured text data make effective management of a crucial issue, and this phenomenon has led to an increase in text classification research. In order to improve the effect of economic text big data, this study examines a Python-based visual classification algorithm. It uses TF-IDF weighting algorithm to determine the feature weight of economic text data, accurately expresses text information, and introduces a simple Bayes algorithm to classify economic text big data. Simulation experiments demonstrate that the proposed method has high classification accuracy and efficiency. However, due to limited conditions, the classification results of this study are insufficient, and future studies need to further improve the clarity and completeness of the classification results.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis of Public Management Performance Evaluation Model Based on Fuzzy DEA Model

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The evaluation of public management performance is the key to identify the effectiveness of the work of public administration, and public policy is an important guarantee for the orderly promotion of the work of public administration; therefore, it is important to analyze the effectiveness of public management policies to evaluate public management performance. Taking environmental protection policies as an example, this paper constructs an environmental-economic DEA efficiency analysis model using the DEA method to conduct a comprehensive evaluation of EEE in different provinces of China. It is found that EEE is highly correlated with the regional economic development level and is highly influenced by policy fluctuations, but the overall EEE of different provinces from 2016 to 2020 tends to be consistent and has a certain degree of stability. The conclusions of this paper have important implications for policy guidance, emphasizing the need to focus on the coordination of economic development and environmental protection, and the need for the improvement of the environmental policy system to be continuously optimized in an incremental manner, taking into account the actual situation of local development.

1. Introduction

Since the reform and opening up, China has made great achievements in economic development, becoming the world's second largest economy, gradually grasping the right to speak in the world economic system and increasing its influence in the international community, but in contrast, the environmental pollution problem has become more and more serious [1], and both the central government and local governments are faced with the dilemma of economic development and environmental protection [2–4]. In 2020, China announced that it would strive to achieve carbon neutrality by 2060 and contribute to the international environmental protection cause, which has aroused widespread concern in the international community and is an important event that will affect China's international reputation in the future. With the main theme of "reducing carbon emissions", guiding environmental protection has become one of the top priorities of the Chinese government [5, 6]. The key to environmental protection lies in sound public policy guidance. At the macro level, the public administration is the core force in guiding enterprises to reduce carbon emissions, which is the key to promote the orderly implementation of public policies [7, 8]. At the microlevel, policy arrangements also help to benignly guide social forces and the general public to deeply participate in environmental protection. Therefore, it is of great theoretical and practical importance to analyze the policy efficiency of public administration in environmental protection from the perspective of performance evaluation.

China's environmental protection work began with the reform and opening up. In 1992, China regarded sustainable development planning as the core element of future planning. In 2006, carbon emission reduction was first introduced as a control indicator for domestic economic development. In 2015, strict environmental protection regulations began to be implemented. In 2018, Several Opinions on Delineating and Strictly Adhering to the Ecological Protection Red Line was promulgated and implemented, and the ecological red line became the the primary guide for the development of national land space.

Along with the continuous iterations and updates of environmental protection policies, China has formed a top-down systematic environmental protection policy mechanism and has made some achievements in environmental protection. However, it is worth noting that economic development has brought environmental pollution problems far beyond policy constraints, with a number of vicious environmental pollution incidents coming to light frequently, sparking widespread concern among public opinion. In December 2016, the country ushered in unprecedented hazy weather, with a rare PM2.5 pollution belt forming in and around Beijing, Tianjin and Hebei. In short, the issue of environmental management has become one of the most important tasks of public administration.

However, policy iterations have struggled to keep up with the pace of environmental pollution, leading public administrations to enact a series of air pollution control strategies that optimize structures, strengthen standards, and provide strong oversight one after another. To sustainably improve air quality, the State Council in 2018 versioned the Three-Year Action Plan for Winning the Blue Sky Defense War and advanced the work plan of the Blue Sky Protection Project. The total investment in air pollution treatment is rapidly rising, according to the "2018–2022 China Air Pollution Treatment Industry Market Research and Development Trend Forecast Research Report" reality, in 2020, the industrial sector air pollution treatment or more than 200 billion yuan, during 2018–2022, the treatment equipment will maintain high growth with an annual growth rate of 9.5%. In the trade-off between air pollution treatment and economic development, in order to improve the existing public policy system, improve the efficiency of policy implementation in public administration, and adapt to the requirements of environmental protection, China urgently needs a scientific assessment of the efficiency of current environmental policies [9, 10]. However, few studies have been conducted to systematically analyze and evaluate the efficiency of environmental policies, and there is a need for further comprehensive evaluation using appropriate methods to provide policy recommendations. Therefore, we focus on how to evaluate public management policies and how to conduct a comprehensive evaluation of public administration performance to ensure the economic efficiency of environmental protection policies. More importantly, given the vast size of China and the huge differences in the level of economic development among regions, it is necessary to evaluate public environmental protection policies in different regions in a fair manner. Therefore, this paper takes air pollution control public policy as a case object, adopts a fuzzy-set DEA model, and draws on performance evaluation theory to establish a policy evaluation system that simultaneously takes into account environmental protection and economic development, so as to provide a practical and reliable theoretical reference for public administrations such as the government.

2. Related Studies

Public policy refers to a series of measures and management programs enacted by a certain country or region for the management of public affairs. In order to optimize and improve public policies, it is necessary to build an evaluation system to measure and evaluate the scientific and effectiveness of public policies [11], and the information obtained from the evaluation of public policies is also an important basis for improving and adjusting public policies. The information from public policy evaluation is also an important basis for public policy improvement and adjustment [12].

The evaluation of public policies mainly focuses on the evaluation of the effects of the policies after their promulgation and implementation, and is mainly based on scientific evaluation tools and instruments to observe the impact and consequences of the policies after their implementation, so as to evaluate the relevance of the policies and the rationality of their contents [13, 14]. Therefore, public policy evaluation is a specialized activity that assesses and judges the social effectiveness, implementation efficiency, and impact of public policies by scientific methods. It is the main reference for the government to formulate and improve policies, and it is also a key measure of the government's administrative and social management capabilities and achievements, and an important indicator of the government's governance [15, 16]. Public policy evaluation mainly focuses on information collection, analysis and evaluation of the effects of policy enactment, which can be divided into several levels according to the nature of the effects [17, 18], such as social benefits, economic benefits, cultural impacts, educational significance, etc. [19, 20], which are the results of a comprehensive evaluation of the objectives of the benefits of public policy design and the actual results and additional benefits. The research on public policy evaluation in international and domestic research fields is focused on three main items: system construction, practical issues and evaluation tools and methods [21].

Although there is no uniformity in the research community regarding the concept of assessing policy performance, policy performance evaluation has attracted extensive attention from scholars. Performance evaluation encompasses both behavioral and outcome evaluations [22]. The last understanding is more widely used in studies related to policy performance [23], which emphasizes that public policy analysis is a necessary process in policy formulation and includes technical aspects of policy implementation, changes in policy goals, audience size, and changes in stakeholder behavior strategies. In addition, due to the complexity of public policy, the evaluation of public policy performance should be conducted from multiple perspectives [24], based on the rationale and logic of public policy, to assess the consistency between policy outcomes and expectations of policy goals [25]. Environmental policy is an important component of public policy and the top priority for Chinese public administration at the moment [26, 27]. Importantly, the implementation process of environmental policies requires a lot of public sector effort and involves several government departments, therefore, the coordination of authority before the departments under resource constraints is crucial, and the evaluation of the enforceability of the policy is related to whether the policy can be implemented. However, few studies have been conducted to evaluate the implementability of policies, and there is a lack of systematic

research on the evaluation of environmental policy efficiency in particular. It is necessary to adopt a suitable method to evaluate the efficiency of environmental policies in China in order to provide a new theoretical perspective to evaluate the performance of public management in China.

3. Methodology

Figure 1 shows the basic process of model construction, including the process of determining the evaluation objectives, selecting DMUs, constructing the index system and analyzing the results.

3.1. CCR Model. The CCR model is the closing model of DEA, which assumes that the payoffs of scale will not change for all decision units, and then the production efficiency of each decision unit over the segment. Assume that there are n evaluation units in the production possibility set, and each evaluation unit is a production system consisting of m inputs and s outputs, where x_{ij} $(i = 1, 2, \ldots, m)$ denotes the value of the i-th input indicator of the j-th evaluation unit DMU_j, y_{rj} $(r = 1, 2, \ldots, s)$ denotes the value of the r-th output indicator of the j-th evaluation unit $v_i\,(i = 1, 2, \ldots, m)$ represents the measure of the i-th input indicator of the production possibility set, and u_r $(r = 1, 2, \ldots, s)$ represents the measure of the r-th output indicator of the production possibility set, both of which are variables. Thus, the planning model for measuring the efficiency of the evaluation unit DMU_{j0} is as follows [28].

$$\begin{aligned} &\max \frac{\sum_{r=1}^{s} u_r y_{rj_0}}{\sum_{i=1}^{m} v_i x_{ij_0}}, \\ &\text{s.t.} \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij_0} \le 0;\ j = 1, 2, \ldots, n, \\ &\qquad u_r \ge 0;\ i = 1, 2, \ldots, m, \\ &\qquad v_i \ge 0;\ i = 1, 2, \ldots, s. \end{aligned} \tag{1}$$

The above model is a nonlinear programming model, which is difficult to compute. Thus, Charnes and Cooper proposed the Charnes-Cooper transformation, which allows the above nonlinear programming model to change to a model equal to equivalent linear programming model. That is, $t = (1/\sum_{i=1}^{m} v_i x_{ij_0})$, $u_r = tu_r$, $\omega_i = tv_i$, thus obtaining the following model.

$$\begin{aligned} &\max \sum_{r=1}^{s} u_r y_{rj_0}, \\ &\text{s.t.} \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} \omega_i x_{ij_0} \le 0;\ j = 1, 2, \ldots, n, \\ &\qquad \sum_{i=1}^{m} \omega_i x_{ij_0} = 1, \\ &\qquad u_r \ge 0;\ i = 1, 2, \ldots, m, \\ &\qquad v_i \ge 0;\ i = 1, 2, \ldots, s. \end{aligned} \tag{2}$$

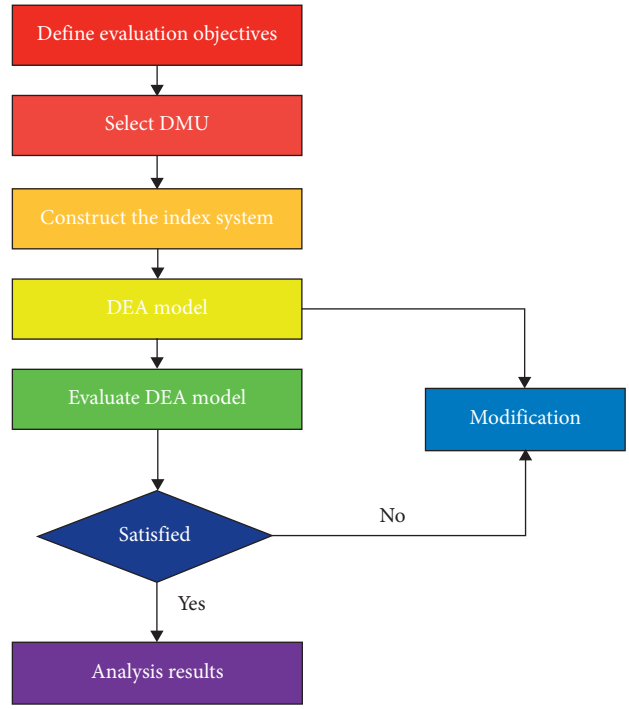

Figure 1: DEA model construction process.

Based on the dual theory of linear programming, the dual form of model (2) is obtained as follows.

$$\begin{aligned} &\min \theta, \\ &\text{s.t.} \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{ij_0};\ i = 1, 2, \ldots, m, \\ &\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rj_0};\ r = 1, 2, \ldots, s, \\ &\lambda_j, s_i^-, s_r^+ \ge 0;\ j = 1, 2, \ldots, n. \end{aligned} \tag{3}$$

When its optimal value is 1, the evaluation unit is technically efficient; it is technically effective; when its optimal value is less than 1, the evaluation unit DMU_{j0} is technically inefficient. For the model in equation (3), when its optimal value is 1, the evaluation unit DMU_{j0} is weakly technically efficient; when its optimal value is 1 and satisfied, the evaluation unit DMU_{j0} is strongly technically efficient; if it is less than 1, the evaluation unit DMU_{j0} is technically inefficient.

3.2. BCC Model. The corresponding CCR model is based on the conjecture of constant returns to scale, so the technical efficiency calculated by the model includes the effect of the scale factor. In order to eliminate the scale factor from the technology level, scholars have developed a data envelopment analysis model based on the variable payoff to scale -BCC model [29].

$$\max \frac{\left(\sum_{r=1}^{s} u_r y_{rj_0} + \mu_0\right)}{\sum_{i=1}^{m} v_i x_{ij_0}},$$

$$\begin{aligned} s.t. \sum_{r=1}^{s} u_r y_{rj} + \mu_0 - \sum_{i=1}^{m} \omega_i x_{ij_0} \le 0;\ j = 1, 2, \ldots, n, \\ \sum_{i=1}^{m} \omega_i x_{ij_0} = 1, \\ u_r \ge 0;\ i = 1, 2, \ldots, m, \\ v_i \ge 0;\ i = 1, 2, \ldots, s, \end{aligned} \tag{4}$$

where μ_0 is the scale factor, reflecting the scale efficiency of the decision unit. Moreover, the above nonlinear planning model is converted into a linear planning model equivalent to it using the Charnes-Cooper transformation. That is, $t = (1/\sum_{i=1}^{m} v_i x_{ij_0})$, $u_r = tu_r$, $\omega_i = tv_i$, $\eta_0 = t\mu_0$, thus obtaining the following model.

$$\begin{aligned} \max \left(\sum_{r=1}^{s} u_r y_{rj_0} + \eta_0 \right), \\ \text{s.t.} \sum_{r=1}^{s} u_r y_{rj} + \eta_0 - \sum_{i=1}^{m} v_i x_{ij_0} \le 0;\ j = 1, 2, \ldots, n, \\ u_r \ge 0;\ i = 1, 2, \ldots, m, \\ v_i \ge 0;\ i = 1, 2, \ldots, s. \end{aligned} \tag{5}$$

According to the dual theory of linear programming, the dual form of model (5) is obtained as follows:

$$\begin{aligned} \min \theta, \\ s.t. \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{ij_0};\ i = 1, 2, \ldots, m, \\ \sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rj_0};\ r = 1, 2, \ldots, s, \\ \sum_{j=1}^{n} \lambda_j = 1, \\ \lambda_j, s_i^-, s_r^+ \ge 0;\ j = 1, 2, \ldots, n. \end{aligned} \tag{6}$$

In order to distinguish the arithmetic data of the BCC model from those of the CCR model, scholars define the efficiency values derived from these models as pure technical efficiency. In subsequent studies, the concept of scale efficiency has been defined as the ratio of pure technical efficiency to technical efficiency, which reflects the difference between the current scale of production of the decision unit and the most efficient scale of production.

3.3. SBM-DEA Model. The SBM model differs from the traditional CCR and BBC models in that it directly incorporates the slack variables into the objective function, and the optimal solution shows that there are too many inputs or too few outputs for any production process. The optimal solution shows that there are too many inputs or too few outputs for any production process, and the amount of excess inputs or too few outputs is called the slack variable. The model is expressed as (7), (8).

$$\min \rho = \frac{1 - 1/m \sum_{i=1}^{m} s_i^- / x_{i0}}{1 + 1/s \sum_{r=1}^{s} s_r^+ / y_{r0}}, \tag{7}$$

$$\begin{aligned} \text{s.t. } x_0 = X\lambda + s^-, \\ y_0 = Y\lambda - s^+, \\ \lambda \ge 0,\ s^- \ge 0,\ s^+ \ge 0, \end{aligned} \tag{8}$$

λ is the weight attached to the efficiency measure of each decision unit, and s^- and s^+ represent the excess input and output deficit. The fraction of too much input and too little production is referred to as slack. In model (7), the decision unit is said to be SBM efficient when and only when the objective function value $\rho^* = 1$. $\rho^* = 1$ means that $s^- s^{-*} = s^{+*} = 0$, i.e., there is no excess input and no output deficit. For an invalid decision unit DMU_0, $x_0 = X\lambda + s^{+*}$ and $y0 = Y\lambda - s^{-*}$. To make this decision unit effective for SBM, the input redundancy s^{-*} needs to be subtracted and the output deficiency s^{+*} needs to be added, a planning process known as SBM planning.

3.4. Environmental and Economic DEA Model. In the face of deteriorating environmental quality, both local and central governments are gradually raising the profile of environmental protection in their work. However, in the face of environmental challenges, governments are still forced to make trade-offs between environmental protection and local economic development. The government cannot sacrifice economic development to protect the environment in the face of pressure from citizens' employment and government finances, nor can it sacrifice environmental quality to support economic development in the face of citizens' growing demands for urban environment and air quality in recent years. The trade-off between economic development and environmental protection is inevitable, and it is therefore important to propose an assessment model that can simultaneously evaluate environmental and economic performance. With this need, Zhou and Wu used the model in equation (9) to assess environmental performance and estimated the environmental-economic efficiency of different countries or regions based on the SBM-DEA model [30].

$$\begin{aligned} \lambda^* = \min \lambda, \\ \text{s.t.} \sum_{k=1}^{k} z_k x_{nk} \le x_{n0};\ n = 1, 2, \ldots, N, \\ \sum_{k=1}^{k} z_k y_{mk} \ge y_{m0};\ m = 1, 2, \ldots, M, \\ \sum_{k=1}^{k} z_k u_{jk} = \lambda u_{j0};\ j = 1, 2, \ldots, J, \\ Z_k \ge 0;\ k = 1, 2, \ldots, K, \end{aligned} \tag{9}$$

where x_{nk} ($n = 1, 2, \ldots, N$) denotes the n-th input indicator value of the k-th evaluation unit DMU_k; y_{mk} ($m = 1, 2, \ldots,$

M) denotes the m-th desired output indicator value of the k-th evaluation unit DMU_k; u_{mk} ($j = 1, 2, \ldots, J$) denotes the m-th undesired output indicator value of the kth evaluation unit DMU_k. denotes the m-th undesired output indicator value of the kth evaluation unit DMU_k. Based on this, this paper improves Wu's model by adding slack variables to the objective function to describe the undesired output, and based on this, the conditional constraints on the undesired output are improved:

$$\min \rho^* = \frac{1 - 1/N \sum_{n=1}^{N} \left(s_n^- / x_{n0}\right)}{1 + 1/M\left(\sum_{m=1}^{M} \left(s_m^- / y_{m0}\right) + \left(s_{uk}^- / \lambda^* u_0\right)\right)},$$

$$\text{s.t.} \sum_{k=1}^{k} z_k x_{nk} + s_{nk}^- = x_{n0};\ n = 1, 2, \ldots, N,$$

$$\sum_{k=1}^{k} z_k y_{mk} - s_{mk}^+ = y_{m0};\ m = 1, 2, \ldots, M,$$

$$\sum_{k=1}^{k} z_k u_{jk} + s_{uk}^- = \lambda u_{j0};\ j = 1, 2, \ldots, J,$$

$$Z_k \geq 0;\ k = 1, 2, \ldots, K. \tag{10}$$

In the model, s_{nk}^- denotes the input redundancy of input variables, s_{uk}^- denotes the redundancy of nondesired output; s_{mk}^+ denotes the redundancy of desired output, where is the planning result of model (9). That is, all decision units in model (10) are effective in terms of environmental pollution. The planning result ρ^* is the economic efficiency when all evaluation units are efficient in terms of environmental pollution, i.e., environmental-economic efficiency. When $\rho^* = 1$ and $s_n^- = s_u^- = s_m^+ = 0$, the evaluation unit is said to be environmentally and economically efficient.

When $\lambda^* = 1$, the evaluation unit is the environmental efficiency value, and $\rho^* = 1$ is the economic efficiency value when $\lambda^* = 1$. On this basis, the environmental-economic efficiency (EEE) can be calculated by assigning different weights to economic efficiency and environmental efficiency. EEE can be expressed by equation (11), and in the empirical study, local governments can assign different weights to environmental efficiency λ^* and economic ρ^* according to the local development characteristics and governance tendencies.

$$EEE = \omega_1 \lambda^* + \omega_1 \rho^*. \tag{11}$$

In other words, the proposed environmental-economic model not only allows for the evaluation of multiple policy objectives simultaneously, but also allows for the setting of weights according to the local governments' preferences for different policy outcomes. In the next section of the empirical analysis, the assumption that economic efficiency and environmental efficiency are equally important will be made, i.e., $\omega_1 = \omega_2 = 0.5$ (Figure 2). In conclusion, the model in this paper overcomes the shortcomings of traditional DEA models and provides a new methodological tool for studying environmental efficiency.

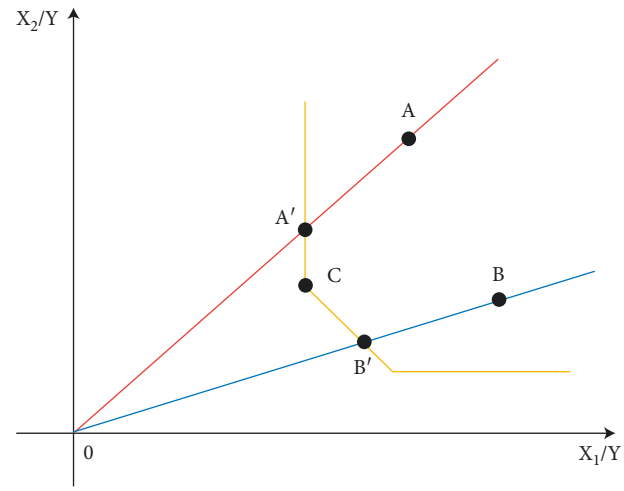

Figure 2: EEE model.

3.5. Index System Construction and Data Sources. This paper argues that it is inevitable that each region in China invests capital, labor, and consumes energy in production activities, while generating GDP. Therefore, this paper selects capital stock, labor force and total energy consumption as input factors based on previous research. The provincial GNP is the desired output indicator, and the total air emission is the nondesired output indicator (Figure 3).

3.5.1. Capital Input. The impact of investment in production activities in different regions on output is not only based on current investment, but also on the capital stock formed by past investment, so this paper uses the capital stock to measure the input of capital factors. There are no direct statistics on capital in each region of China. Instead, the perpetual inventory method has been used in the literature to estimate the capital stock in different regions [30]. The estimation of the fixed capital stock $K_{n,t}$ can be calculated by

$$\begin{aligned} K_{n,t} &= K_{n,t-1} + I_{n,t} - D_{n,t} \\ &= \left(1 - d_{n,t}\right) K_{n,t-1} + I_{n,t}, \end{aligned} \tag{12}$$

where $K_{n,t}$ denotes the fixed capital stock of province n in year t; $I_{n,t}$ denotes the new investment in fixed assets in province n in year t. In this study, the total value of fixed capital formation published in the China Statistical Yearbook in that year is used; $D_{n,t}$ denotes the depreciation of fixed assets in province n in year t, and $d_{n,t}$ denotes the depreciation rate. In the empirical analysis of this paper, 10% is used as the depreciation rate, and 2000 is used as the base period. In other words, the fixed capital stock of each province and city region is estimated by (11), and the data from 2016 to 2020 are finally used as input variables for the study.

3.5.2. Labor Input. Labor is a very basic factor of production, which is crucial for economic growth. In the classical

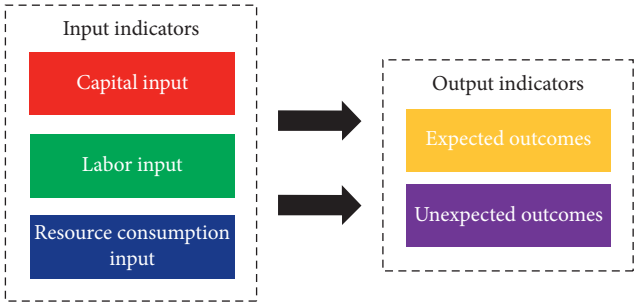

Figure 3: Index system.

growth theory stage of the economic growth system, the quantity of labor is considered to play an important role in economic growth. In both classical and neoclassical trade theories, labor endowment is also a central element. Labor and other productive resource factors play a key role in a country. This has an impact on comparative advantage, industrial structure and trade structure. China's cheap labor force is very large and has become a key advantage for the country's economic development. It also influences China's industrial output and trade imports and exports. It plays a key role in the country's economic growth. In order to provide a more realistic picture of the production life of a region, this paper uses labor force inputs including "urban unit workers", "private enterprise workers", and "urban and rural workers engaged in self-employment activities". In this paper, the labor input includes "urban single-employee", "private enterprise", and "urban and rural self-employed".

3.5.3. Resource Consumption Input. Adequate energy input is the basic material basis to ensure the normal development of economic and social production and life, and to maintain the survival and development of human beings. Rough energy consumption patterns have led to a series of energy problems, which have become two bottlenecks limiting the economic development of China. It is imperative to conserve energy, reduce consumption, and improve energy efficiency. In this paper, resource consumption inputs are used as "total energy consumption" published in the China Energy Statistics Yearbook.

3.5.4. Expected and Unexpected Outcomes. GDP is taken as the desired output of the production process. The nondesired output is the negative output of the production process, the less the better. In this paper, the nondesired output is the total emissions of each province as the target of environmental efficiency of each province. In the calculation, the total emissions include the sum of sulfur dioxide, nitrogen oxides, and soot emissions published in the China Statistical Yearbook. The emissions come from industrial processes, urban living, motor vehicle emissions, and emissions from centralized pollution control facilities. Since the total emissions as undesired output are the local emissions of the evaluation unit, the environmental efficiency evaluation results estimated by the model reflect the local emissions efficiency. In practice, the emission sources of urban pollutants in a certain area may come from other neighboring areas, which means that the local air quality is affected not only by the local air pollution emission efficiency, but also by the air pollution emission efficiency of the neighboring areas, so the local environmental efficiency assessed by the model cannot fully reflect the local air quality. Therefore, this paper concludes that although the proposed environmental-economic model does not fully reflect the air quality of a region, it is sufficient to assess the efficiency of air pollution control and economic development of the local government.

Due to the lack of data for some regions, Tibet, Hong Kong, Macau, and Taiwan are excluded from the decision unit of this study. The raw data for the model variables are obtained from the China Statistical Yearbook and the China Energy Statistical Yearbook published by the National Bureau of Statistics.

4. Results and Discussion

As shown in Table 1, Beijing and Tianjin have been assessed as having a valid EEE among the 30 provinces and municipalities assessed. Hebei Province was assessed as EEE-valid in 2016, and its EEE score and EEE ranking decreased each year for the next four years, dropping from sixth place in China to 18th place in 2020. Shanghai's EEE has improved over the five-year period, reaching EEE validity in 2018–2020. Other provinces EEE rankings are more stable and less volatile. The kernel density distributions of the x-axis and y-axis indicators are obtained by fitting the Kernel function accordingly. The kernel density distribution shows a relatively flat single-peaked feature, which indicates that the economic and environmental efficiency of most provinces converge to a steady-state level, while a few provinces are at more extreme (too high and too low) levels (Figure 4).

The heat map (Figures 5–10) of EEE in China shows that the geographical variation of EEE in China in 2016–2020 is small in magnitude and maintains a steady state, with the highest EEE in Beijing-Tianjin-Hebei region, and the Yangtze River Delta and Pearl River Delta also in the top, but with lower EEE out of the marginal provinces. In other words, EEE is positively correlated with the level of economic development. However, there are some provinces with large fluctuations, such as Hunan Province, which saw a significant rise in EEE in 2020, but provinces such as Shandong, Jiangsu and Guangdong saw a large decline. 2020 saw a large change in the national environmental policy system, with the drawing of ecological red lines forming a compulsory constraint on regional development and construction, stimulating the effective implementation of environmental policies, which to some extent had a significant impact on regional EEE impact, in short, policy arrangements are the primary factor affecting EEE.

Figure 11 similarly shows that the annual variation in EEE is small, with the top cities and cities with higher levels of economic development ranking high in EEE efficiency, but the environmental problems of resource-dependent

Table 1: EEE evaluation in China.

Region	2016–2020 mean value on EEE	2016	2017	2018	2019	2020
Beijing	1.00	1.00	1.00	1.00	1.00	1.00
Tianjin	1.00	1.00	1.00	1.00	1.00	1.00
Shanghai	0.97	0.95	0.88	1.00	1.00	1.00
Shandong	0.94	1.00	1.00	1.00	1.00	0.72
Jiangsu	0.89	1.00	0.74	1.00	1.00	0.73
Guangdong	0.85	1.00	1.00	1.00	0.65	0.60
Zhejiang	0.75	0.73	1.00	0.76	0.62	0.63
Hunan	0.74	0.69	0.77	0.65	0.61	1.00
Fujian	0.64	0.62	0.67	0.67	0.65	0.57
Hebei	0.61	1.00	0.55	0.54	0.50	0.46
Hubei	0.58	0.58	0.59	0.57	0.58	0.59
Sichuan	0.56	0.67	0.59	0.58	0.48	0.46
Guangxi	0.53	0.56	0.54	0.54	0.55	0.48
Hainan	0.53	0.57	0.54	0.53	0.51	0.49
Jiangxi	0.52	0.57	0.53	0.52	0.49	0.49
Anhui	0.52	0.58	0.54	0.52	0.50	0.46
Shanxi (陕西)	0.51	0.56	0.51	0.51	0.48	0.47
Henan	0.50	0.55	0.51	0.50	0.48	0.47
Liaoning	0.50	0.54	0.53	0.52	0.53	0.38
Jilin	0.47	0.53	0.48	0.47	0.43	0.42
Chongqing	0.46	0.49	0.46	0.45	0.46	0.45
Neimenggu	0.44	0.50	0.46	0.43	0.42	0.39
Heilongjiang	0.43	0.43	0.41	0.45	0.47	0.40
Guizhou	0.42	0.38	0.39	0.42	0.46	0.44
Yunnan	0.40	0.38	0.38	0.38	0.48	0.39
Shanxi (山西)	0.35	0.40	0.37	0.35	0.34	0.31
Gansu	0.35	0.39	0.37	0.36	0.33	0.32
Qinghai	0.33	0.35	0.34	0.34	0.33	0.30
Xinjiang	0.32	0.35	0.34	0.34	0.31	0.28
Ningxia	0.31	0.33	0.34	0.32	0.30	0.28

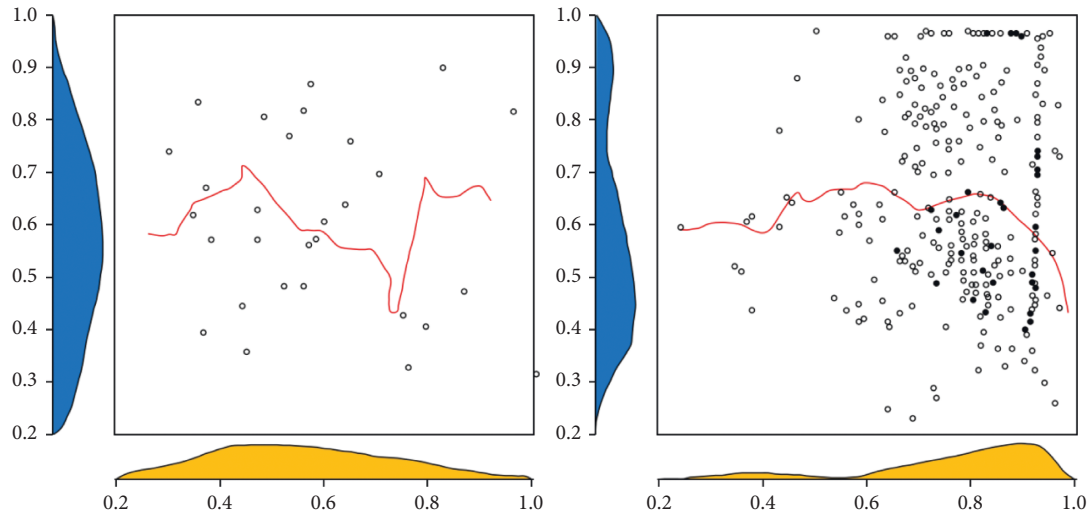

Figure 4: EEE scatter plot.

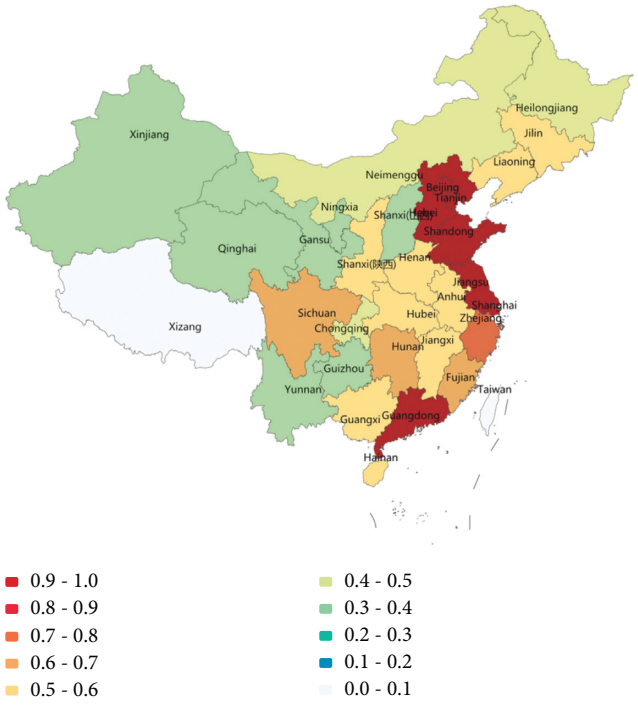

Figure 5: 2016 EEE value in China.

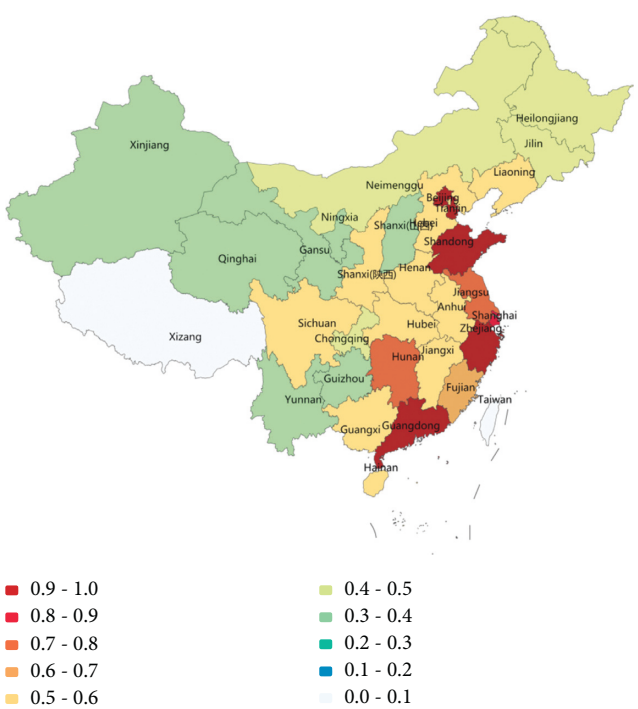

Figure 6: 2017 EEE value in China.

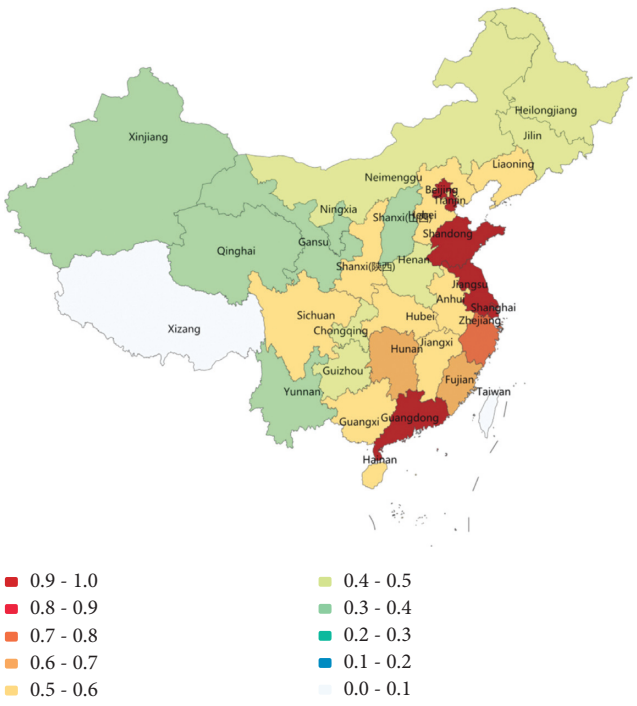

Figure 7: 2018 EEE value in China.

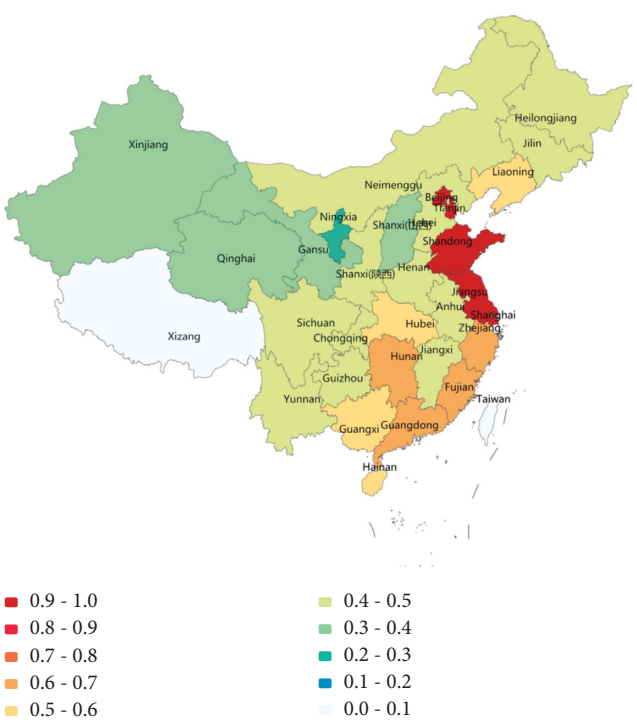

Figure 8: 2019 EEE value in China.

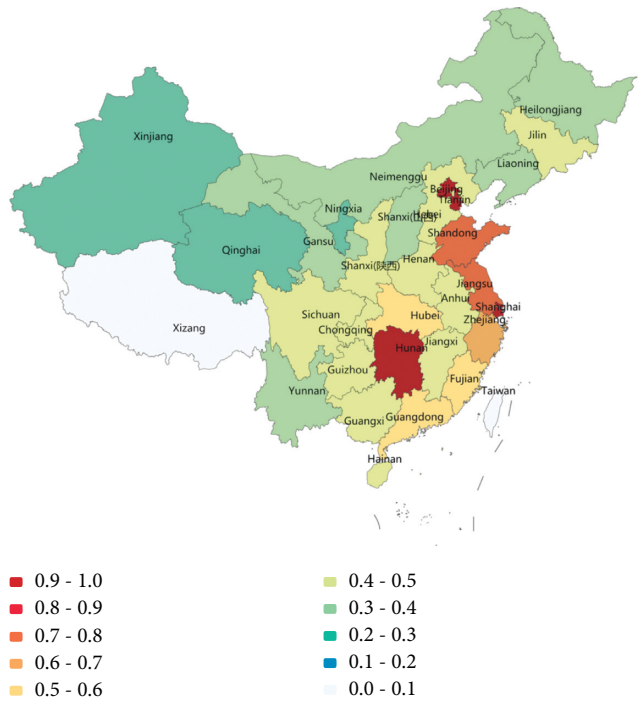

Figure 9: 2020 EEE value in China.

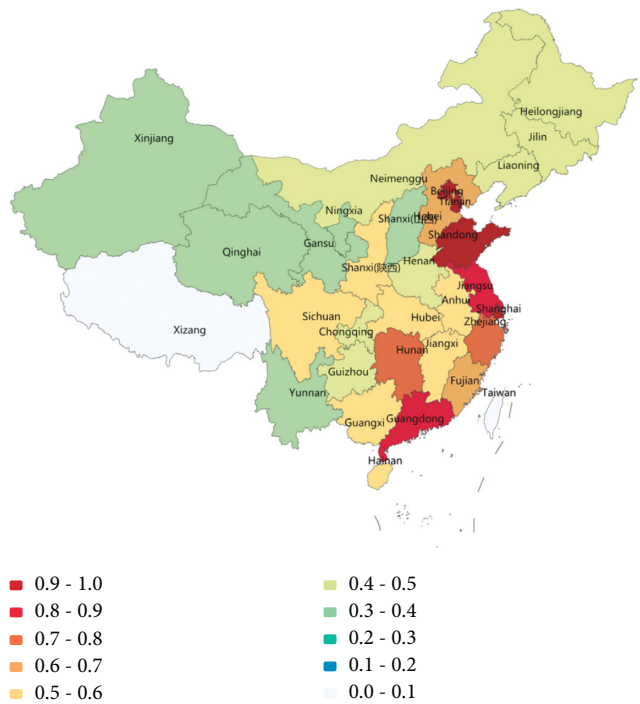

Figure 10: 2016–2020 EEE mean value in China.

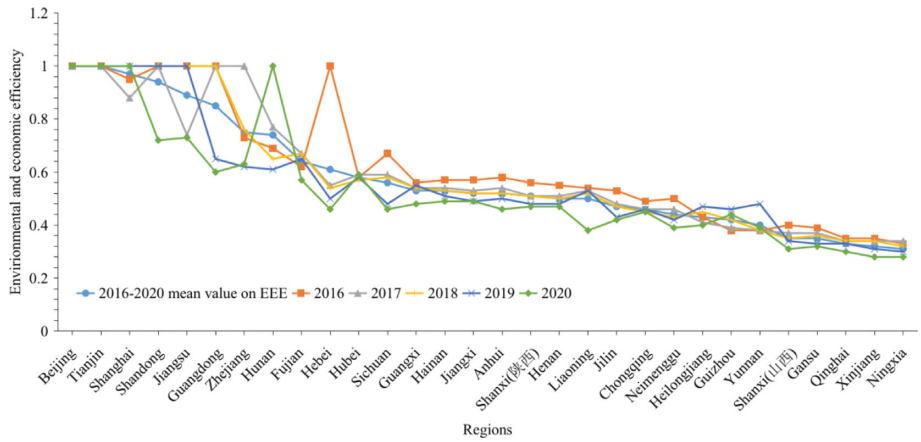

Figure 11: EEE value in different regions.

provinces (e.g., Shanxi and Gansu) and economically underdeveloped provinces (e.g., Qinghai, Xinjiang, and Ningxia) should not be underestimated and require further attention.

5. Conclusions

Environmental policy efficiency is the most important part of evaluating public management performance. This paper proposes an improved environmental-economic DEA model, which not only takes into account the environmental efficiency and economic efficiency of air pollution prevention and control policies, but also sets the corresponding weights according to the different policy objectives of the government, so as to obtain the evaluation results that meet the actual needs. Theoretically, this paper represents the first comprehensive evaluation of the performance and efficiency of public administration in China, analyzing intercity differences in the efficiency of public administration in China in terms of public policy. In the empirical study, the model is used to assess the overall efficiency of regional air pollution prevention and control in China, providing a methodological and data base for the subsequent assessment of policy efficiency. The study finds that when environmental and economic objectives are given the same policy preferences, environmental inefficiency is the main reason for the low environmental-economic efficiency of air pollution prevention and control in the region. Specifically, the heterogeneity of environmental economic efficiency in different Chinese provinces is highlighted, indicating that regional imbalances remain an important issue to be addressed in China's environmental protection policy system. The findings of this study have important value for public policy making in China, suggesting that future environmental public policies in China should be tilted towards the backward regions. There are still some limitations in this paper. For example, the time span of this paper is 2016–2020, and a dataset with a longer time horizon could be selected in the future to analyze the efficiency of public management over time. Second, although the selection of input-output indicators is based on extensive literature, there is still a possibility that some indicators are overlooked and do not reflect the real world. [31].

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Refinement Economic Management Method Based on Management Accounting

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The economic strength of a country is the external manifestation of its comprehensive national strength. In order to increase a country's international influence, it must strengthen its own economic development. China's economy is in a period of rapid development. At this stage, enterprise development is an important factor in promoting steady economic growth. However, economic management plays an important role in the development of an enterprise. Therefore, how to use effective economic management methods to promote the development of enterprises is very important. This method helps to enhance the competitiveness of enterprises and improve the economic efficiency of enterprises. This approach needs to get people's attention. For productive enterprises, the biggest problem is that the economic benefits are not up to expectations. In addition, spending costs are always well over budget. In fact, this has a lot to do with business management. Before the market, economic system was reformed. The comprehensive management of productive enterprises is mostly extensive management. This makes the economic costs of certain links and details out of control. Therefore, effective management of the economy of a productive enterprise is critical. Although productive enterprises cannot be said to be highly profitable, their economic benefits are at least achievable. For productive enterprises, the most effective management method for the economy is refined management. This article starts from the perspective of improving the speed of enterprise development. Specifically, the starting point is to promote the improvement of the country's comprehensive national strength. The article analyzes the inherent relationship between economic management and enterprise development, hoping it can provide positive help for China's social and economic progress.

1. Introduction

While economic management promotes the development of enterprises, it also imposes certain constraints on enterprises. This restriction can ensure that the development of enterprises will not be out of people's control and that the company will move forward steadily in accordance with the wishes of the managers. When managers manage enterprises, using effective economic management methods can help enterprises to become standardized. The management of assets by the financial department is only one stage. This is not enough for the entire life cycle of an asset. Such an asset management model can easily lead to the separation of the asset management mechanism from reality in modern enterprise management. The standardized management of enterprises can promote the better development of enterprises. Standardized management can make employees have higher work enthusiasm and improve the competitiveness of enterprises. When an enterprise faces difficulties in the operation process, standardized management can help the enterprise improve its ability to deal with risks. Therefore, managers should pay attention to the use of economic management tools. Managers need to work hard to bring the enterprise closer to standardization and promote the rapid and stable development of enterprises [1–3]. Every company wants to grow in the market. It must have a sound management system. Therefore, these tasks are also an important guarantee for the refined management of enterprises.

Effective economic management is helpful to the systematic development of enterprise management. In China's

current enterprise development process, the systematization of enterprise management is an important basis for establishing an enterprise economic management system. At the same time, it is also an important basis for realizing the refined management of enterprises. Refinement management means that enterprise managers use effective methods to manage the marketing process of enterprise products [4–7], help enhance the influence of enterprise products, and improve the competitiveness of enterprises. However, this management method is also based on the systematic management of enterprises. An effective method specifically meets the requirements of the demander and then develops it. This method highlights the scientific nature of enterprise management. Specifically, it has become an important means to improve the efficiency and competitiveness of enterprises. Under the pressure of competition for a long time, it is difficult for enterprises to develop a virtuous circle. Business-to-business communication is also more difficult. However, with efficient economic management, a certain competitive consensus has been reached among peer companies. The lack of sufficient attention to asset management has led to the emergence of fixed asset management loopholes. It affects the effective implementation of refined management of corporate financial accounting. Businesses can improve their relationship with each other. Businesses are managed by applying similar economic management methods. Then an effective link is formed between enterprises in order to strengthen the internal connection between enterprises and promote the effective development of market competition [8–11].

In addition, economic management can provide effective reference conditions for business operation. There are many similarities between different management models, all of which are to maximize the interests of the enterprise. In addition, the implementation of economic management within the enterprise can meet the inner needs of employees. At the same time, it can also stimulate consumers to consume. It has become an important means to ensure the efficiency of enterprises. Companies will use high salaries, awards, punishments, and other means to stimulate employees' enthusiasm for work. In order to achieve the purpose of accelerating the development of enterprises, integrating employee compensation with corporate benefits can strengthen the internal management of enterprises. Thereby, it plays an important role in the future development and efficiency of the enterprise [12–15]. We want to strengthen the development of enterprises; effective competition is an important safeguard measure. Human development is inseparable from competition, and survival of the fittest is the foundation of social progress. Therefore, in order to promote the rapid development of enterprises and help them grow effectively, it is necessary to formulate reasonable competition strategy standards for enterprises. Competitive strategies among enterprises are characterized by refinement and they are often manifested in their own competitive advantages and competitive direction. We need to ensure that the business remains in an effective strategic direction and further develop its own advantages [16–19].

It is necessary to strengthen the economic management and personnel training of enterprises, as well as the construction of their own strategic teams, and cultivate elite talents and make the enterprise system closer to refinement. It has become an important means to promote the rapid growth of enterprises [20–24]. In addition, in order to achieve refined management, we must rely on high-quality economic management. However, refined management is also an important development direction of enterprise economic management. There is a necessary internal connection between the two. At the same time, this behavior is also the basic condition to ensure the healthy development of enterprises [25–28]. China's economy has achieved rapid development in recent years. Many companies are also expanding their business scale. China's achievements in many aspects are also very remarkable. However, there are still some problems in the economic management of enterprises. This is an important situation facing Chinese companies. This should get people's attention. Many business managers have not received systematic economic education, leading to insufficient understanding of economic management [29, 30]. At the same time, their awareness of economic management is weak, and they are blind in the face of important decisions. Managers' own management ideas are not novel and avant-garde. This also limits the development and growth of the business. In the process of development, some enterprises only focus on market expansion and business volume improvement. Business managers also ignore the importance of economic management activities, although, in this way, enterprises will get many economic returns in a short period. However, this has a negative impact on their long-term development. The research framework of this paper is shown in Figure 1.

2. The Importance of Economic Management

2.1. Contribution to the Systematization of Enterprise Management. When an enterprise faces development risks, managers will use the most conservative methods to avoid its losses as much as possible. However, choosing a conservative method is an important means to test the economic ability of enterprise managers. Enterprises rely excessively on payment centers for asset management. The enterprise does not register the fixed assets, nor does it assign a special person to be responsible for the daily inventory. Therefore, these assets will be quietly lost in the course of business operation. Therefore, this will lead to a very serious financial management accident. For corporate financial users and decision leaders, their daily concern is the operation of corporate funds. At the same time, it is also a problem that managers have been studying. In turn, it is necessary scientifically to use economic management methods to strengthen the management of enterprises. In addition, they can improve the ability of enterprises to deal with risks so as to control the development direction of the enterprise. Therefore, the internal economic management of the enterprise needs to take into account its own development needs and the external market environment. Enterprises must continuously accumulate their own economic management experience in the

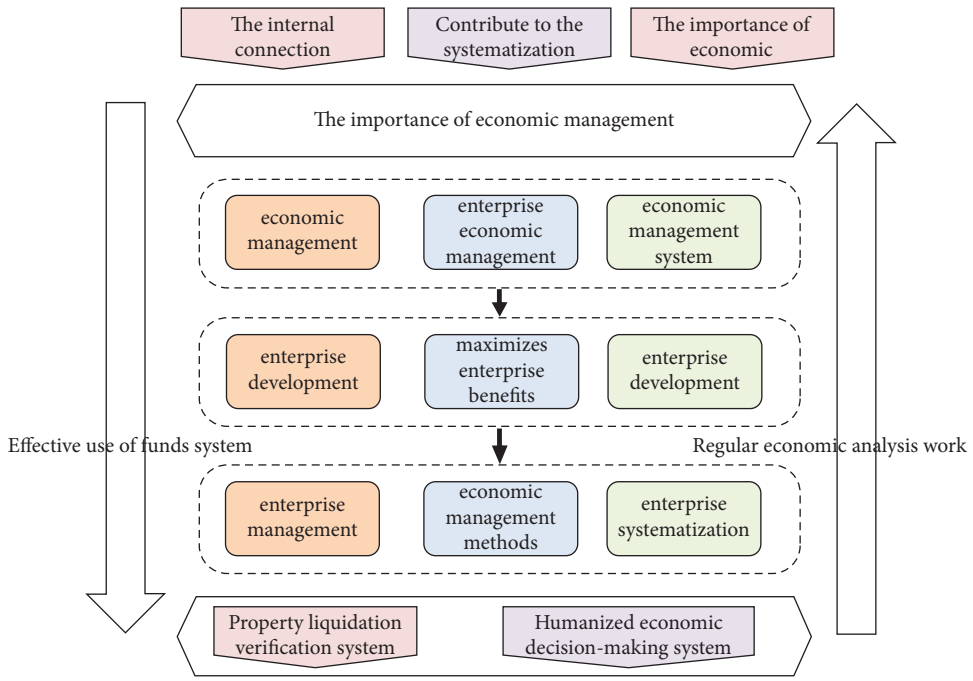

Figure 1: The overall framework of enterprise economic management system.

process of development. Enterprises need to rationally innovate economic management plans according to their own actual conditions. Enterprises need to build a management system that serves their own business requirements. The model research framework is shown in Figure 2.

Refinement management refers to every link related to economic and financial affairs in the production and operation of an enterprise. Small details of the business are under strict monitoring. Through the standardized operation of relevant systems, the relevant work was made more standard and efficient. This paper mainly analyzes the economic management methods of small- and medium-sized enterprises.

2.2. The Internal Connection between Enterprises and Enterprises. The economic management system should be consistent with the actual development of small- and medium-sized enterprises. There will be no contradiction in the comprehensive management system of the enterprise. After all, both serve to achieve the economic goals of the enterprise. In the refined management of the economy and finance of small- and medium-sized enterprises, the frequency of property inventory must increase. In addition, business management time is irregular. This will serve as a restraining warning to those involved in financial contact. Under the background of the information age, the refined management of financial accounting of enterprises must have a high level of information. This is also an important guarantee for giving full play to the advantages of refined financial management. In the construction of financial management information, the implementation progress of most enterprises is not ideal. In addition, this can also detect financial flow problems in time, thereby minimizing losses. In addition, doing so can find those involved as quickly as possible. It takes legal measures to punish them. Regardless of the size of the financial work incident, the financial department as well as the audit department must carefully check. Then, the situation and whereabouts of capital flows can be mastered as a whole. On this basis, leaders can also know the thin links of production and operation and then take effective measures to improve the economic benefits of this link.

2.3. The Relationship between Economic Management and Enterprise Development. Leaders of SMEs tend to take an arbitrary approach when making economic decisions. In the formulation of enterprise development goals and the implementation of relevant measures, the opinions of managers and grass roots personnel will not be easily listened. The decision-making of leaders is sometimes biased, so it is necessary to establish a humanized economic decision-making system. In this way, managers and grass roots personnel are given more rights to express their suggestions and opinions. The decision-making after brainstorming can be more conducive to avoid enterprise development risks. Finally, enterprises need to combine the efforts of all parties to achieve their own strategic goals of development. The main influencing factors of sports performance and training process are shown in Figure 3.

3. Small- and Medium-Sized Enterprise Economic Management System

The democratized decision-making system knowledge is relatively reasonable voice. The real decision-making power is still in the hands of leaders. Leaders hold high positions of

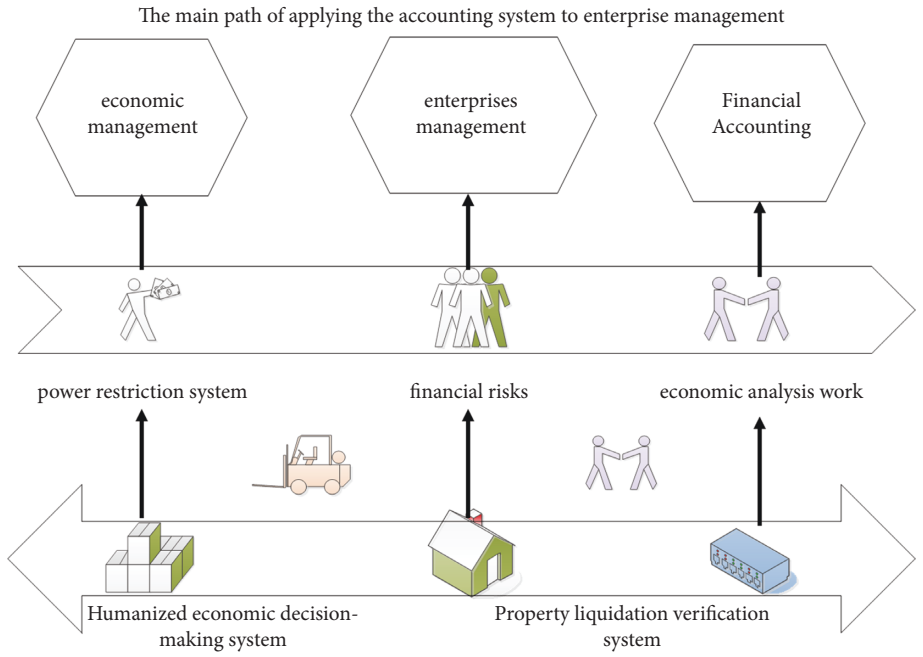

Figure 2: The main path of applying the accounting system to enterprise management.

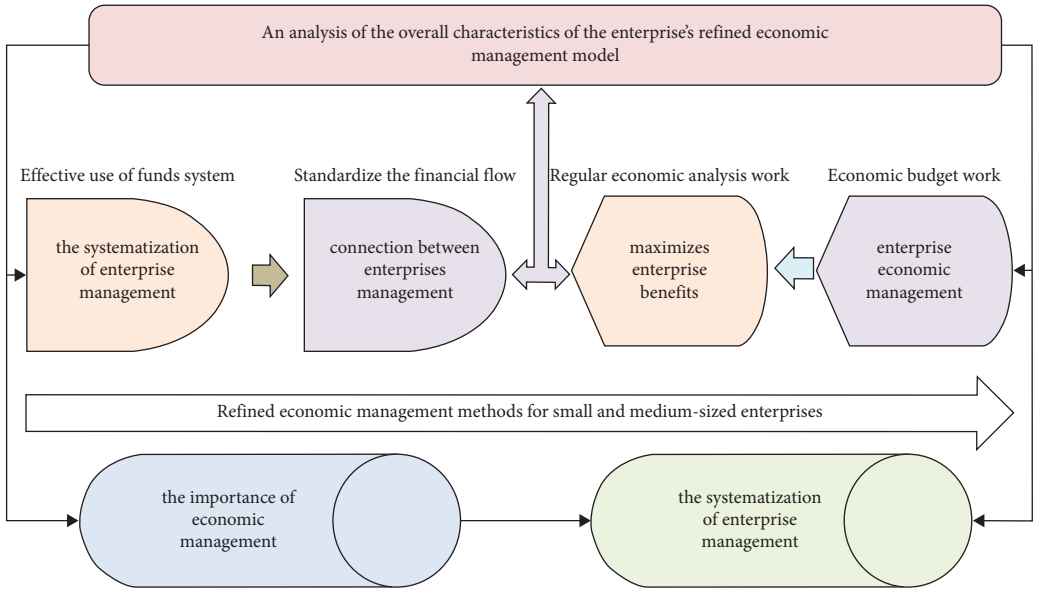

Figure 3: The analysis of the overall characteristics of the enterprise's refined economic management model.

power and take democratic decision-making as surface work for their own benefit. However, in actual operation, dictatorship is implemented. At this time, enterprises need to establish a power restriction system. A special supervisory department restricts the rights of leaders so that the decision-making measures after brainstorming can be implemented. The management system is made to run through the work of each department. A person or a department should not be overpowered. This is also an important measure to ensure the refined economic management of small- and medium-sized enterprises.

3.1. Economic Management Maximizes Enterprise Benefits. SMEs need to have funds managed efficiently. First, every dollar needs to be worthwhile. That is, the use of value should be maximized. This can bring more profits. Thus, no time is wasted. Therefore, it is necessary to establish a management system for the use of funds according to the requirements for the use of funds. The specific performance is that when the company opens an account, the choice of bank and the handling of related business must be reported. Although some enterprises are fully prepared for hardware, the information technology level limited to financial

managers is extremely limited, and the advantages of information cannot be fully utilized. The financial information of some enterprises is only the information of some functions. All leaders of the enterprise need to punish those who violate the law. The use of funds by enterprises is subject to strict audits. At the very beginning of the execution process, stakeholders develop detailed plans for financial activities. This plan makes it a reference standard for the use of funds. Leaders' private accounts should not be linked to company accounts. In order to avoid the confusion of property flow and make financial use reasonable and legal, full-cost refined management in small- and medium-sized enterprises is applied. It can integrate human, material, and financial resources into one and categorize them. In order to ensure that small- and medium-sized enterprises can meet the market development trend, in the process of application, due to the low management awareness of some managers, they did not manage the cost. Therefore, in order to improve this situation, the operation process needs to be improved. Further, a refined information management system is built, ensuring that the economy of small- and medium-sized enterprises can be reasonably managed. Model analysis results are shown in Figure 4.

In the economic management of small- and medium-sized enterprises, there is a problem that the awareness of cost refinement management is not strong. Specifically, it can be understood from the two following aspects: First, SMEs are divided into two types: public SMEs and private SMEs. Individuals mainly run private SMEs. Public SMEs are mainly supported by the state and every year the government allocates money to them. However, this category of SMEs lacks capital management awareness. Even some enterprises often have the problem of overbudget. For example, common financial information sharing is far from meeting the actual needs of refined management. The degree of information development of financial data collection, sorting, analysis, sharing, mining, and so forth has a profound impact on the level of refined financial management of enterprises. This will have a certain impact on the sustainable development of small- and medium-sized enterprises. Second, the external environment and internal operation of small- and medium-sized enterprises have an impact on the economic management of enterprises. Due to the low professional ability of relevant personnel, it is difficult to apply scientific methods for management. Even it is difficult for the enterprise to meet the needs of the initial budget, which increases the cost of the enterprise. In turn, it has a certain impact on the development of small- and medium-sized enterprises. Model analysis results are shown in Figure 5.

There is a problem of imperfect management methods in the refined management of all costs in the economic management of small- and medium-sized enterprises. Specifically, it can be understood from the two following aspects: First, most small- and medium-sized enterprises conduct accounting work after cost expenditure. Employees need to organize and escalate invoices in order to ensure the stable operation of the relevant financial management work of the enterprise. However, in this process, some financial personnel have low awareness of cost management.

The function of forgetting gate is to determine the part discarded from the input information h_{t-1} and x_t and output a value between 0 and 1. The larger the value is, the more information is retained. The output of forgetting gate is calculated as follows:

$$f_t = \sigma\left(W_f \cdot \left[h_{t-1}, x_t\right] + b_f\right), \tag{1}$$

$$i_t = \sigma\left(W_i \cdot \left[h_{t-1}, x_t\right] + b_i\right), \tag{2}$$

$$C_t' = \tan h\left(W_C \cdot \left[h_{t-1}, x_t\right] + b_C\right). \tag{3}$$

Suppose that the index evaluation set is represented by A, r_j is represented by the membership degree vector, and the data set is represented as

$$r_j = \left(r_{j1}, r_{j2}, r_{j3}, r_{j4}, r_{j5}\right). \tag{4}$$

In the above formula, r_j represents the membership degree vector corresponding to the index evaluation set A. Assume that

$$B = \left(B_1, B_2, B_3, B_4, B_5\right). \tag{5}$$

Self-organizing process adaptively forms the first-level intermediate model:

$$z_k = f_k\left(v_i, v_j\right), i, = 1, 2, \ldots, 6. \tag{6}$$

These people are difficult to manage according to plan. There are even problems such as unsatisfactory bill reconciliation. Second, when conducting financial management of small- and medium-sized enterprises, the financial departments of some small- and medium-sized enterprises do not have high awareness of supervision. These personnel have not formulated a sound management plan, and it is difficult to exert the significance of refined management. Model analysis results are shown in Figure 6.

3.2. Problems Existing in Current Enterprise Economic Management. In the application of full-cost refined management in the economic management of small- and medium-sized enterprises, it is necessary to improve the awareness of cost management. Specifically, it can be understand from the two following aspects: First, cost management has a certain impact on enterprise development. In order to ensure the stable operation of small- and medium-sized enterprises, it is necessary to carry out employee training. Then the relevant knowledge can be fully grasped and managed scientifically and effectively. Combined with practice, major enterprises have achieved effective and refined management in financial accounting work. The strict implementation of comprehensive budget management is an indispensable and important measure. For example, managers can hire economic management experts to teach them knowledge such as expense management and financial reconciliation and form the cost of refined management capabilities to ensure the stable operation of relevant

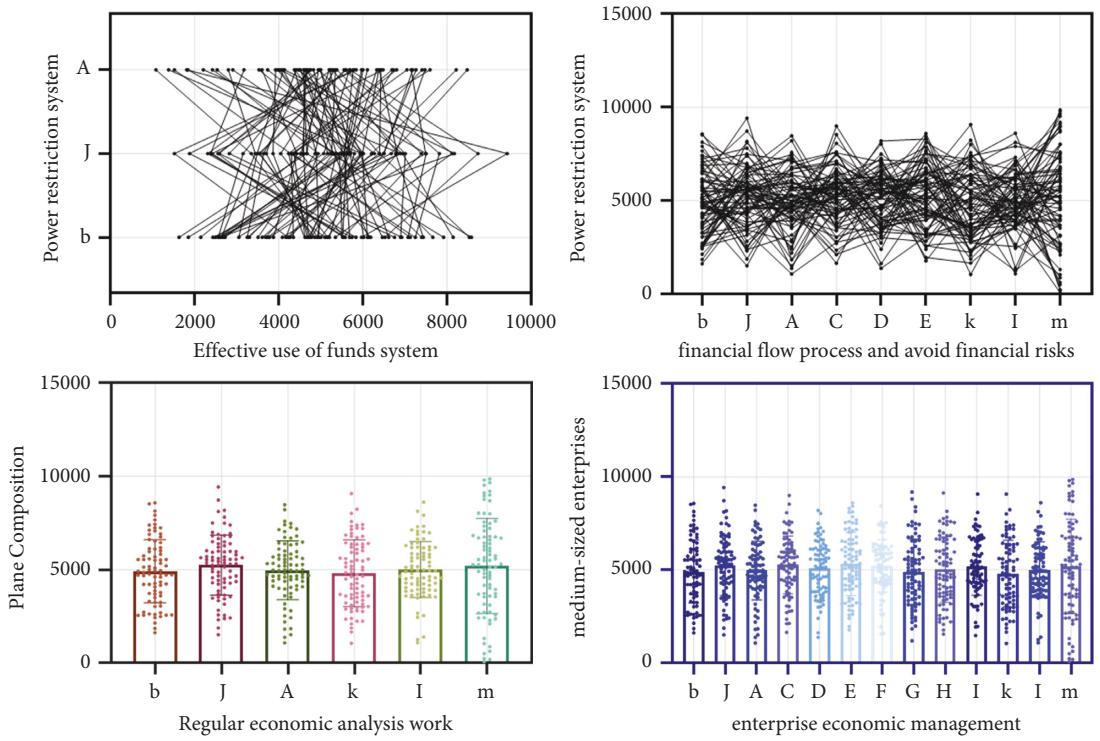

Figure 4: The application effect of enterprise refined economic management model.

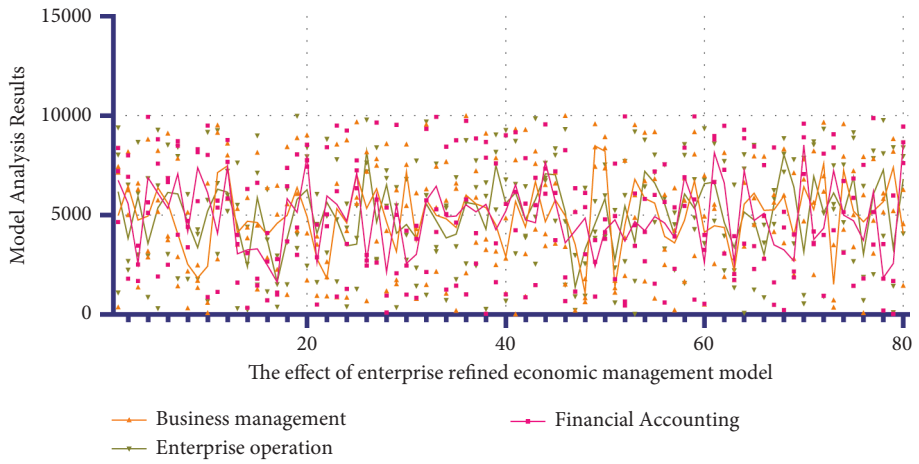

Figure 5: The application effect of enterprise refined economic management model.

financial management work. Second, due to the continuous updating of the knowledge of cost meticulous management, in order to promote the stable economic development of small- and medium-sized enterprises, enterprises need to arrange financial personnel to enter colleges and universities to study relevant content. Therefore, financial personnel can fully understand the relevant knowledge and work flow of refined financial management.

Consider that we have a set of subjects $N = \{i = 1, 2, \ldots, n\}$. S is a subset of N, which represents the cooperative alliance that may be formed between the subjects and is the characteristic function of forming the cooperative alliance, representing the benefits obtained through the cooperative alliance.

$$\begin{cases} V(\phi_i) = 0, \\ V(S_1 \cup S_2) \geq V(S_1) + V(S_2), S_1 \cap S_2 = \phi_i, \end{cases} \tag{7}$$

$$\phi_i = \sum W(|S|)[V(S) - V(S/i)], \tag{8}$$

$$W(|S|) = \frac{(n - |S|)!(|S| - 1)!}{n!}. \tag{9}$$

Further, it lays a good foundation for the financial development of small- and medium-sized enterprises. In addition, refined cost management can reduce unnecessary financial expenditures of various departments and help

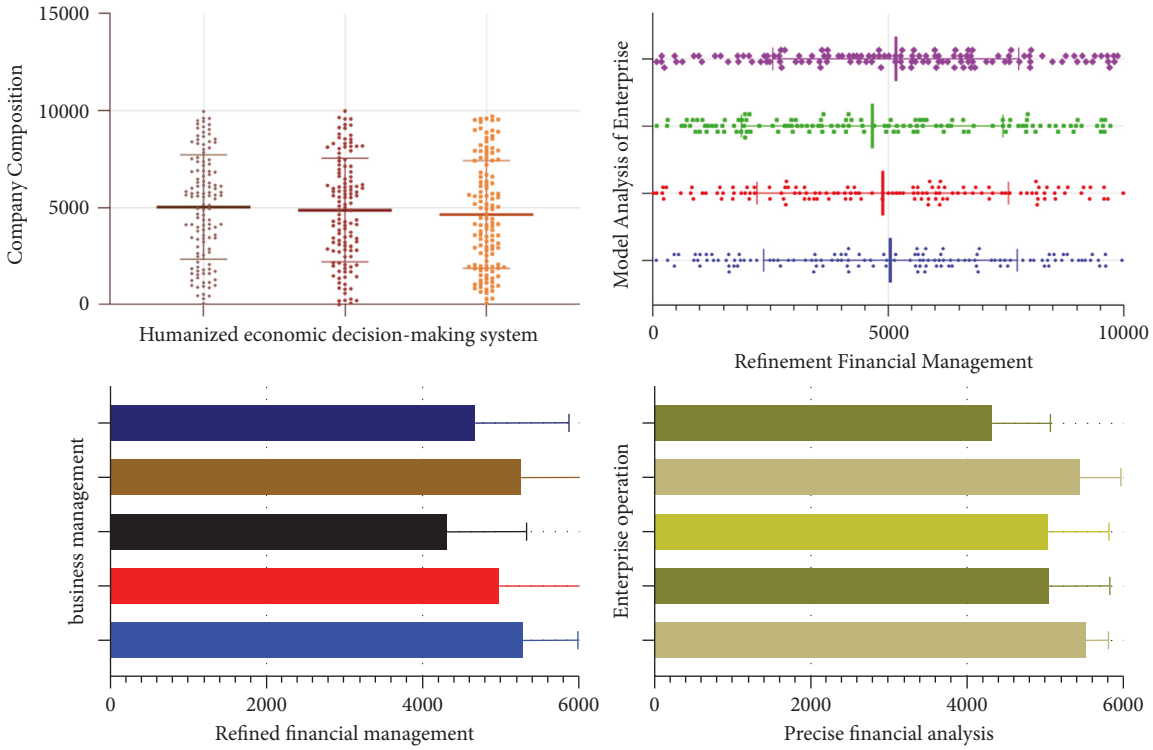

Figure 6: The model analysis of enterprise refinement financial management.

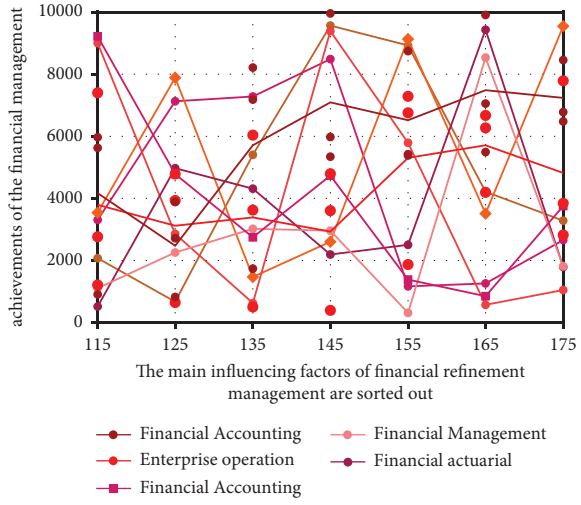

Figure 7: The main influencing factors of financial refinement management are sorted out.

small- and medium-sized enterprises reduce operating costs in order to improve the economic benefits of small- and medium-sized enterprises and promote their further development. Model analysis results are shown in Figure 7.

The full-cost refined management method is applied in the economic management of small- and medium-sized enterprises. There is a need to build a refined information management system. It can be understood from the two following aspects: First, enterprise financial management workload is large, and there are many types of data when the company conducts financial management work.

The constraint conditions are as follows:

$$f(x_i, \omega) - y_i \le \xi_i + 0, \quad 0 = 1, 2, \ldots, 10, \tag{10}$$

$$y_i - f(x_i, \omega) - \le \xi_i + 0, \quad i = 1, 2, \ldots, 10, \tag{11}$$

$$\xi_i, \xi_i * \ge 0, \quad i = 1, 2, \ldots 1. \tag{12}$$

There is a need to manage the existing financial projects and manage the market environment and then promote the stable economic development of small- and medium-sized enterprises. For example, when building a refined information management system, in order to improve the

efficiency of data analysis, it is necessary to design an automatic classification system. Furthermore, to install a monitoring system in it, the enterprise needs to know the operation of the information system in time and then play the significance of financial management. Second, for the enterprise to improve the efficiency of financial work processing and to play the significance of full-cost refinement, it needs professionals to sort out the operation of each financial department before the system is built and build the system. First, corporate accounting staff comprehensively manage various financial activities in production and operation. Enterprises must fully understand the actual situation of the unit and sort out the flow of funds inside and outside the enterprise. Enterprises need to integrate nonfinancial resources and sort out the daily production and operation process and ensure that data can be processed in depth and the stable operation of small- and medium-sized enterprises needs to be promoted. In addition, the operation of the refined information management system will be affected by the outside world. In order to ensure stable operation, professional technicians need to arrange for operation and maintenance management. A refined information management system can exert application advantages in small- and medium-sized enterprises. Model analysis results are shown in Figure 8.

The refined economic management model is built in SMEs. There is a need to build a cost management team. First, the professional ability of cost management personnel has a certain relationship with the quality of economic management. However, when building a management team, managers need to apply assessment methods to select employees with strong professional abilities. They are regularly trained so that they can drive the further development of SMEs. For example, managers can hire economic management experts to train management teams. The security system can improve data collation, market environment analysis, and other capabilities and guarantee the stable operation of the full-cost refined economic management work. In addition, enterprises need to avoid employee work attitude problems through various forms. Second, in various stages of budget execution, accounting staff must compare budget indicators with actual data in a timely manner. When the enterprise finds that the latter exceeds the reasonable range of the index, it should carry out corresponding control, thereby laying a solid foundation for ensuring the realization of corporate budget goals. To avoid the problem of underemphasizing training, it is necessary to conduct assessment work after training and eliminate employees with insufficient professional ability and then achieve the purpose of building a professional cost management team. In order to improve the efficiency of cost management, managers are required to supervise employees in cost accounting and ensure that all parts of the funds can be allocated reasonably. In addition, in order to improve the accuracy of cost management, the cost collection and allocation method can be applied for inspection. This in turn enables SME managers to understand the economic management situation. Model analysis results are shown in Figure 9.

3.3. Economic Management Should Meet the Needs of Enterprise Development. In order to make full-cost refined management take advantage of economic management, it is necessary to improve the operation process. First, economic management work has a certain relationship with drugs. In order to avoid drug quality problems, it is necessary to organize the operation process according to relevant standards. If an enterprise wants to implement the refined management of financial accounting, it must pay full attention to the supervision system of the enterprise. In addition, a special supervision team is established to be responsible for the implementation of the system. For example, in the management of fixed assets, a corresponding management ledger must be established to standardize the change process of assets. In addition, the logistics are managed and controlled to improve the operational stability of small- and medium-sized enterprises. In addition, because the equipment is prone to problems when it is running and circulating, in order to protect the economic benefits of small- and medium-sized enterprises from being affected, it is necessary to apply a refined management model. Management of drugs and equipment is separated to promote the stable operation of small- and medium-sized enterprises. Second, when building operational processes, companies need to exert their economic control capabilities. It needs to classify and design according to the needs of refined management and improve the rationality of capital circulation and ensure the stable development of the economic structure of small- and medium-sized enterprises. Model analysis results are shown in Figure 10.

Refinement management is to implement management measures into every link of economic activities. This ensures that all funds are effectively utilized and managed. Therefore, when managing the corporate economy, it is necessary to focus on relatively large-scale financial activities. At the same time, it is necessary to implement the basic management of financial activities. Thus, the large and small capital of coal enterprises will not be lost at will. The development space of refined economic management methods has expanded. Model analysis results are shown in Figure 11.

3.4. Refined Economic Management Methods for Small- and Medium-Sized Enterprises. Small- and medium-sized enterprises belong to high-yield production, but there are also many places for capital expenditure. Therefore, the financial activities of SMEs are very frequent and concentrated. Financial risks can easily arise in this process, making it impossible for SMEs to manage the economy effectively. Asset changes can be carried out after completing the approval procedures. At the same time, a record of changes is made and they are reported to the archives. Enterprises need to control the refined management level of assets. Therefore, the refined management should be divided into two parts and different parts should be managed separately. These two parts are income and expenses. Leaders need to have real-time control over financial information and create a plan for income and expenses. In addition, several parties do financial management. These parties shall supervise and

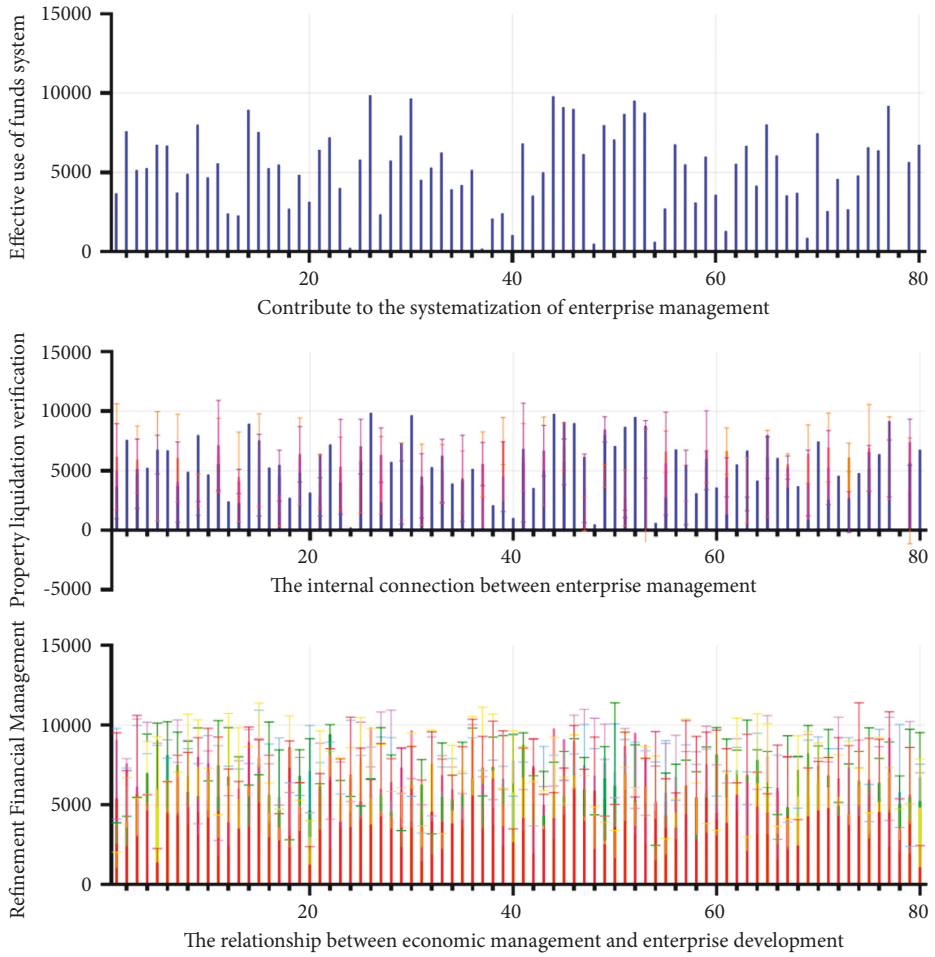

Figure 8: The relationship between economic management and enterprise development.

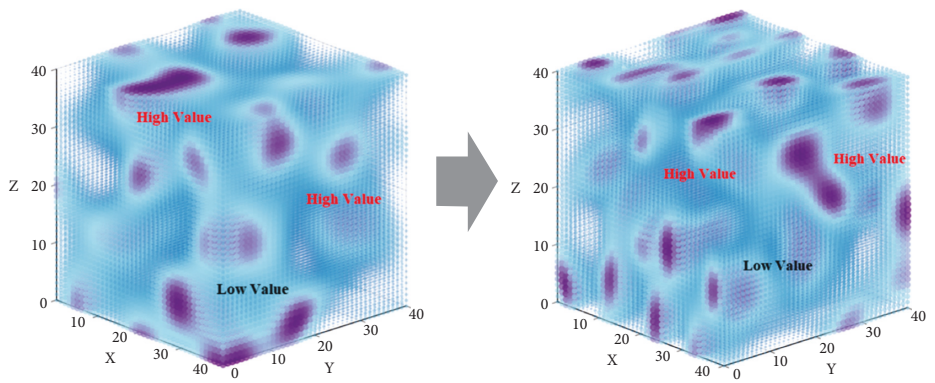

Figure 9: The results of small- and medium-sized enterprise economic management system.

review one another and make where each financial transaction is going clear. For the key financial contents such as chapters, different personnel should also take care of them. In this way, the property of the enterprise will not be lost due to the movement of internal personnel.

Regular economic analysis is an important part of a refined economic management approach. All financial activities can be only accounted for by economic analysis. In addition, the corresponding accountability system should improve according to the actual situation of enterprise development, loss of business assets should be avoided, and the maintenance of fixed assets should be strengthened. This makes financial flows clear at a glance. The financial income and expenditure status and production and operation status are all directly visible. Leaders can conduct research on links with more financial expenditures. Leaders need to consider whether equipment costs are too high. They can then take improvement measures. You can also think about lower-

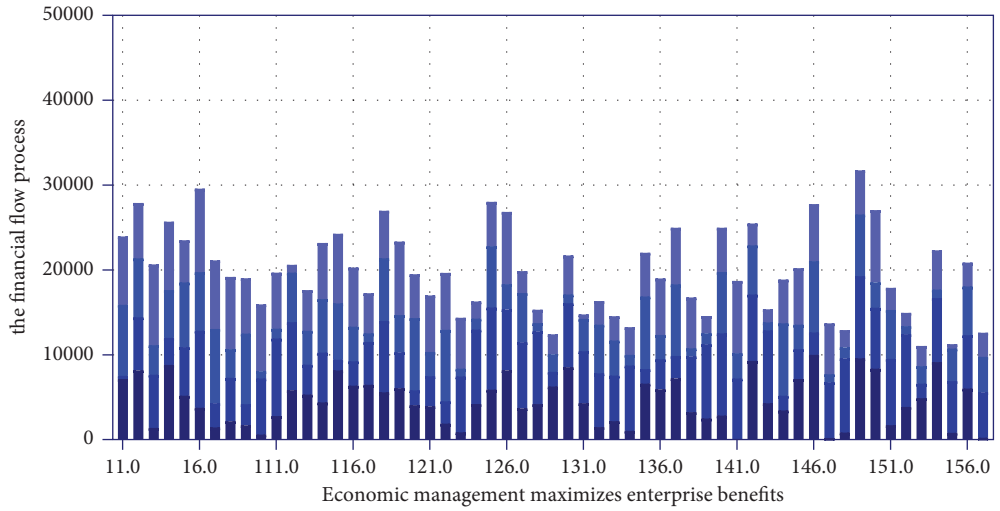

Figure 10: The results of economic management maximizing enterprise benefits.

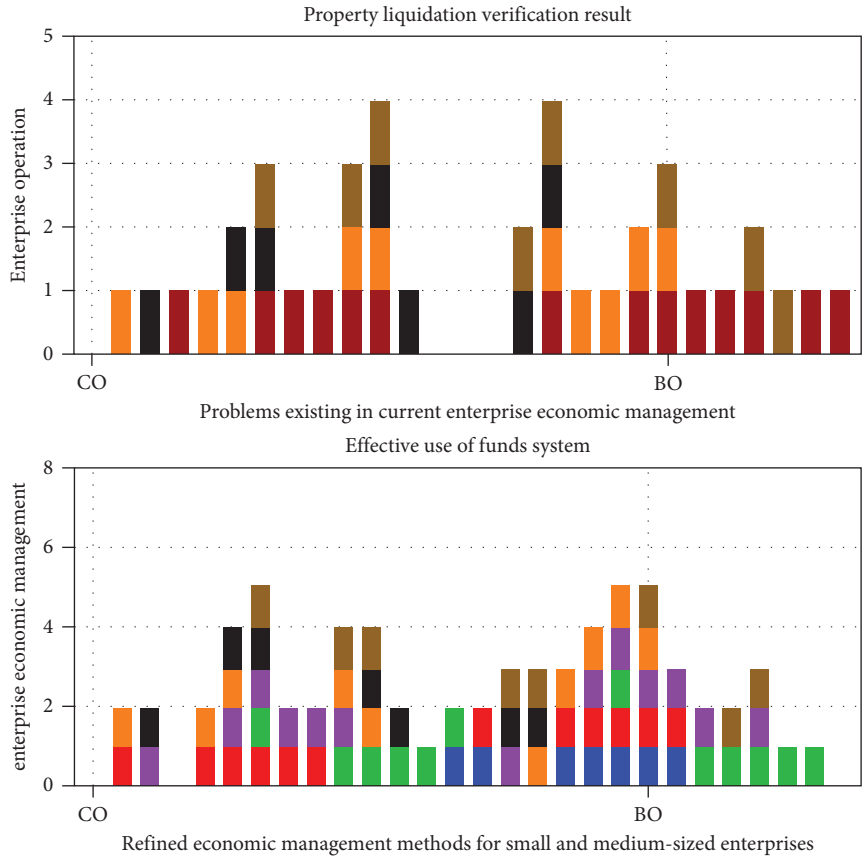

Figure 11: Refined economic management results for small- and medium-sized enterprises.

income areas. Leaders need to further find the crux of the problem. Economic analysis can also directly reflect the overall operating conditions of the enterprise and then take new management measures.

4. Conclusion

4.1. Strengthening Measures of Enterprise Economic Management Methods. Budget work is an important reference for enterprises to make economic decisions, and it is the premise for the formulation of cost-saving measures. Only by understanding the budgetary funds required for the production and small- and medium-sized enterprises can leaders plan the use of funds in each link and then control the use of funds according to the weak points of capital saving in each link and realize the preservation of assets. The company appoints a special person to carry out a detailed inventory of fixed assets and grasp the dynamic changes of the assets in time. For example, the leasing, scrapping, seconding, and so forth of assets all need to go through the approval process, ensure the authenticity and objectivity of financial management, and promote the implementation of refined financial management of enterprises. Doing a good job of budgeting is an inevitable requirement of refined management. Each department should cooperate with the financial department to integrate the information related to the financial activities of the department. It was reported to the finance department. The finance department budgets this information. Finally, the finance department needs to prepare the relevant budget reports. Leaders and related financial personnel should make cost-saving plans for budget reports and then they are distributed to each department. Saving measures are implemented.

4.2. Property Liquidation Verification System and Power Restriction System. Economic management is only a part of enterprise management, and it is very important to do a good job in the daily management of the enterprise. Economic benefits can naturally be guaranteed, so simply adopting economic management is not enough. Therefore, it is necessary to refine the internal management of the enterprise, so that the enterprise can achieve long-term development. There are two main aspects to the refined economic management method. Employees of small- and medium-sized enterprises can have a concept of refined financial management. Also, specific behaviors are linked to company management. For example, in the production and operation of enterprises, employees can operate equipment in accordance with relevant standards and specifications in their own positions, thereby supporting the implementation of production technology in small- and medium-sized enterprises and making the production activities of small- and medium-sized enterprises more rigorous. The chance of production equipment failure is further reduced. The financial department is a very important work for the management of assets. In some important life cycles of asset management, the effective management of enterprise assets can easily lead to unrealistic consequences. The production efficiency of the enterprise can be improved. The maintenance cost is further reduced, and the capital gain becomes more. The economic benefits of the enterprise can be guaranteed. In addition, each employee executes a budget plan. You cannot overbudget by spending your own money. If it has nothing to do with production and operation, employees have to pay for the part that exceeds the budget. When choosing production equipment and other aspects, we must pay attention to the quality of equipment and financial flows and prevent relevant personnel from taking kickbacks from the root cause.

Also, economic management is combined with human resource management. After all, all financial activities are through people. If the overall quality of the staff is high, the problem of operational errors will be less serious. The production efficiency of the enterprise will inevitably improve. High-quality personnel will restrain and regulate their own behavior. In turn, the associated costs are not too high. When human resources are streamlined, labor costs are also reduced. In the way of human resource management, enterprises should adopt a combination of incentive mechanism and assessment mechanism, enable employees to think about financial savings for the company, and help themselves to save costs spontaneously.

To sum up, economic management and enterprise development are complementary to each other. Only by using reasonable economic management methods to manage the enterprise can we ensure the rapid and stable development of the enterprise. The transition of the enterprise relies on the financial management center for asset management. Enterprises also need special personnel to take inventory of their daily operating conditions. When faced with difficulties, the company's losses can be reduced. Of course, after certain achievements have been made in the development of the enterprise, more attention should be paid to its own economic management. Only in this way can the enterprise occupy an important position in the market competition and further strengthen its ability to deal with risks and in turn accelerate its healthy growth. The economic management methods of small- and medium-sized enterprises mainly focus on refined management. The links that spend more money in production and operation can be controlled.

Small and medium-sized enterprises need to realize the benign operation of enterprises through refined management. Enterprises can effectively improve their own development level by changing their development concepts. Enterprises need to classify and control all aspects of their own internal management. This control method can ensure the smooth operation of the enterprise economy and improve the market competitiveness of the enterprise. In addition, because some managers of small- and medium-sized enterprises do not pay much attention to refined management, they do not manage it. This has resulted in unstable operating costs. In order to improve this situation, it is necessary to increase its emphasis on economic management and apply it rationally.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Application of Discrete Mathematical Model in Edge Distortion Correction of Moving Image

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The existing edge distortion correction methods of moving images ignore the consistency of human subjective vision in the restoration process. Therefore, this study proposes an edge distortion correction method of moving images using a discrete mathematical model. According to the image binarization, the moving target region is segmented, the motion fuzzy degradation model is constructed by using the discrete mathematical model, the global structure information of the image is considered by the structure similarity, the image gradient is transformed from the rectangular coordinate system to the polar coordinate system, the image deconvolution algorithm of the edge distribution of the natural image is used to enhance the image edge features, and the edge distortion correction of the moving image is realized. The experimental results show that the astringency of the experimental scattergram is obviously improved, the fitting line is almost a straight line, and it has good recognition of the jump of the gray level of noise points, which can meet the requirements of the consistency of the subjective vision of human eyes.

1. Introduction

The key of motion-blurred image restoration is to know the process of image degradation, that is, to know the degradation model of the image, and then take the opposite process to get the original clear image [1]. There are many reasons for the degradation of image quality. If there is relative motion between the camera and the object during the shooting, the image blur is called motion blur [2–5]. Because the image is often accompanied by noise, the existence of noise not only reduces the image quality but also affects the acquisition of image degradation model and then affects the restoration effect of blurred image [6–8].

The restoration of motion-blurred image is a difficult problem in image processing. The reason is that the causes of image blur are complex, and the image damage is large, so the restoration of motion-blurred image is also very difficult. For example, the camera shakes when taking pictures on the aircraft or spacecraft, moving objects or still objects with the camera [9–12]. Because of the relative motion between the camera lens and the object at the moment of exposure, this kind of blur or even distortion will be caused. In order to restore the image, the plane image processing software is usually used to process the image before, but this software cannot completely and effectively remove the blur distortion, and even if the image quality is significantly reduced after partial removal of the distortion, it is not satisfactory. So, the restoration of motion-blurred image is also an important topic in the field of image restoration [13–16].

The traditional fuzzy image restoration methods are mainly divided into three categories: one is the blind restoration of the fuzzy image based on the frequency-domain characteristics of the digital image; the other is the defocused fuzzy image restoration, which keeps the original edge characteristics; the other is the fuzzy restoration of the moving image in the direction of coordinate transformation [17, 18]. Each blurred image has its own characteristics, such as the degradation of a specific region in the image and the front and back distortion of the image. Kim et al. [19] and Stark [20] proposed local histogram equalization. The basic idea is to define a sub-block of the image and carry out a histogram equalization operation on it and update the gray

level after histogram equalization with the gray level value of the current sub-block. After the update, the sub-block is translated from left to right and from top to bottom, and the above operations are repeated every time, so as to access all sub-blocks of the whole image as the termination condition. This method can well express the image features because the neighboring pixels of each pixel are processed. Because of data redundancy and a large number of floating-point operations in the process of processing sub-blocks, this kind of algorithm has high time complexity and huge computation. In order to reduce the computational complexity of local histogram equalization, in theory, the overlapping degree of sub-blocks should be reduced, while completely nonoverlapping sub-blocks often lead to too large differences in histogram equalization of self-built sub-blocks, resulting in a very serious blocking effect, so they are rarely used. In view of the above problems, Kim et al. [21] proposed a local histogram equalization algorithm with partial overlapping of sub-blocks. By compromising the algorithm efficiency and image quality, the time complexity of this algorithm is obviously reduced compared with the algorithm with overlapping of sub-blocks, and its blocking effect has been greatly weakened compared with the algorithm with nonoverlapping of sub-blocks. Not only that, but it can also be overcome by blocking effect elimination filtering. However, the motion-blurred image is dominated by low-frequency components, while the high-frequency components are few. Therefore, the above method is not applicable. Park et al. [22] designed a fusion heterogeneous confrontation network based on the variants of confrontation generation network, Cyclic GAN and cGAN. On the one hand, the network uses Cyclic Gan to ensure the clarity of the image, on the other hand, cGAN to preserve the texture details of the image. In addition, a fusion loss function is proposed in the network to minimize the artifacts generated by Gan and recover the fine detail color components as much as possible. Because of making full use of the game characteristics of GAN network, it has achieved a good deblurring effect. However, without considering the difference of image degradation degrees at different depths, it is easy to cause information loss and color distortion.

The continuous frame difference method and background difference method are the most widely used independent change detection algorithms [23–26]. In addition, the optical flow method is also one of the commonly used algorithms [16, 27–31]. Because the image inevitably introduces different noises (e.g., environment noise, such as illumination change, image acquisition equipment disturbance, and image enhancement noise), various processing algorithms are different in real time, accuracy, anti-interference, and other indicators. Based on the above research, the edge distortion of moving image is corrected by using the discrete mathematical model, the adaptive threshold method is proposed, and the segmentation algorithm is also added to the image binarization problem. Through the segmentation algorithm, the appropriate threshold can be adaptively selected, and the moving target area can be more accurately separated from the differential image.

2. Edge Distortion Correction Method of Moving Image Based on Discrete Mathematical Model

2.1. Moving Target Tracking. The target detection of moving image sequence is mainly to detect the difference between the two images before and after and obtain the different target areas. In the moving image sequence, the changes of the front and back two frames can reflect the subtle motion of the target. By detecting the changed area, the moving target can be obtained, and then its motion state can be analyzed. The background of moving image sequence is the scene, which has been invariable or changed little in the image frame. The invariable background template is extracted by the background extraction operation. The background is invariable in a period of time.

The process of background extraction is as follows: in a period of time, N consecutive image frames G_i, of which $i = 1, 2, \ldots N$ are obtained by sampling; for each pixel (a, b) in the image, the pixel extraction formula is as follows:

$$D(a,b) = \frac{\sum_{i=1}^{N} G_i(a,b)}{N}. \tag{1}$$

From the formula, it can be seen that the larger N is, the more average the pixel value is, the more accurate the background extraction is, but, at the same time, it will increase the computational complexity. Extracting the moving objects from each frame of the moving image sequence is an essential step for tracking the moving objects [32–35].

When extracting a moving object, there may be multiple blocks in the binary image. Generally, the block where the moving object is located is the largest, and the area is greater than 100, so the block with the largest area can be found. If the condition is met, the target can be determined. Because the moving target and the static background are different in the gray-scale domain, the current frame image and the background image are subtracted, and then the binary operation is used to obtain all the moving point clusters of the current frame.

Image binarization is a key step in target detection. There are two common binarization methods: fixed threshold binarization and adaptive threshold binarization. Among them, the fixed threshold binarization is that the value of preset U can be obtained according to experience. When the difference value of a pixel is greater than U, it will be determined as a moving target pixel; otherwise, it is a background pixel. The judgment is as follows:

$$f_u(a,b) = \begin{cases} \text{background} & f(a,b) < U \\ \textit{motion} & f(a,b) \geq U \end{cases}. \tag{2}$$

The limitation is the selection of U, and a good strategy can bring good accurate target extraction. There are a lot of small holes and isolated points in the target area of binary image, and some of them have broken lines, so they cannot be directly used for target tracking, and usually need to use morphological filtering method to process binary image. The basic idea of morphological filtering is as follows: corrosion

template is used to eliminate isolated noise points, and expansion template is used to eliminate cavities and broken lines. Two basic operations are commonly used: expansion operation and corrosion operation.

The expanding effect makes the groove in the image be filled and gradually expanded into a rectangle with rounded corners. The effect of corrosion makes the grooves in the image wider and deeper. Two morphological filtering operations, open operation and closed operation, are derived from expansion and corrosion. The difference between open operation and close operation is obvious; the effect of open operation is to eliminate isolated points and small targets. The effect of closed operation is to increase pixel points so that areas such as cavities can be connected together.

The expansion operation can make the target more "full" (increase the number of target pixels, fill holes, and cracks); the corrosion operation can eliminate the isolated small points and redundant small lines in the target. The specific process is as follows: morphological filtering needs to use structural elements, square is one of the three commonly used structural elements, and the inversion of its definition of structural elements is as follows:

$$D^c = \{-d | d \in D\}. \tag{3}$$

The corrosion is as follows:

$$\alpha_D(A) = A \oplus D^c = \bigcap_{d \in D} A_{-d}. \tag{4}$$

After mathematical morphology filtering, the image still cannot be used for target tracking, because there are still large holes in the image, which has a great impact on target determination, so it is also necessary to carry out connectivity analysis on the image of opening and closing operation. For a set of pixels, if each pixel in the set is connected with other pixels in the set, the set of pixels is a connected component. Connectivity analysis is to find out all the connected components in the morphologically processed image and mark all the pixels in each connected component with the same mark. Different connected components have different marks. Connectivity analysis often uses 4-connected and 8-connected methods. Sequential algorithm and recursive algorithm are used to identify each target position. Among them, the recursive algorithm is relatively inefficient, so the sequential algorithm is more often used.

Based on an 8-connected sequential algorithm, the specific operation steps are as follows:

(1) Scan the image from left, right, up, and down in sequence. If the gray value of the pixel point is 1, the process to be followed is as follows:

(2) If only one of the four points on the left, the top left, the right, and the top right has a mark, then the mark is also used for the pixel point; if there are four same marks, the mark is also used for the pixel point.

(3) If these four points have different marks, then any mark is randomly selected as the mark of the pixel, and this mark and different marks are recorded in the equivalence table and treated as equivalent marks; otherwise, a mark is regenerated and assigned to the pixel point, and the new mark is recorded in the equivalence table as equivalent marks.

(4) Repeat until all points are marked. Scan the whole image and replace each mark with the lowest mark in each equivalence set in the equivalence table.

(5) Calculate the proportion value of all pixels owned by each marker to the whole image pixels, and then use this value to compare with the preset target pixel threshold value to determine the target: if it is greater than the specified threshold value, it is the target to be found; otherwise, it is not the target.

2.2. Acquisition and Restoration of Motion Fuzzy Parameters Based on Discrete Mathematical Model. Because the target is in motion, the image is blurred. For motion-blurred images, blur can be regarded as the moving track of objects. When objects are distinguished from their backgrounds, this kind of blur looks very clear. Therefore, there are two very important model parameters: fuzzy direction and fuzzy scale.

Assuming that the opening and closing time of the shutter is very short, the optical imaging process will not be interfered by the motion, and the motion blur degradation of the image will not appear. If the exposure time is set, then motion blur degradation occurs. If T is set as the exposure time, then the motion blur degradation model is as follows:

$$h(x, y) = \int_0^T f\left(x - x_0(t), y - y_0(t)\right) + m(x, y). \tag{5}$$

In the above formula, $h(x, y)$ is the blurred degraded image, $f(x, y)$ is the original image, $m(x, y)$ is the noise, t is time, and $x_0(t)$, $y_0(t)$ are the moving distance of pixels in t time. In order to speed up the calculation, a Fourier transform should be carried out for the above formula when there is no noise.

When the length and width of the processed image are not equal, it is not accurate to simply think that the blur angle and the slant angle of the stripe are vertical. If the image is cropped improperly, the original image information will be destroyed. Especially for the captured high-speed vehicle image, the background is still and only the vehicle moves, so the original pixel information will be better preserved. For example, forcibly trimming the image to a square will bring adverse effects on the detection of fuzzy parameters. For any size image, once the angle of spectrum fringes of degraded image is detected, the motion blur angle is determined.

For motion-blurred images, we need to collect edge information of different gradient directions. First, we transform the image gradient from the rectangular coordinate system to the polar coordinate system, then divide the gradient direction into four regions to avoid the local minimization of the threshold, and select the first t edges with the largest intensity for each region. According to the size of image and blur kernel, the appropriate threshold is selected. The threshold t is determined by the following formula:

$$t = \max\left(\frac{\sqrt{p_I p_k}}{m, n}\right). \tag{6}$$

In the formula, p_I represents the total number of pixels in the image, p_k represents the size of the blur kernel, n represents the minimum threshold value, which guarantees the minimum edge information needed in the blur kernel estimation process, and m represents the weight.

Mathematically, images use continuous or discrete methods to represent the spatial distribution and color intensity of their pixels. In discrete space, a matrix is usually used instead of continuous space. If the ideal image is matrix l, the degraded image is matrix b, and the point spread function is matrix h, then the image degradation model can be defined as follows:

$$b = h \cdot l. \tag{7}$$

The definition domain of point spread function is $(-\infty, +\infty)$, which indicates that every pixel in the degraded image is affected by other points in the whole scene space, and any change of point will lead to error.

For the two-dimensional function, randon transformation is used to calculate its projection transformation in a certain angle ray direction, that is, its line integral in a certain direction. For an image, the randon transform reflects the projection properties of the image in different directions. First, the obtained spectrum image is preprocessed by binarization. If the coordinate axis turns to be perpendicular to the direction of the fringe, the maximum value of the randon transform is the maximum value of the maximum value of the randon transform of each angle, so the tilt angle of the dark fringe can be determined by finding this maximum value. The width of the two-dimensional transformed image obtained by randon transformation at this angle corresponds to the width of the center adjacent dark stripe in the spectrum image, and the adjacent dark stripe spacing corresponds to the corresponding position.

In the mathematical model, the edge statistical property is usually regarded as a regularization term, thus the deconvolution problem is transformed into a well-posed problem. The image deconvolution algorithm based on the edge distribution of natural image can be expressed by the following mathematical model:

$$\widehat{l} = \arg\min_{l} \|l \cdot k - b\|^2 + \mu\|\nabla l\|^{\rho}. \tag{8}$$

In the formula, $\|l \cdot k - b\|$ represents data matching term, which requires that the degradation process conforms to the description of fuzzy kernel K, $\|\nabla l\|^{\rho}$ represents image prior knowledge, that is, image gradient distribution fitting term, and ∇l represents image gradient.

Because when processing the image, detecting the distance between adjacent dark fringes will produce an absolute error, with a maximum of 1 pixel. In this case, the absolute error can be reduced by detecting the total distance between multiple dark fringes, detecting the absolute error generated by the length, and then taking the average value of the distance between fringes [36]. For the general resolution image with lower resolution, when the smaller noise exists in the spectrum image, except the center dark stripe is still clear and visible, other dark stripes are blurred. In this way, it can detect the spacing of multiple dark stripes and reduce the resistance to noise by taking the average value. The mathematical formula is as follows:

$$\frac{\partial I}{\partial t} = -sign(G_\sigma \cdot \Delta I)\|\nabla I\|. \tag{9}$$

In the formula, ∇I represents the first-order and second-order directional derivatives of image I. The first-order edge detection operator and Laplace operator are used to obtain them respectively. $sign(x)$ represents the positive and negative of return x, which makes the sharp jump at the inflection point in the input signal and sharpens the signal, thus enhancing the edge characteristics of the image.

Based on the above theoretical analysis, we can design a method to detect the angle and length of motion blur, realize the automatic restoration of degraded image, and realize the edge distortion correction of moving image.

3. Experimental Verification and Analysis

The development tool for this experiment is MATLAB2015, vs2013+opencv2.4.9. The processor is Inter(R) Core(TM) i7-6700 CPU, with the main frequency of 3.4 GHz and the memory of 8 G. The experimental data are based on the live image quality estimation database II provided by the image and video Engineering Laboratory of Texas University in the United States. There are 779 distorted images in the image database, including four types of distortion: Gaussian blur, white noise, JPEG, and fast fading, in which fast fading is the image distorted due to errors during the transmission of JPEG 2000 code stream in a fast fading channel. The live image library also provides DMOS of subjective score difference. The larger the DMOS value is, the worse the image quality is. The smaller the DMOS value is, the better the image quality is. Because DMOS is the difference between the subjective score MOS and the full score (100), its value range is [0100].

Four commonly used parameters of objective image quality evaluation methods are used as evaluation indexes in the experiment, namely, correlation coefficient, absolute error mean value, root mean square error, and rank correlation coefficient under the condition of nonlinear regression. Root mean square error is a kind of numerical index to measure the measurement accuracy. Its value is the square root of the mean value of the square sum of the deviation between the predicted value and the true value:

$$MSE(x, y) = \frac{1}{n \times m} \sum_{i=1}^{n \times m} (x_i - y_i)^2, \tag{10}$$

where x represents the real image and y represents the corrected image.

Using the correction method designed above, the five types of distortion images are tested separately, and the results are compared with the existing methods. The existing methods are set as the control group, and the designed

(a) (b)

Figure 1: Image restoration effect. (a) Blurred image (b) Restoration rendering.

method is the experimental group. Through the subjective score difference, the differences between the two are analyzed, and the experimental conclusions are drawn.

3.1. Experimental Results of Gaussian Blur Distortion Image. Gauss blurred image is mainly due to the loss of edge information, resulting in the degradation of image quality. The proposed method extracts the edge information as an area separately and focuses on it. The image correction effect is as follows:

As can be seen from Figure 1, the method in this study can well correct the distorted part of this kind of image, which is highly consistent with the subjective feeling of human eyes. The specific experimental results are shown in Table 1 and Figure 2.

It can be seen that the performance indexes of the experimental group are significantly better than those of the control group, in which the correlation coefficient value under the condition of nonlinear regression is increased by 0.1038, the mean absolute error is reduced by 3.0133, and the square root of mean square deviation is reduced by 4.3037. The astringency of the scatter diagram is very good, the fitting line is almost straight, and the correction of the image with serious distortion is more accurate.

3.2. Experimental Results of White Noise Distortion Image. The white noise distortion image is obtained by adding Gaussian white noise to the undistorted image, and the noise points in the image are randomly scattered on the whole image, independent of the content and structure of the image. The correction effect is shown in Figure 3.

In the experimental group, JND threshold is used to judge whether the distortion is visible or not, and the jump of the gray level of noise points is well recognized. Therefore, the correction results of the experimental group are in good agreement with the subjective evaluation (Table 2 and Figure 4).

From the comparison of the above results, we can see that each index of the experimental group is better than that of the control group, and for the images with higher fidelity, the scatter diagram is more convergent.

Table 1: Comparison of edge correction performance of Gauss blur distortion image.

	Experience group	Control group
Correlation coefficient	0.9768	0.8730
Mean absolute error	2.7437	5.7570
Root mean square error	3.3643	7.6680
Rank correlation coefficient	0.9755	0.8953

3.3. Experimental Results of Fast Fading Distorted Image. Fast fading distortion is a full frequency distortion. The correction effect chart is shown in Figure 5.

In the frequency domain, the edge contour information represents the medium and high-frequency information of the image. The experimental group modifies the medium and high-frequency information, and the result is better than that of the control group (Table 3).

It can be seen from the experimental results that each index of the experimental group is better than that of the control group, and the consistency between the results of the experimental group and the subjective evaluation is significantly better than that of the control group in the case of large distortion of the scatter diagram (Figure 6).

3.4. Experimental Results of JPEG Distorted Image. JPEG is an image coding method based on DCT transform. After quantization coding, the image will produce a block effect. The higher the compression rate, the more obvious the block effect is. It looks like some false edges to human eyes. The existence of block effect may lead to obvious distorted edge in the nonedge region, while the experimental group mainly considered the loss of real edge information during the correction process (Table 4).

It can be verified from the experimental results that the results of the experimental group are only slightly higher

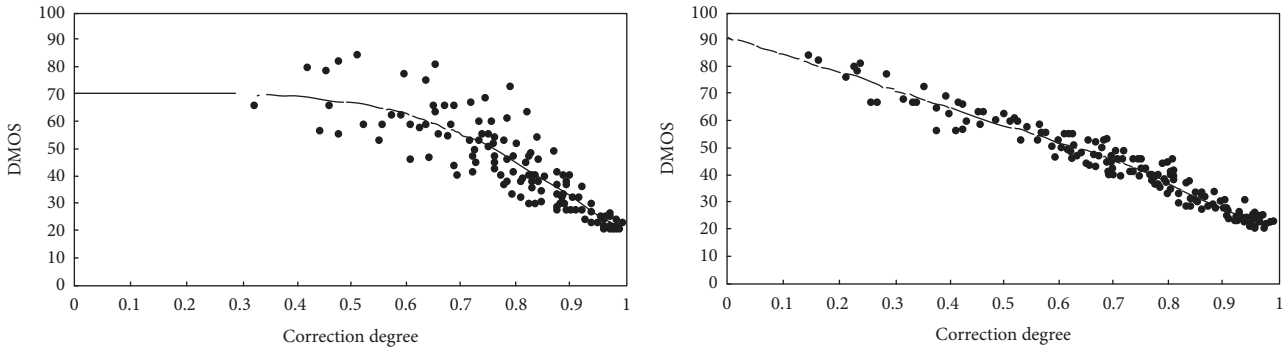

Figure 2: Edge correction scatter of Gauss blur distortion image. (a) Control group. (b) Experience group.

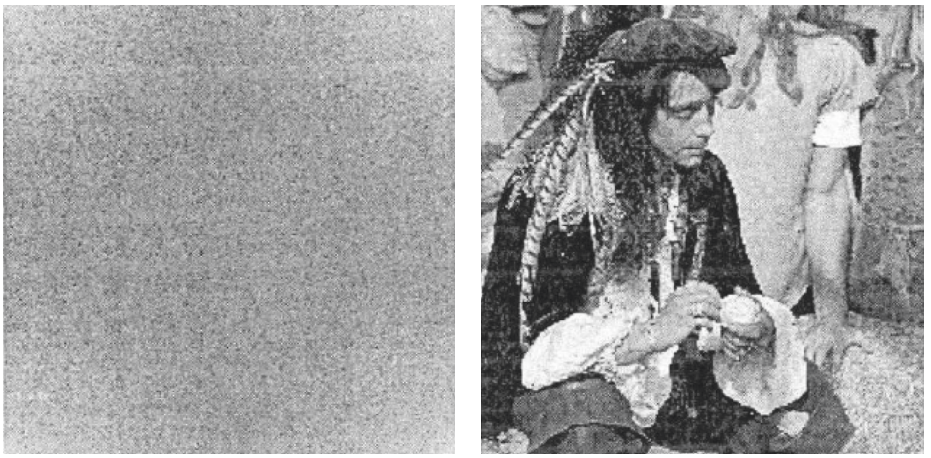

Figure 3: Correction effect. (a) White noise image. (b) Corrected image.

Table 2: Comparison of edge correction performance of white noise distortion image.

	Experience group	Control group
Correlation coefficient	0.9826	0.9724
Mean absolute error	2.3896	3.1049
Root mean square error	2.9669	3.7259
Rank correlation coefficient	0.9780	0.9633

than that of the control group under the JPEG distortion, and the scatter diagram is more similar (Figure 7).

From the above results, we can see that this method has a better correction effect for different blurred moving images. The main reason is that the edge distortion correction method is based on the discrete mathematical model, which emphasizes the influence of human visual characteristics on the basis of structure similarity. It not only considers the structural similarity to the global structure information of the image but also extracts the edge region of the image according to the physiological and psychological characteristics of human vision and strengthens the obvious edge distortion that can be perceived by human eyes. It not only makes up for the shortcomings of the existing methods for correction of serious distortion and cross distortion but also reduces the complexity of correction.

4. Discussion

In this study, a method of image edge distortion correction is studied by constructing a discrete mathematical model of motion blur. Experiments show that this method can effectively correct the distorted part of the image, the mean absolute error and the root mean square error are both small, and it can cope with various types of distorted images and maintain good application performance.

In practice, many cases of motion blur are caused by nonlinear and nonuniform motion, but many of them can also be approximately regarded as uniform linear motion or synthesized by uniform linear motion, so uniform motion blur has certain representativeness. Digital image restoration is to use the prior knowledge of image degradation to restore the degraded image. Its goal is to recover the original image from the degraded image. Mathematically speaking, it belongs to the mathematical inversion problem of calculus equation. Image restoration is an important and difficult

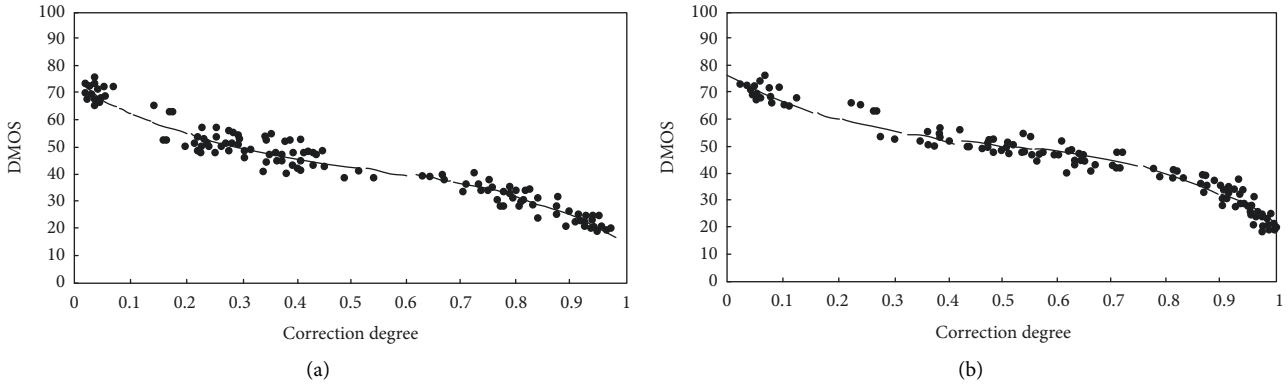

Figure 4: Edge correction scatter of white noise distortion image. (a) Control group. (b) Experience group.

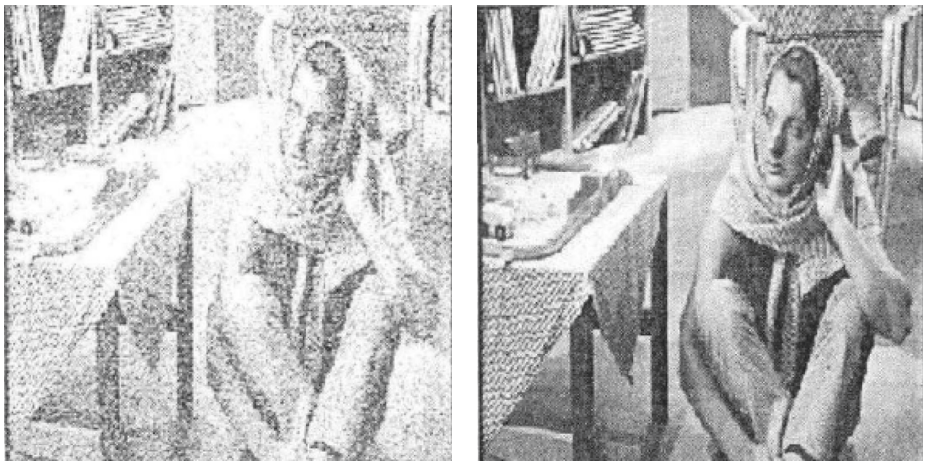

Figure 5: Correction effect. (a) Fast fading distorted image. (b) Corrected image.

Table 3: Comparison of edge correction performance of fast fading distorted image.

	Experience group	Control group
Correlation coefficient	0.9696	0.9401
Mean absolute error	3.1432	4.4445
Root mean square error	4.0236	5.6087
Rank correlation coefficient	0.9660	0.9401

problem in image processing, which has not been completely solved.

For the restoration of degradation, two methods are generally used: one method is suitable for the case where the image lacks prior knowledge. At this time, the degradation process can be modeled and described, and then a process of removing or weakening its influence can be found. Because this method attempts to estimate the situation before the image is affected by some relatively known degradation processes, it is an estimator law. If the other method has sufficient prior knowledge of the original image, it is more effective to build a mathematical model for the original image and fit the degraded image according to it. For example, if the known image only contains a circular object of a certain size, this is a detection problem because only a few parameters of the original image are unknown [37–42].

In image restoration, there are many other choices in mathematical methods. First of all, the problem can be solved by either continuous mathematics or discrete mathematics; second, the problem can be solved in both spatial domain and frequency domain. In addition, when the restoration must be done by mathematical method, the processing can be realized by convolution in the spatial domain or multiplication in the frequency domain [43]. In this way, we can choose the most suitable method according to the requirements and constraints of the problem under the condition of making clear assumptions. For physical problems, linear motion in any direction can be decomposed into two perpendicular directions. But for any direction of linear motion-blurred image, it cannot be considered in this way. Different from the physical problem, the image degradation process involves the image information in a specific direction, which is decomposed into two mutually perpendicular directions, which will inevitably make the image

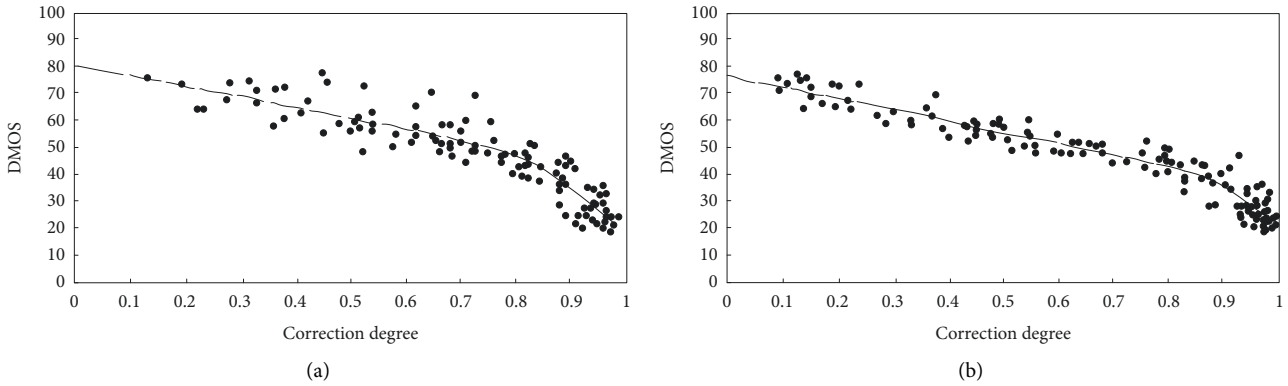

Figure 6: Edge correction scatter diagram of fast fading distorted image. (a) Control group. (b) Experience group.

Table 4: Comparison of edge correction performance of JPEG distorted image.

	Experience group	Control group
Correlation coefficient	0.9381	0.9284
Mean absolute error	4.1282	4.4901
Root mean square error	5.5385	5.9397
Rank correlation coefficient	0.9087	0.9030

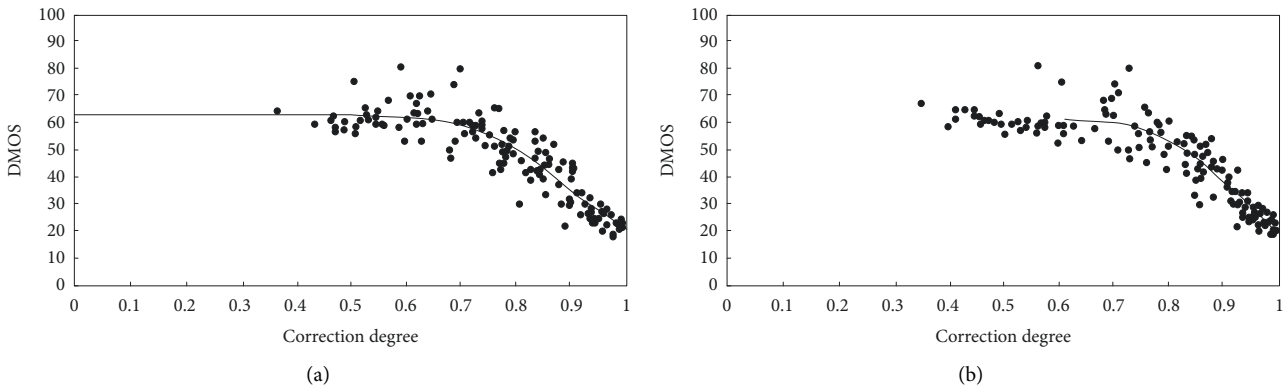

Figure 7: Edge correction scatter of JPEG distorted image. (a) Control group. (b) Experience group.

information obtained by the two processes very different. Therefore, the blurred image generated by straight-line motion in any direction can only be recovered directly in its motion direction and cannot be decomposed into two one-dimensional directions.

Moving target tracking has a wide application prospect in aerospace exploration, military field, unmanned driving, robot, and other fields, and it is an important research topic in the field of computer vision [44]. It is an important research direction of target tracking research to mark the moving objects interested in moving image sequence or video sequence and track the moving objects accurately and continuously for a long time by using the target tracking algorithm. The moving target data are obtained and analyzed how to achieve a good tracking effect for a long time in the scene of illumination change, target shape change, and so on.

In the follow-up study, we will propose a low contrast enhancement algorithm for the moving image sequence with unbalanced illumination to achieve the image brightness balance and a good distinction between background and foreground. Using the target tracking algorithm, we can track the moving target and achieve a better target tracking effect under the dynamic background and object deformation. The proposed target tracking method can accurately track the target under static background and background change and can also adaptively adjust the target shape change to prevent the target from losing or error. A moving image sequence target tracking tool is designed and developed. Its main function modules are as follows: image preprocessing module, target detection module, and target tracking module. It is convenient to set parameters and execute the specific algorithm, which saves the tedious work of manually modifying parameters and facilitates the integrated management.

The object tracking of brightness changing video sequence is divided into video enhancement and object

tracking. The video sequence of shape changing is gradually studied from simple to complex, and the object tracking algorithm of video sequence is studied step by step from static background to dynamic background to shape changing. The multicamera target tracking system not only includes the knowledge of computer vision and information fusion but also involves the theory of pattern recognition and artificial intelligence. It is a multidisciplinary research problem. Multicamera target tracking with the overlapping visual field can track the moving target from different angles, which can effectively solve the problem of target loss when the target is occluded or enters a dead angle. However, it is difficult to correctly match the target information obtained by cameras with different viewing angles. Multitarget and multicamera tracking are directions for future research.

5. Conclusion

In this study, the discrete mathematical model is used to optimize the fuzzy motion image correction. According to the image binarization, the moving target area is segmented. The discrete mathematical model is used to build the motion fuzzy degradation model, obtain and restore the parameters of the motion fuzzy image, and realize the edge distortion correction of the motion image. It is hoped that the above content can provide a reference for the research in related fields. Due to the urgency of the research time, there are still some deficiencies that need to be improved in the follow-up research.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Tax Incentive Policy and Enterprise Innovation: From Enterprise Heterogeneous Perspective

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In the study, data of Chinese listed companies in city Hangzhou, Ningbo and Wenzhou from 2012 to 2019 are used for detailed analysis. According to the data analysis, we have got several results: (1) the tax incentive policy has a significant promoting effect on the innovation activities of enterprises. (2) For such microlevel data, we also can get more detailed conclusion by enterprise heterogeneity. Heterogeneous factors do affect the effect of tax incentives on enterprise innovation input. Based on these findings, we can provide well-directed suggestions for future actions of enterprises and policy makers.

1. Introduction

Innovation is the core of competitiveness in changeable market. But how can innovation help society to develop sustainably? It is a heated question concerned by policy makers and researchers. Among the policy instruments, tax policy is one of the common incentive tools related to technological innovation. Tax tools can be used as flexible policy instruments to participate in government support and guide enterprises to carry out innovation. Giving the role of market players, different tax policy tools can provide targeted support to key developing industries and effectively promote the steady development of innovation and entrepreneurship. It is of great applicable significance that we clarify the influence mechanism between tax incentive policy and enterprise Innovation.

In China, the conventional corporate income tax rate is 25%, but high-tech enterprises can enjoy a preferential tax rate of 15%. In addition to preferential tax rates, R&D expenses can be extradeducted, which also reflects the encouragement of tax policies for enterprises' innovative behaviors. Different from the crowding-out effect that direct government subsidy may bring to enterprise innovation, tax incentive, as a postincentive, can effectively improve the effectiveness of policy tools and bring crowding-in effect to improve enterprise innovation efficiency [1]. Similarly, in Europe, there are special "patent boxes" in which profits generated by patents receive special tax benefits. Studies have shown that such "patent box" policy can indeed promote R&D investment of enterprises, even if such tax advantages are sometimes not fully reflected [2]. In addition, front-end tax policy and back-end tax policy have different functions. Front-end tax incentive policy is more likely to promote patent acquisition, while back-end tax policy is more likely to promote patent trading [3].

Although there is a long history of literature on the impact of policy instruments on firm innovation activities, but previous studies on this topic mostly used yearbook data of region or industry [1] to discuss it at the macro level, also some comparative studies at the national level [3, 4]. The purpose of the study is to bridge the research gap of microlevel on the topic. In this study, enterprise data of city Hangzhou, Ningbo and Wenzhou were adopted, since these cities are located in a very innovative district of China. In this way, the study could be deeply explored from the perspective of enterprise heterogeneity, and the conclusions obtained would have more practical significance and guiding value for policy making, which is the main contribution of the study.

Next, the study will be expanded from the following parts: the second part is the literature review and hypothesis;

the third part introduces data source, variable setting and model establishment. In the fourth part, empirical analysis is conducted to test whether tax incentive policies have a promoting effect on enterprises' innovation activities, and what the specific influence mechanism is, from the direction of overall sample and heterogeneity of different enterprises. The last part is the conclusion and discussion, which provides suggestions for enterprise management and policy makers according to the research conclusions of the study.

2. Literature Review and Hypothesis Development

In the short run, innovation can have a negative impact on corporate profits, but innovation-related tax incentives can offset this negative effect [5]. In addition, cheaper R&D directly stimulates R&D because of the tax-saving capacity of R&D activities [6]. In this way, a benign closed loop is formed. Similarly, R&D and import are also complementary. R&D can promote the increase of enterprise income and profit, while reducing cost and increasing profit through import can further promote R&D investment. Both R&D and import are aimed at reducing costs [6]. And control tax rate rise, also be the effective way that controls cost for the business [7, 8].

In this way, we propose:

H1: tax incentive policies can promote the innovation input of enterprises.

On the contrary, some scholars believe that, compared with solving financing constraints and creating a good IP right protection environment, tax policy is not an efficient means to promote innovation. Stronger creditor rights and more generous R&D tax credits have a negative differential relation with R&D in more innovative industries [9, 10]. Sometimes in a small range and in a short term, it may not reflect the obvious promotion effect of tax policies on innovation and entrepreneurship [11]. However, more often than not, we still believe that tax policies can effectively promote the innovation of enterprises. Although tax may seem expensive relative to other policy tools, it is still a sustainable policy support in a time of public spending cuts [12, 13]. In addition, the degree to which enterprises are closely connected with other enterprises in the social network will also affect the effect of tax incentive policies [14]. Meanwhile, for young knowledge-based firms, subsidies are a more direct support to start innovation compared with tax incentive [15]. However, some studies think that compared with subsidies' selectivity towards the company's productivity, there is no selectivity from tax policy [16]. Sometimes, however, tax policies introduced by governments seeking short-term stabilization will stifle innovation and economic development [17]. It also illustrates the risks posed by policy uncertainty. Moreover, if companies receive multiple R&D policy supports (for example, both subsidies and tax incentives) at the same time, the efficiency of policy support will be reduced [18].

Then, we propose the following:

H2: tax incentive policies can promote the innovation output of enterprises.

The effect of tax incentive policies is also different in different situations, which reflects the influence of heterogeneity on the effect. Even if tax policies can promote enterprise innovation, they still have different effects on different enterprises [19]. For example, for enterprises of different sizes [20], the effects of policies are different [21]. For example, enterprises that receive more preferential treatment have more obvious effects on promoting innovation [22]. For example, in technology-intensive industries, enterprises will enjoy more tax incentive policies, thus increasing the positive external effects of innovation input and output [4]. Those enterprises that truly establish themselves in the market through innovation will continue to take advantage of tax incentives, but not just for short-term benefits [23]. However, the influence of tax incentive policies on non-high-tech enterprises or enterprises without innovation profits is not obvious [24]. When enterprises are poorly managed and innovative activities are diversified, tax policies are hard to play the expected role of incentive [25].

Then, we propose:

H3: heterogeneous factors (H3a: property right nature, H3b: high-tech enterprise, H3c: industry type, H3d: district) will affect the effect between tax incentive policies and enterprise innovation input.

3. Data and Methodology

3.1. Data Sources. In this study, the data of Chinese listed companies in city Hangzhou, Ningbo and Wenzhou from 2012 to 2019 are collected from CSMAR (China Stock Market and Accounting Research) database. After eliminating the missing values, 1037 valid samples are obtained.

3.2. Variable Measurement

3.2.1. Dependent Variable. Innovation Input: Innovation investment is mainly capital investment, measured by research and development costs [26].

Innovation Output: innovation output can be measured both quantitatively and qualitatively. The most common way to measure innovation output is the number of patents of an enterprise, while the quality of innovation is generally measured by invention patents [27].

3.2.2. Independent Variable. Tax incentive policy: in this paper, the tax policy tool is represented by tax incentives. The actual income tax rate is obtained by (income tax expense/the total profit of the enterprise), and then the tax incentive enjoyed by the enterprise is obtained by (the conventional enterprise income tax rate of 25%-actual income tax rate) [28].

3.2.3. Control Variable. The R&D activities of an enterprise are also affected by the size of the enterprise (usually larger enterprise has more economic power and strategic insight

for R&D), asset-liability ratio and the return on total assets (these two factors are tightly related the enterprise's financial performance, which is the foundation of R&D investment) [29]. Therefore, these indicators are also put into the model as control variables.

3.3. Model Set. According to the second part of the theoretical foundation and the hypothesis proposed, we know that tax incentive policies, on the one hand will affect the enterprise's innovation input, on the other hand may also affect the innovation output of the enterprises. And the enterprise heterogeneity factors (such as the property rights, industry, district) will affect the tax incentive policy effect on enterprise innovation investment. On this basis, we draw the following theoretical frame, and establish the analysis model in Figure 1.

Firstly, a model of the impact of tax incentive policies on enterprise innovation input is established. In order to eliminate heteroscedasticity, logarithmic transformation is taken for enterprise innovation input. In Model 1, ordinary mixed regression was used for testing. Since the sample data is unbalanced panel data, fixed-effect model was also used for further verification in Model 2.

$$\ln RD\exp_i = \alpha + \beta_1 \text{taxincen}_i + \beta_2 \ln \text{asset}_i + \beta_3 assetliab_i + \beta_4 ROA_i + \varepsilon_i, \quad (1)$$

$$\ln RD\exp_{it} = \alpha + \beta_1 \text{taxincen}_{it} + \beta_2 \ln \text{asset}_{it} + \beta_3 assetliab_{it} + \beta_4 ROA_{it} + \varepsilon_{it}. \quad (2)$$

Then we examine the impact of tax incentive policy on enterprise innovation output. Since the dependent variable is a counting variable, model 3 first adopts mixed Poisson regression to test, and then adopts ordinary mixed regression for the robustness.

$$\text{Invention/Patent}_i = \alpha + \beta_1 \text{taxincen}_i + \beta_2 \text{lnasset}_i + \beta_3 \text{assetliab}_i + \beta_4 \text{ROA}_i + \varepsilon_i, \quad (3)$$

where i is each sample Chinese enterprise; t is each year, $t = 2012, 2013, \ldots, 2019$; lnRDexp is the logarithm of innovation capital input; Invention/Patent is the innovation output; taxincen represents the tax incentive policy the sample enterprises applied; lnasset, assetlib and ROA, respectively, is the logarithm of enterprise asset, asset-liability ratio and the return on total assets as control variables. α is the intercept that does not change with individuals; β is the parameter to be estimated; ε is the error term subject to normal distribution.

4. Results

4.1. Descriptive Statistics. Descriptive statistics of main variables are shown in Table 1. It can be found that there is a huge gap in the sample enterprises' application of tax incentive policies. Some enterprises can apply very low tax rates after enjoying tax incentive policies, while others hardly enjoy any tax incentive policy at all. In terms of enterprise innovation input, there is a huge difference between enterprises with least investment and those with most investment, and the difference is more than millions of times. Therefore, in terms of innovation output, some enterprises may have no innovation achievements, while others have very fruitful innovation achievements. Such huge differences among major variables require subsequent data models to reveal the influence mechanism.

4.2. Correlation Analysis. Through the correlation analysis showing in Table 2, it is found that there is a significant correlation between the main independent variable tax incentive and the dependent variable R&D input, which lays a good foundation for the next regression analysis.

4.3. Regression Analysis. Firstly, according to model1and model2, mixed regression and panel regression with fixed effect were respectively used to test the relationship between tax incentive policy and enterprises' innovation input. In Table 3, the results show that, under the two models, tax incentive policies both had a promoting effect on enterprises' innovation input, but there were some differences in the degree of influence and significance. Under the mixed regression model, the promotion effect of tax incentive policy on innovation input is more obvious and significant. It might be that the sample data is unbalanced panel data. After considering the time effect and individual effect, the influence mechanism of tax incentive policy on enterprise R&D input has slightly changed. However, the conclusion is consistent from the overall direction, and the robustness of the conclusion is also proved. Hypothesis 1 is verified.

Then based on model 3, we test the relationship between tax policy and innovation output from two aspects, innovation quantity and innovation quality. Since innovation output is a counting variable, Poisson mixed regression and ordinary mixed regression are performed for verification respectively. In Table 4, the results show that both innovation quantity and innovation quality are significantly affected by tax incentive policies positively. However, the result of Poisson mixed regression and mixed regression is a little bit different. Under Poisson mixed regression, tax incentive policy has a more significant effect on the quality than the quantity of enterprises' innovative output. While under ordinary mixed regression, tax incentive policy has a more significant effect on the quantity of enterprises' innovation output. However, from all aspects, tax incentive policies can effectively promote the innovative output of enterprises, and hypothesis 2 is supported.

The heterogeneous factors of enterprises provide different application scenarios for the tax incentive policies, and the influence mechanism is inevitably different. Now, to test hypothesis 3, the study considers the effect of heterogeneous factors on tax policy and enterprise innovation input.

In terms of property right, we classify the ownership types of the sample firms as private and other. Zhejiang Province of China, where the sample enterprises located, is an area where

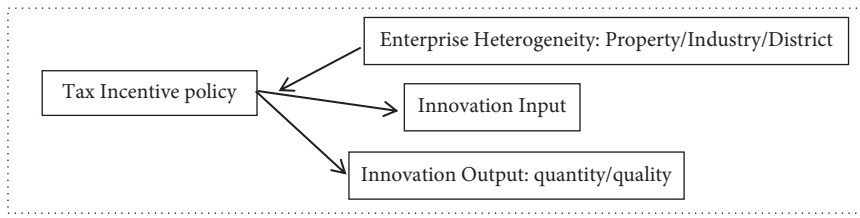

Figure 1: Research conceptual model.

Table 1: Descriptive statistics of main variables.

Variable	Mean	sd	min	p50	Max
Taxincen	0.119	0.0589	0.000424	0.114	0.250
RDexpense	1.446*e*+08	3.624*e*+08	26269	5.745*e*+07	5.484*e*+09
Patent	43.70	83.50	0	20	882
Invention	14.90	28.70	0	6	407

Table 2: Correlation analysis of main variables.

lnRDexp	lnRDexp 1	Taxincen	Lnasset	Asset-liab	ROA
Taxincen	0.061**	1			
Lnasset	0.647***	−0.101***	1		
Asset-liab	0.193***	0.0500	0.411***	1	
ROA	0.135***	−0.299***	0.0130	−0.329***	1

t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$.

Table 3: Tax incentive policies-innovation input model.

Variables	(1) Mixed	(2) FE
Taxincen	3.973***	0.754*
	(7.58)	(1.82)
Lnasset	0.782***	0.892***
	(26.75)	(16.70)
Asset-liab	−0.290	−0.172
	(−1.53)	(−0.72)
ROA	2.389***	0.007
	(6.55)	(0.02)
Constant	0.356	−1.564
	(0.58)	(−1.39)
Observations	1,037	1,037
R-squared	0.466	0.544
Individual	NO	YES
Year	NO	YES
Number of code		211

t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: Tax incentive policies-innovation output model.

Variables	(3) Poisson Patent	(3) Mixed Patent	(3) Poisson Invention	(3) Mixed Invention
Taxincen	1.314***	94.175*	3.573***	64.315***
	(12.72)	(1.84)	(20.64)	(3.66)
Lnasset	0.583***	30.510***	0.588***	10.404***
	(105.74)	(9.91)	(61.76)	(9.81)
Asset-liab	0.103**	−5.074	0.054	−2.055
	(2.55)	(−0.27)	(0.79)	(−0.31)
ROA	5.038***	262.513***	4.640***	88.536***
	(56.30)	(5.23)	(30.61)	(5.12)
Constant	−9.675***	−645.655***	−11.076***	−223.647***
	(−82.23)	(−10.00)	(−54.47)	(−10.05)
Observations	681	681	681	681
R-squared		0.182		0.181

t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Tax incentive policies-innovation input (property right) model.

Variables	(5) Other	(5) Private
Taxincen	6.736***	3.423***
	(3.96)	(6.58)
Lnasset	0.335***	0.910***
	(3.53)	(29.43)
Asset-liab	0.110	−0.479**
	(0.15)	(−2.57)
ROA	5.503***	1.974***
	(2.97)	(5.74)
Constant	9.636***	−2.238***
	(4.55)	(−3.44)
Observations	135	902
R-squared	0.231	0.542

t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

private enterprises flourishing. Private enterprises accounted for 87 percent of the sample data. We marked the private enterprises in the sample as 1 and the nonprivate enterprises as 0, and conducted grouped mixed regression based on the model 1. The results in Table 5 shows, tax incentive policies can significantly promote innovation input of enterprises whether they are private enterprises or not. However, the promotion effect of nonprivate enterprises is more obvious, but the model fitting of private enterprises is better. After all, the survival of the enterprise is still profit oriented, but R&D costs are huge and may not be profitable in the short term. For private enterprises, the contradiction of abandoning immediate profits for future development may be more prominent than that for

other types of enterprises [19]. Therefore, under the influence of tax incentive policies, the enthusiasm for innovation input of private enterprises will be correspondingly reduced.

When it comes to enterprise innovation investment, high-tech enterprise is an enterprise type that we cannot ignore. Under the guidance of many innovation incentive policies, in recent years, enterprises have been paying more attention to R&D investment to meet the evaluation standards of high-tech enterprises, so as to further obtain more preferential policies. Therefore, we classify sample enterprises according to whether the enterprise is high-tech enterprise or not. From the number of observation of the two sample groups in Table 6, it can be seen that non-high-tech enterprises account for a higher proportion. The model results show that, both for high-tech and non-high-tech enterprises, the tax incentive policy have a significant promotion effect on enterprise innovation investment. Even non-high-tech enterprises have a more obvious promotion effect, which is different from the hypothetical expectation, the model fitting degree of high-tech enterprises group is better and the result is more convincing. It might be that high-tech enterprises have enjoyed tax incentive policies for many years [30], and the marginal effect of policy facilitation is degraded. And the non-high-tech enterprises need to make full use of the tax incentive policy to obtain more benefit, so the effect of the tax incentive policy will be more obvious on non-high-tech enterprises.

The inspection of high-tech enterprise finished, followed by the further inspection according to the classification of industries. After the model analysis of all industries involved in the sample, the two industries with the largest sample size, manufacturing industry (777/1037) and technical service industry (109/1037), were selected for the results display in Table 7. The analysis results show that tax incentive policies have significant positive correlation with enterprise innovation input in both manufacturing and technical service industries, and the promotion effect is more obvious in technical service industries. It is inseparable from the fact the technology services industry enjoys more tax incentive policies. Besides, from Table 7, we can also see that among the listed enterprises, manufacturing enterprises account for the largest proportion. Therefore, the research on promotion effect of tax incentive policy on enterprise innovation investment for the manufacturing enterprises appears to be of practical significance.

Finally, we look at the effect of the heterogeneity factor district on the model influence mechanism (Table 8). From the geographical point of view, the number of listed companies in Hangzhou area is the most, Ningbo followed, Wenzhou the least. In city Hangzhou group, tax incentive policy has a significant promoting effect on enterprise innovation input, but in city Ningbo group and city Wenzhou group, there is promoting effect, but not significant. It may be related to the small number of enterprises in the sample group, or due to the regional policy difference. We know that city Hangzhou, as the provincial capital of the district, naturally has some advantages in the development and implementation of regional policies. Therefore, there will be more innovation incentive policies for enterprises in city Hangzhou to attract high-tech enterprises to enter, so as to stimulate the innovation vitality of the city, which is the administrative regional advantage that city Ningbo and City Wenzhou does not have as an ordinary city.

Table 6: Tax incentive policies-innovation input (high-tech) model.

Variables	(6) Non-high-tech	(6) High-tech
Taxincen	4.173***	3.312***
	(6.47)	(4.92)
Lnasset	0.759***	0.971***
	(21.43)	(23.32)
Asset-liab	−0.415*	0.022
	(−1.76)	(0.09)
ROA	2.480***	1.481***
	(5.64)	(2.82)
Constant	0.820	−3.527***
	(1.09)	(−4.06)
Observations	767	270
R-squared	0.427	0.732

t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Tax incentive policies-innovation input (industry) model.

Variables	(7) MA	(7) Tech
Taxincen	3.981***	6.343***
	(6.14)	(6.89)
Lnasset	0.744***	0.838***
	(21.33)	(15.66)
Asset-liab	−0.617***	1.029***
	(−2.63)	(3.04)
ROA	2.316***	4.045***
	(4.90)	(4.88)
Constant	1.271*	−1.538
	(1.72)	(−1.37)
Observations	777	109
R-squared	0.410	0.801

t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5. Conclusion and Discussion

5.1. Conclusion. From the above data analysis, it can be seen that, for the listed companies in city Hangzhou, Ningbo and Wenzhou, the tax incentive policy has a significant promoting effect on the innovation activities of enterprises. All the hypothesis are be supported (Table 9). On the one hand, it can promote the innovation input of enterprises, consistent with previous studies [31, 32], which support the hypothesis one; on the other hand, it can also promote the innovation output of enterprises, no matter the quantity or quality of the innovation output, which support the hypothesis two and enrich the current research [23]. At the same time, heterogeneous factors do affect the effect of tax incentives on enterprise innovation input, which support the hypothesis three [29], but different from (Martinsson, 2017). By the property, the tax incentive effect on the innovation

Table 8: Tax incentive policies-innovation input (district) model.

Variables	(8) HZ	(8) NB	(8) WZ
Taxincen	4.980***	1.408	0.231
	(9.11)	(1.11)	(0.16)
Lnasset	0.786***	0.685***	0.952***
	(24.58)	(11.20)	(11.04)
Asset-liab	0.065	−0.662*	−0.716
	(0.32)	(−1.66)	(−1.03)
ROA	2.709***	3.275***	−0.089
	(6.74)	(2.86)	(−0.15)
Constant	0.147	2.613*	−2.843
	(0.22)	(1.97)	(−1.60)
Observations	622	327	88
R-squared	0.577	0.308	0.657

t-statistics in parentheses*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Hypothesis validation results.

No. of hypothesis	Hypothesis description	Support or not
Hypothesis 1	H1: tax incentive policies can promote the innovation input of enterprises.	YES
Hypothesis 2	H2: tax incentive policies can promote the innovation output of enterprises	YES
Hypothesis 3	H3: heterogeneous factors (H3a: Property right nature, H3b: high-tech enterprise, H3c: Industry type, H3d: district) will affect the effect between tax incentive policies and enterprise innovation input.	YES

activities of the private enterprise and non-high-tech enterprise is more evident. By the industry, manufacturing and technology industry, as top 2 industries with more industrial strength on economics and innovation, affected by tax incentives more than other industries. And by the district, the effect is more significant in the listed companies in Hangzhou, which is the capital of the district with more political resource [22].

5.2. Discussion. In this way, we can find that the targeted expectation of tax incentive policies can effectively promote the innovation input of enterprises, so as to further improve the innovation out of enterprises. And we can provide some suggestions to management of enterprise management and policy-makers.

For the enterprise management, in order to achieve the sustainable development for the future, continuous innovation is the strategic direction that must be chosen. In this way, huge innovation investment is also an important cost factor that enterprises need to consider. As a result, it is an effective way for enterprises to reduce the innovation cost if they can take advantage of the tax incentive policies from the aspects of preferential tax base and preferential tax rate. On the one hand, the increased innovation investment can enable enterprises to enjoy preferential tax base policies (additional deduction of R&D expenses). On the other hand, abundant innovation outputs can also help enterprises meet the standards of high-tech enterprises, so as to enjoy the preferential tax rate exclusive by high-tech enterprises. No matter the enterprise is a private enterprise, in a high-tech industry or located in a big city, continuous innovation will inevitably become an effective tool to enhance its competitiveness in the future.

For the policy maker, targeted policies need to be designed to guide enterprise innovation activities according to specific conditions. First of all, tax incentives can be carried out differently for different kind of enterprises, due to the property right. Compared with state-owned enterprises and foreign-owned enterprises, private enterprises pay different priorities, which also need to be considered in policy guidance. For example, the innovation of private enterprises is more likely to affected by financing constraints, which need to be taken into consideration when planning tax incentive policies. Secondly, for manufacturing enterprises and high-tech enterprises, we can carry out focused innovation guidance through tax incentive policies. Since these two industries are the foundation of China. Especially for the traditional manufacturing industry, technological innovation may have no urgent demand compared with other high-tech industries. But innovation is essential to seek longer development and enter a broader market. Then, policy makers can use tax incentive policies to guide the innovation activities of the huge manufacturing industry, providing strong support for the national development strategy. For example, tax incentives can be given according to the increased innovation investment of enterprises, but attention should be paid to avoid enterprises who deliberately whitewash the innovation investment in order to get the tax incentive [24]. In addition, flexible and autonomous regional policies should be constructed according to specific regions. Although tax regulations at the national level are important, the different characteristics of regional market environment should be considered when

specific implementation. Therefore, it is necessary to set supplementary policies for support at the regional level. Such stratified and classified tax policy formulation can more actively and effectively guide enterprises to carry out innovative activities and improve their innovation strength.

Data Availability

The data that support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

Evolutionary Game Analysis of Consumer Complaint Handling in E-Commerce

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Untimely complaint handling can affect the reputation of the e-commerce platform and lead to customer loss, which is not conducive to the sustainable development of the e-commerce industry. To address the problem of untimely handling of consumer complaints, based on the evolutionary game theory, the e-commerce dispute mediation platform is introduced, the authenticity of consumer complaints and the probability of e-commerce platform to be in the mediation platform are considered, a tripartite evolutionary game model of consumer-mediation platform-e-commerce platform is constructed, and the problem of which strategy the mediation platform and e-commerce platform choose to handle consumer complaints is studied. Numerical simulation and simulation analysis are conducted using MATLAB 2020b, and corresponding suggestions are given. The research results show that under certain conditions when the probability of mediation platform and e-commerce platform positively handling complaint increases or the penalty for consumer distortion complaint increases; when the probability of consumer's real complaint increases, the probability of mediation platform positively handling complaint increases; the consumer tend to choose real complaint, the mediation platform tends to choose positively handling strategy, the e-commerce platform positively enters the mediation platform, the mediation platform and consumer's behavior to the reputation of the e-commerce platform increases, which can promote the e-commerce platform to positively handle the consumer complaint.

1. Introduction

The main e-commerce dispute mediation platforms are Electric Complaint Treasure and Black Cat Complaint in China. Up to now, Electric Complaint Treasure has accepted more than 100,000 complaints, affecting more than 100 million users. Black Cat Complaint has accumulated more than 5.9 million effective complaints. However, the problem of untimely processing of complaints is still serious, and some consumers' complaints are handled very inefficiently or even some long time after the problem has not been handled. This leads to consumer dissatisfaction with the e-commerce platform, reduces consumers' trust in the e-commerce platform, affects the mediation platform and the reputation of the e-commerce platform, thus affecting the sustainable development of the entire e-commerce industry. In this context, the study of consumer complaint handling strategies can better coordinate disputes between consumers and the complained e-commerce platform/sellers, better solve after-sale problems, safeguard the legitimate rights and interests of consumers, enhance consumer satisfaction with the services of the e-commerce platform, improve the reputation of the e-commerce platform, build a harmonious e-commerce business-consumer relationship, and promote the healthy and sustainable development of the e-commerce industry.

Electric complaint treasure and black cat complaint platform have realized a key complaint, 24 h online, self-help rights, synchronization direct, real-time processing, progress inquiry, evaluation system, legal help, big data analysis, and many other functions. According to the data of Electric Complaint, there are more complaints about retail e-commerce, life service e-commerce, online travel, online education, and online takeaway in 2020, among which, retail e-commerce complaints account for more than half of the total complaints. The hot issues of complaints are refund

problems, quality of goods, delivery problems, network fraud, after-sales service, network sales counterfeit, bullying terms, false promotion, difficulty to return and exchange goods, order problems, goods are not right, logistics problems, etc.

The emergence of e-commerce dispute mediation platforms, which are third-party complaint handling organizations that coordinate disputes, resolve disputes, and provide specific assistance to individual or collective complainants, has brought significant changes to the entire e-commerce industry. The data from the Electric Complaint and Black Cat complaint platforms shows that consumers' awareness of their rights is getting stronger and stronger [1], and the voice from consumers is gradually becoming an important factor in the market [2], and consumer complaints are contributing more and more to the sustainable development of the entire e-commerce industry. Consumer complaining is a series of possible responses to an unsatisfactory consumer situation [3–6]. When consumers encounter an unsatisfactory shopping experience, they are likely to express their dissatisfaction by filing a complaint [7]. Online complaint behavior is punitive, affecting the public perception of a business and damaging the image of a platform or company's reputation [7–9]. Poorly handled complaints also may lead to customer loss [10]. Consumer complaints play an indirect regulatory role for online sellers and help companies to better improve their services [11, 12]. Satisfaction with complaint handling also affects the corporate image and reputation [13, 14], and effective complaint handling also has a considerable chance of winning back the complaining consumers [15–17].

Currently, domestic and foreign scholars have studied the issue of consumer complaints from different aspects, and in the existing literature on consumer complaints, most of them are still dominated by empirical studies [18–26]. Boote [27] developed a two-factor taxonomy of consumer complaint behavior, classifying complaints according to whether they are primary or secondary, involved or uninvolved; and constructed a model of consumer complaint behavior that divides the entire consumer complaint behavior into four processes: rational reasoning, affective response, triggering of consumer dissatisfaction response, and effective action. Brennan et al. [28] consider consumer vulnerability and complaint handling organizations and examine new models of consumer dispute system design and the operation of complaint handling organizations. Lu et al. [29] developed a four-dimensional scale of consumer complaints and recovery efforts, which consists of procedural, cognitive, temporal, and affective components. Bastani et al. [30] extracted thematic and temporal trends in complaints and proposed an intelligent method based on Latent Dirichlet Allocation (LDA) to analyze consumer complaints in the Consumer Financial Protection Bureau.

In addition, studies on the handling of consumer complaints have focused on their impact on corporate reputation. Fast and effective handling of consumer complaints can improve the organization's reputation to some extent. Einwiller and Steilen [14] analyzed how large companies handle their complaints on Facebook and Twitter by applying content, and the study showed that public complaints can damage the organization's reputation, but effective handling of complaints can demonstrate the organization's ability and willingness to solve problems, which may improve its reputation. Istanbulluoglu [15] considered the response time of consumer complaints and showed that both faster first response and faster conclusive response increase consumer satisfaction with complaint handling and that negative complaint handling can lead to loss of existing customers, shape negative word of mouth, and negatively affect the company's reputation. Johnen and Schnittka [10] introduced an observer's perspective under hedonism and utilitarianism, using the reason for the complaint as a condition, and the study showed that under certain conditions complainants and observers of the brand's communication on social media may be more inclined to respond defensively rather than accommodatingly. Researchers mostly study the impact of untimely handling of consumer complaints on the reputation of enterprises or organizations empirically, and fewer scholars introduce consumer complaints into the model to study the problem of consumer complaint handling.

In recent years, the simple two-party evolutionary game is no longer enough to satisfy scholars' research, and most scholars study the stability strategies of game subjects under different models [31–37], or the evolutionary game problems involving three or even four parties. Zhang et al. [38] considered the outsourcing model and the licensing model, and constructed a competitive closed-loop supply chain consisting of two original equipment manufacturers and two third-party remanufacturers. Chen and Hu [33] examine the behavioral strategies of both suppliers and governments under various combinations of carbon taxes and subsidies. Sun et al. [39] developed a two-sided evolutionary game-theoretic model of suppliers and manufacturers under the government subsidy mechanism to study the optimal green investment strategy under the government subsidy policy. Feng et al. [40] introduced a public oversight mechanism (two regulators and one regulated) and developed a model based on multiplayer evolutionary games and system dynamics. Ma and Zhang [41] constructed a two-sided dynamic evolutionary game model consisting of construction firms and recycling firms with and without government incentives to study the construction waste recycling management problem. Liu et al. [42] construct a tripartite evolutionary game model of the State Coal Mine Safety Supervision Bureau, local coal mine safety supervision departments, and coal enterprises, and use dynamic penalty control and penalty-incentive to control fluctuations to study the coal mine safety supervision problem in China. Kang et al. [43] studied a two-level supply chain consisting of retailers and manufacturers, and used the Stackelberg game to solve the low-carbon strategy combinations of four retailers and manufacturers, and then used the evolutionary game for further analysis, examining the choice of a competitive closed-loop supply chain third-party remanufacturing model. Sheng et al. [44] constructed a tripartite game model of the national government, local government, and enterprises to study incentive-compatible

environmental regulatory policies. In the existing literature on consumer complaints, traditional evolutionary game theory has mostly been applied to study regulatory problems, but generally, consumer complaints are introduced into the model as parameters. He and Zhu [11] introduced consumer feedback into a three-way evolutionary game involving government regulators, sellers, and the e-commerce platform, and found that consumer complaints can indirectly regulate sellers and influence the choice of the e-commerce platform through fines imposed on them by government regulators. Fewer scholars have used the evolutionary game theory approach to study the problem of consumer complaint handling. As the e-commerce model is evolving, the complaint handling system is improving, consumers' awareness of their rights is increasing, and the interests of relevant subjects are changing. Evolutionary game theory can provide help for the strategy selection of consumer complaint handling subjects.

In summary, a review of the literature reveals that most of the theoretical research on consumer complaint handling has been conducted empirically to study the impact of consumer complaint handling on enterprises, but there is a lack of research and analysis on consumer complaint handling by consumers, mediation platforms and the e-commerce platform. There are also fewer studies that use evolutionary game theory to study consumer complaint handling.

Therefore, this study aims to address the following questions.

(1) What complaint strategies consumers should choose under what conditions?

(2) What consumer complaint handling strategies should be chosen by the e-commerce platform and mediation platforms under what conditions?

(3) What measures should be taken by consumers, mediation platforms, and the e-commerce platform in the future to promote the positive, healthy, and sustainable development of the entire e-commerce industry?

In summary, this paper differs from other scholars' studies in that: firstly, the e-commerce dispute mediation platform was introduced according to the actual situation, while considering the authenticity of consumer complaints and the probability of the e-commerce platform being in the mediation platform are considered, a tripartite evolutionary game model with consumers, the mediation platform and the e-commerce platform as the main players are constructed. Secondly, the stability of the three-game subjects is analyzed, as well as the effects of factors such as e occupancy rate, processing cost, penalty, and impact on reputation, and the stability of pure strategy combinations are analyzed based on Lyapunov's first law. Finally, numerical simulation through MATLAB 2020b, the effect of the probability of the e-commerce platform being enrolled in the mediation platform, the probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively, impact of factors leading to the loss of e-commerce platform reputation on the choice of e-commerce platform strategy on the strategy choice of the game subjects were analyzed.

2. Materials and Methods

In this section, the problems under study are described in detail, the assumptions used, specific notational descriptions are depicted, and the tripartite game payment matrix is presented.

The e-commerce dispute mediation platform was introduced, and the issue of consumer complaint handling was studied with the process shown in Figure 1. The consumer makes a complaint in the e-commerce dispute mediation platform; the mediation platform reviews the consumer's complaint and docks with the e-commerce platform to transfer the consumer's complaint; the e-commerce platform accepts the complaint information transferred by the mediation platform and negotiates with the consumer for compensation.

The consumer can make a one-click complaint in the mediation platform system and check the progress of the complaint processing at any time. For those the e-commerce platform that is not part of the mediation platform, the mediation platform staff will contact them directly and actively promote the e-commerce platform or merchants to solve the problem complained by the consumer. After the e-commerce platform has been stationed in the mediation platform, the e-commerce platform logo entrance can be linked in a prominent position in the mediation platform, and there is a dedicated person through the microblogging, mediation platform system and another docking, enjoy the privilege of priority review, transfer distribution, and at any time can view real-time data, lists, rankings, ratings, etc. The mediation platform will also use the relying media to promote the resident e-commerce platform, etc. The publicity service of the mediation platform has increased the reputation of the settled e-commerce platform, which is set as G. After the complaint processing is completed, the consumer can evaluate the satisfaction of the e-commerce platform's processing. When the e-commerce platform is negatively handled, the probability that consumers are not satisfied with the processing results of the e-commerce platform is set to β. The mediation platform supervises the behavior of the consumer and the e-commerce platform, exposes the mistakes according to the real complaint and the feedback of the complained e-commerce company, and ranks, rates, and writes data analysis reports on the e-commerce platform according to the data collected by the mediation platform. Therefore, the positive evaluation of the mediation platform has increased the reputation of the e-commerce platform N_1 and the reputation loss of the e-commerce platform caused by negative reports of the mediation platform is N_2.

The tripartite evolutionary game model with the consumer, mediation platform, and e-commerce platform as the main players is constructed. The assumptions are as follows.

Assumption 1. The probability of consumer's real complaint is p and the probability of distorted complaint is $1 - p$; the probability of mediation platform's positive handling and

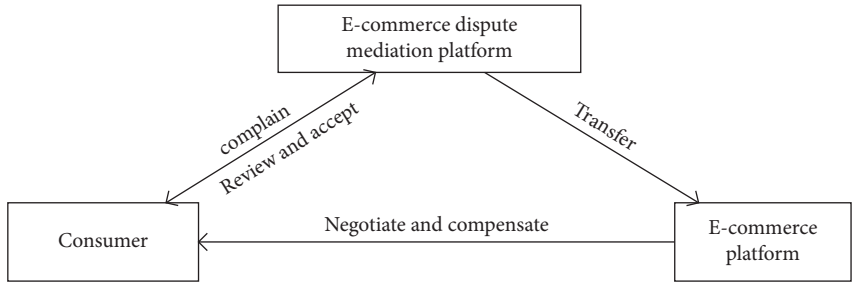

Figure 1: Flow chart of multisubject complaint processing.

the probability of negative handling is $1-q$; the probability of e-commerce platform's positive handling and the probability of negative handling is $1-g$. $p, q, g \in [0,1]$. All three parties are finite rational and keep adjusting their strategy choices over time according to the benefit maximization principle.

Assumption 2. When a consumer's complaint is judged to be a distorted complaint, the mediation platform rejects the relevant complaint order, bans the relevant offending complaint account in serious cases, and the complainant may also bear certain legal responsibilities. Therefore, set the penalty of consumer distortion complaint as S.

Assumption 3. The probability of the e-commerce platform settling in the mediation platform is α. The settlement of e-commerce platform in the mediation platform will pay a certain fee, which is set to V. The resident e-commerce platform enjoys the privilege of prioritizing the review, handing over distribution, and assisting customers in dealing with after-sales matters, and the mediation platform will not deal with it negatively.

Assumption 4. When the mediation platform is negatively handled, the nonresident e-commerce platform can contact the mediation platform and submit corresponding evidence when it finds distortion complaints in the process of handling complaints, and the mediation platform will verify and handle them accordingly according to the rules. The nonsettled e-commerce platform that positively handles consumer complaints proves that the cost of consumer distortion complaints is Q_1. The nonsettled e-commerce platform that negatively handles consumer complaints proves that the cost of consumer distortion complaints is Q_2.

The specific symbols and descriptions are listed in Table 1.

Table 2 shows the payoff matrix constructed for the tripartite game between consumer, mediation platform, and e-commerce platform.

3. Results of Stability Analysis of Each Game Subject's Strategy

To determine the consumer complaint handling strategy, this section will analyze the evolutionary game from the perspective of consumers, mediation platforms, the e-commerce platform, and strategy combinations, respectively. In addition, the influence of relevant parameters on the evolutionary process will be analyzed.

3.1. Stability Analysis of Consumer's Complaint Strategies. The expected benefits of consumer who chooses to make a real complaint or distortion complaint, and the replicated dynamic equation and the first derivative of the complaint strategy are, respectively:

$$\begin{cases} \pi_p = qg(-C_1 + A_1) + (1-q)g(-C_1 + A - U_1) + q(1-g)(A - \beta J - C_1 - U_1) \\ +(1-q)(1-g)(A - \beta J - C_1 - J - U_1 - U_2) \\ \pi_{1-p} = qg(-C_2 - S) + (1-q)g(-C_2 - S - U_1) + q(1-g)(-C_2 - S - U_1) \\ +(1-q)(1-g)(-C_2 - S - U_1 - U_2) \end{cases}, \tag{1}$$

$$\begin{aligned} F(p) &= \frac{dp}{dt} \\ &= p(1-p)(-J + gJ + Jq - gJq + S - J\beta + gJ\beta + A - C_1 + C_2), \\ F'(p) &= (1-2p)(-J + gJ + Jq - gJq + S - J\beta + gJ\beta + A - C_1 + C_2). \end{aligned}$$

Table 1: Summary of notations.

Symbols	Meaning and description
C1	Real complaint cost of consumer
T1	Positive handling cost of a mediation platform
L1	Positive handling cost of e-commerce platform
U1	Consumer waiting cost when the mediation platform is handled negatively
M	Mediation platform operating cost
Y	Other benefits of a mediation platform
A	Compensation to the consumers by e-commerce platform (A > C1 > C2)
X1	The increased reputation of the e-commerce platform due to consumer's satisfaction with the result of processing
L0	Handling costs by the e-commerce platform that have been enrolled
D1	Increased reputation due to positive handling of a real complaint by mediation platform
C2	Distortion complaint cost of consumer
T2	Negative handling cost of a mediation platform (T1 > T2)
L2	Negative handling cost of an e-commerce platform (L1 > L2)
U2	Consumer waiting cost when the e-commerce platform is handled negatively
F	Mediation platform service cost for the resident platform
B	Other benefits of e-commerce platform
J	Loss caused by consumer's dissatisfaction with the result of a complaint
X2	Loss of reputation of e-commerce platform lost due to consumer's dissatisfaction with the result of processing
Z	Loss of reputation of e-commerce platform due to the consumer's complaint
D2	Loss of reputation of the mediation platform due to negative handling of a real complaint by the mediation platform

Proposition 1. *Under* $0 \le q_0 \le 1, 0 \le g_0 \le 1$, *when* $q > q_0$, $g > g_0$, *the consumer's stability strategy is true complaint; when* $q < q_0$, $g < g_0$, *the consumer's stability strategy is distorted complaint; when* $q = q_0$, $g = g_0$, *the consumer's stability strategy is uncertain, where the threshold is* $q_0 = 1 - S - (1-g)J\beta + A - C_1 + C_2/(1-g)J$, $g_0 = 1 - S + A - C_1 + C_2/J(1-q+\beta)$.

See Appendix A for the specific certification process.

Proposition 1 shows that under certain conditions, the probability of the consumer's true complaint increases with the probability of positive handling by the mediation platform and the probability of positive handling by the e-commerce platform. Both the mediation platforms and the e-commerce platform positively handle consumers' complaints, which can increase the rate of true consumers' complaints and thus provide better after-sales service to consumers.

The phase diagram of consumer strategy choice is shown in Figure 2.

Let the probability of consumer's real complaint is V_{P1}, the probability of consumer's distortion complaint is V_{P2}. Let $i = A + S - C_1 + C_2/(1-g)J(1+\beta)$. , $V_{p2} = \int_0^1 \int_0^{1-S-(1-g)J\beta+A-C_1+C_2/(1-g)J} [1 - S + A - C_1 + C_2/J(1-q+\beta)]\mathrm{d}q\mathrm{d}p = \ln i(A + S - C_1 + C_2)/J$ $V_{p1} = 1 - \ln i(A + S - C_1 + C_2)/J$

Corollary 1. *Under* $i < 1/e$, *the consumer tends to choose the real complaint strategy when the penalty for consumer distortion complaint is higher or real complaint cost of the consumer is lower or distortion complaint cost of the consumer is higher.*

Corollary 2. *When* $S + A - C_1 + C_2 < 0$, *the higher the loss caused by consumers' dissatisfaction with the complaint result or the lower the probability of consumers being dissatisfied with the outcome when the e-commerce platform is handled negatively, the consumer tends to choose the real complaint strategy. When* $S + A - C_1 + C_2 > 0$, *the higher the loss caused by consumer's dissatisfaction with the result of a complaint or the higher the probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively, the consumer tends to choose the distortion complaint strategy. When* $S + A - C_1 + C_2 = 0$, *the loss caused by consumers' dissatisfaction with the complaint result and the probability of consumers being dissatisfied with the outcome when the e-commerce platform is handled negatively do not affect the choice of consumer's complaint strategy.*

See Appendix A for the specific certification process.

3.2. Stability Analysis of Mediation Platform's Complaint Handling Strategies. The expected benefits of mediation platform who chooses to make positive handling or negative handling, and the replicated dynamic equation and the first derivative of the complaint strategy are, respectively:

$$\begin{cases} \pi_q = p[\alpha(V-F) - (1-\alpha)T_1 - M + Y + D_1] \\ \quad +(1-p)[\alpha(V-F) - (1-\alpha)T_1 - M + Y] \\ \pi_{1-q} = p[\alpha(V-F+D_1) - (1-\alpha)(T_2+D_2) - M + Y] \\ \quad +(1-p)[\alpha(V-F) - (1-\alpha)T_2 - M + Y] \end{cases},$$

$$F(q) = \frac{\mathrm{d}q}{\mathrm{d}t} = q(1-q)\{(1-\alpha)[p(D_1+D_2) - T_1 + T_2]\},$$

$$F'(q) = (1-2q)\{(1-\alpha)[p(D_1+D_2) - T_1 + T_2]\}. \quad (2)$$

Table 2: Tripartite game payoff matrix.

		E-commerce dispute mediation platform			
		Positive handling q	Negative handling $1-q$		
Consumer	Real complaint p	$\{-C_1 t + nAq, h\alpha_1(V-F)x - 7(1-\alpha)CT_1 - M + Y + D_1, \alpha(G-V-L_0) - (1-\alpha)L_1 t + nN_1 q - hZ_xA7 + CB; +X_1\}$	$\{-C_1 t + nAq - hU_{1_}xa7(V-F+D_1)C - (1-\alpha) * (T_2+D_2) - M + Y, \alpha(G-V-L_0) - (1-\alpha)L_1 + N_1 - Zt - nAq + hB_1 xX_1\}$	Positive handling g	E-commerce platform
	Distortion complaint $1-p$	$\{-C_2 t - nSq, h\alpha_1(V-F)x - 7(1-\alpha)CT_1 - Mt + nYq, h\alpha_1(G-V)x + 7B\}$	$\{-C_2 t - nSq - hU_{1_}xa7(V-F)C - (1-\alpha)T_2 - M + Y, \alpha(G-V) + Bt - n(1-\alpha)qQ_1\}$		
	Real complaint p	$\{A - t\beta nJq - hC_{1-}xU_1 7, C\alpha; (V-F) - (1-\alpha)T_1 - M + Y + D_1, \alpha(G-V-L_0) - (1-\alpha)L_2 - N_2 - Zt - nAq - h\beta X_2 x + 7(1-\beta)CX_1; +B\}$	$\{A - t\beta nJq - hC_{1-}xJ7 - CU_1; -U_2, \alpha(V-F+D_1) - (1-\alpha)(T_2+D_2) - M + Y, \alpha(G-V-L_0) - (1-\alpha)L_2 - N_2 - Z - A - \beta X_2 + (1-\beta)t * nX_1 q + hB\}$	Negative handling $1-g$	
	Distortion complaint $1-p$		$\{-C_2 t - nSq - hU_{1_}xU_2 7, C\alpha; (V-F) - (1-\alpha)T_2 - M + Y, \alpha(G-V) + B - t(1-\alpha)nQ_2\}$		

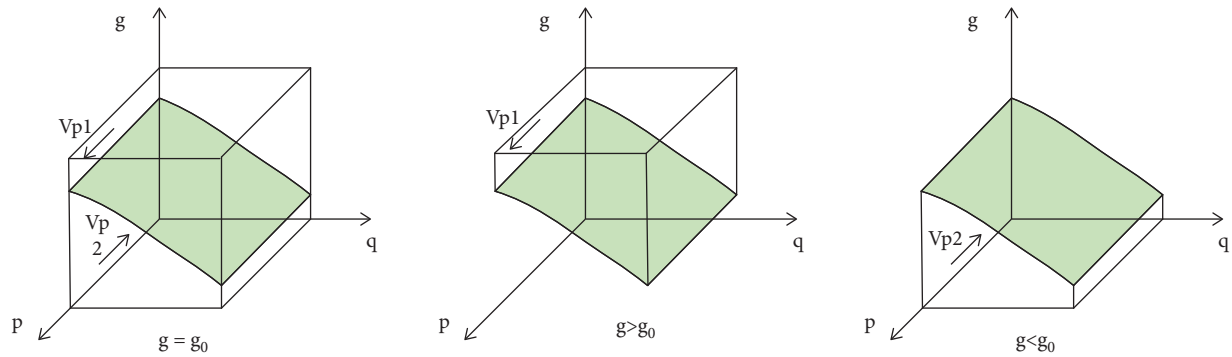

Figure 2: Phase diagram of consumer strategy choice.

Proposition 2. *When $\alpha = 1$, mediation platform selects complaint handling strategy uncertainty. Under $0 \le p_1 \le 1$, when $p \rangle p_1$, mediation platform stabilizes the choice of positive handling strategy; when $p < p_1$, mediation platform stabilizes the choice of negative handling strategy; when $p = p_1$, uncertainty in the choice of complaint handling strategy by the mediation platform. Where the threshold is $p_1 = (T_1 - T_2)/(D_1 + D_2)$.*

See Appendix A for the specific certification process.

Proposition 2. *shows that under certain conditions, the probability of the mediation platform positively handling the consumer complaint increases with the probability of the real consumer complaint.*

The mediation platform strategy selection phase diagram is shown in Figure 3.

Let the probability of the mediation platform being positive and the probability of the mediation platform being negative be. $V_{p2} = \int_0^1 \int_0^{T_1 - T_2/D_1 + D_2} (T_1 - T_2/D_1 + D_2) dg dq = (T_1 - T_2)^2/(D_1 + D_2)^2$, $V_{p1} = 1 - V_{p2} = 1 - (T_1 - T_2)^2/(D_1 + D_2)^2$.

Corollary 3. *The probability that the mediation platform chooses to deal actively increases with the increase of reputation caused by its active handling of real complaints and the increase of reputation loss caused by its passive handling of real complaints.*

See Appendix A for the specific certification process.

Corollary 4. *When the positive handling cost of the mediation platform decreases or the negative handling cost of the mediation platform increases, under* $D_1 - (1-g)(1-\alpha)(T_1 - T_2) \rangle 0$, $0 \le g[D_2 - (1-\alpha)(T_1 - T_2)]/ - D_1 + (1-g)(1-\alpha)(T_1 - T_2) \le 1$, *when* $D_1 - (1-g)D_2 > 0$, *mediation platform stabilizes the choice of positive handling strategy; when* $D_1 - (1-g)D_2 \rangle 0$, *mediation platform stabilizes the choice of negative handling strategy. Under* $D_1 - (1-g)(1-\alpha)(T_1 - T_2) \langle 0$, $0 \le g[D_2 - (1-\alpha)(T_1 - T_2)]/ - D_1 + (1-g)(1-\alpha)(T_1 - T_2) \le 1$, *it's the opposite.*

See Appendix A for the specific certification process.

3.3. Stability Analysis of E-Commerce Platform's Complaint Handling Strategies. The expected benefits of an e-commerce platform that chooses to make positive handling or negative handling, and the replicated dynamic equation and the first derivative of the complaint strategy are, respectively:

$$\begin{cases} \pi_g = p[\alpha(G - V - L_0) - (1-\alpha)L_1 + N_1 - Z - A + B + X_1] + (1-p)q[\alpha(G - V) + B] \\ +(1-p)(1-q)[\alpha(G - V) + B - (1-\alpha)Q_1] \\ \pi_{1-g} = p[\alpha(G - V - L_0) - (1-\alpha)L_2 - N_2 - Z - A - \beta X_2 + (1-\beta)X_1 + B] \\ +(1-p)q[\alpha(G - V) + B] + (1-p)(1-q)[\alpha(G - V) + B - (1-\alpha)Q_2] \end{cases}, \tag{3}$$

$$F(g) = \frac{dg}{dt}$$

$$= g(1-g)\{p[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2] + (1-p)(1-q)(1-\alpha)(Q_2 - Q_1)\},$$

$$F'(g) = (1-2g)\{p[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2] + (1-p)(1-q)(1-\alpha)(Q_2 - Q_1)\}.$$

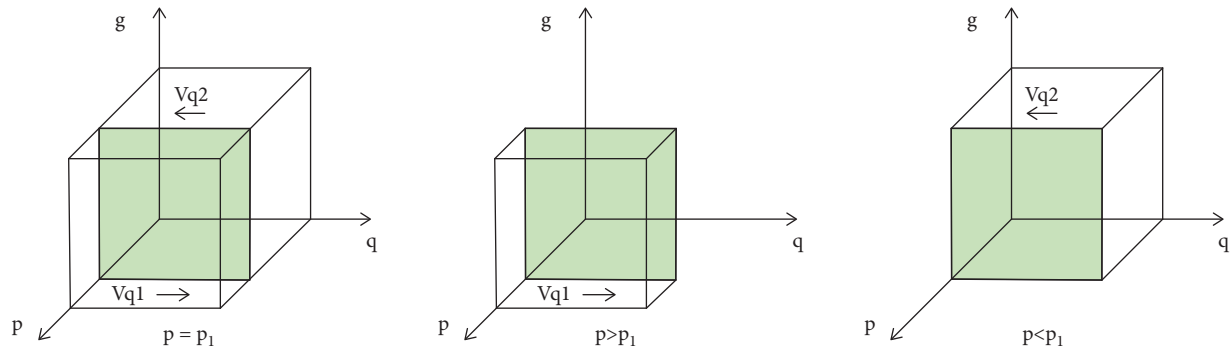

Figure 3: Phase diagram of mediation platform strategy selection.

Let $a = (1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2$, $b = (1-\alpha)(Q_1 - Q_2)$

Proposition 3. *Under and , when and , stable choice of positive handling strategy for e-commerce platform. When $p < p_2$ and $q < q_2$, stable choice of negative handling strategy for e-commerce platform. Where the threshold is $p_2 = 1 - a/a + (1-q)b$, $q_2 = 1 - pa/(1-p)b$.*

See Appendix A for the specific certification process.

Proposition 3 shows that under certain conditions, the probability of the e-commerce platform choosing to actively handle increases with the increase of the probability of consumers' real complaints and the probability of mediation platforms actively handling. The more real consumer complaints are, that is, the more real problems appear on the e-commerce platform, and the more active the e-commerce platform will handle consumer complaints. The mediation platform chooses to actively deal with consumer complaints. At this time, complaints accumulate on the e-commerce platform. In order not to stop the complaint processing progress on the e-commerce platform and damage the reputation of the e-commerce platform, the e-commerce platform will choose to actively deal with them.

The phase diagram of e-commerce platform strategy choice is shown in Figure 4.

Let the probability of e-commerce platform's positive handling is V_{g1}, the probability of e-commerce platform's negative handling is V_{g2}.

$$V_{g2} = \int_0^1 \int_0^{1-pa/(1-p)b} \int_0^1 \left[1 - \frac{a}{a+(1-q)b}\right] dq\,dq\,dg = 1 + \frac{a\{p + (1-p)\ln[a/(a+b)(1-p)]\}}{b(1-p)},$$
$$V_{g1} = 1 - V_{g2} = \frac{-a\{p + (1-p)\ln[a/(a+b)(1-p)]\}}{b(1-p)}. \quad (4)$$

Corollary 5. *Under $0 \le a/[a + (1-q)b] \le 1$, There are several ways to increase the probability of the e-commerce platform choosing a positive handling strategy: increased probability of e-commerce platform being enrolled in mediation platforms; decreased negative handling cost of e-commerce platform; increased cost of negatively handling consumer complaints; decreased Cost paid by e-commerce platform that actively handle complaint to prove consumer distortion complaint; raised increased reputation of e-commerce platform due to consumer's satisfaction with the result of processing; increased loss of reputation of e-commerce platform lost due to consumer's dissatisfaction with the result of processing; increased loss of reputation of the mediation platform due to negative handling of genuine complaints by the mediation platform; increased cost paid by the e-commerce platform proving consumer distortion complaints by the negative handling of complaints; enlarged increased reputation of e-commerce platform due to positive evaluation of mediation platform.; increased loss of reputation of the e-commerce platform due to negative reports on the mediation platform; probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively.*

See Appendix A for the specific certification process.

3.4. Stability Analysis of Strategy Portfolio. In the replicated dynamic system, the stability of the strategy combinations of the tripartite game subjects, the consumer, mediation platform, an e-commerce platform, can be judged according to Lyapunov's first law. The stability of eight pure strategy equilibrium points in the tripartite evolutionary game is analyzed in Table 3. The Jacobi matrix is obtained from the replicated dynamic equations of each game subject.

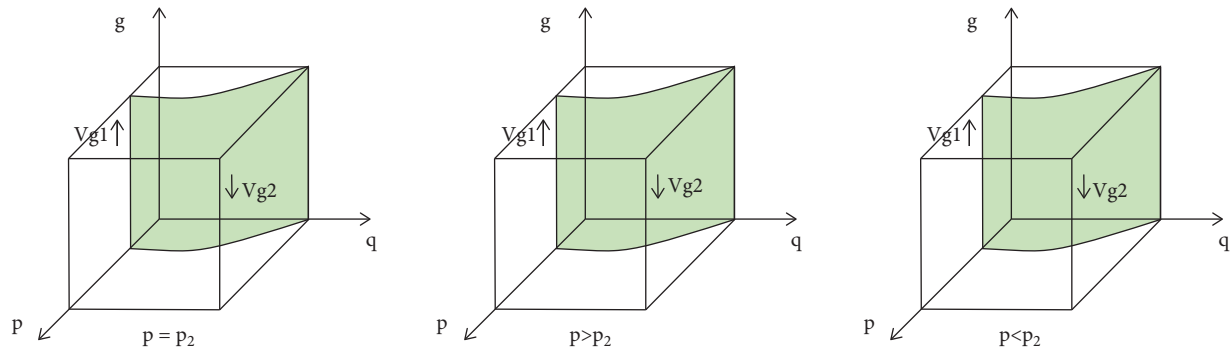

Figure 4: Phase diagram of e-commerce platform strategy selection.

Table 3: Replicated dynamic system equilibrium point asymptotic stability analysis.

Equilibrium point	Eigenvalue	Eigenvalue symbols	Stability
(0, 0, 0)	$\{-(1-\alpha)(Q_1-Q_2), -(1-\alpha)(T_1-T_2), A-C_1+C_2-J+S-J\beta\}$	−, −, ×	ESS when condition a is satisfied
(0, 1, 0)	$\{0, (1-\alpha)(T_1-T_2), A-C_1+C_2+S-J\beta\}$	0, +, ×	Unstable
(0, 0, 1)	$\{(1-\alpha)(Q_1-Q_2), -(1-\alpha)(T_1-T_2), A-C_1+C_2+S\}$	+, −, ×	Unstable
(0, 1, 1)	$\{0, (1-\alpha)(T_1-T_2), A-C_1+C_2+S\}$	0, +, ×	Unstable
(1, 1, 1)	$\{C_1-C_2-A-S, -[(1-\alpha)(L_2-L_1)+N_1+N_2+\beta X_1+\beta X_2], (1-\alpha)[-(D_1+D_2)+T_1-T_2]\}$	−, −, ×	ESS when condition *b* is satisfied
(1, 1, 0)	$\{C_1-C_2-A-S+J\beta, (1-\alpha)(L_2-L_1)+N_1+N_2+\beta X_1+\beta X_2, -(1-\alpha)(D_1+D_2-T_1+T_2)\}$	×, +, ×	Unstable
(1, 0, 1)	$\{C_1-C_2-A-S, -[(1-\alpha)(L_2-L_1)+N_1+N_2+\beta X_1+\beta X_2], (1-\alpha)(D_1+D_2-T_1+T_2)\}$	−, −, ×	ESS when condition *c* is satisfied
(1, 0, 0)	$\{C_1-C_2-A+J-S+J\beta, (1-\alpha)(D_1+D_2-T_1+T_2), (1-\alpha)(L_2-L_1)+N_1+N_2+\beta X_1+\beta X_2\}$	×, ×, +	Unstable

1 Condition a : $A-C_1+C_2-J+S-J\beta<0$; Condition b : $-D_1-D_2+T_1-T_2<0$; Condition c : $D_1+D_2-T_1+T_2<0$.

$$J=\begin{bmatrix} \dfrac{\partial F(p)}{\partial p} & \dfrac{\partial F(p)}{\partial q} & \dfrac{\partial F(p)}{\partial g} \\ \dfrac{\partial F(q)}{\partial p} & \dfrac{\partial F(q)}{\partial q} & \dfrac{\partial F(q)}{\partial g} \\ \dfrac{\partial F(g)}{\partial p} & \dfrac{\partial F(g)}{\partial q} & \dfrac{\partial F(g)}{\partial g} \end{bmatrix}. \quad (5)$$

Here, $\partial F(p)/\partial p = (1-2p)(-J+gJ+Jq-gJq+S-J\beta+gJ\beta+A-C_1+C_2)$, $\partial F(p)/\partial q = p(1-p)(1-g)J$, $\partial F(p)/\partial g = p(1-p)(1-q+\beta)J$, $\partial F(q)/\partial p = q(1-q)(1-\alpha)(D_1+D_2)$, $\partial F(q)/\partial q = (1-2q)(1-\alpha)[p(D_1+D_2)-T_1+T_2]$, $\partial F(q)/\partial g = 0$, $\partial F(g)/\partial p = g(1-g)[(1-\alpha)(L_2-L_1)+N_1+N_2+(1-q)(1-\alpha)(Q_1-Q_2)+\beta X_1+\beta X_2]$, $\partial F(g)/\partial q = g(1-g)(1-p)(1-\alpha)(Q_1-Q_2)$, and $\partial F(g)/\partial g = (1-2g)\{p[(1-\alpha)(L_2-L_1)+N_1+N_2+\beta(X_1+X_2)]+(1-p)(1-q)(1-\alpha)(Q_2-Q_1)\}$

As can be seen from Table 3, there is only one stable point (0,0,0) when the condition a is satisfied, so to avoid consumer distortion complaints, mediation platform negative treatment, e-commerce platform negative treatment to become a stable strategy combination, to increase the penalty for distortion complaints, enhance consumer awareness of their rights, at least should satisfy $S \geq -A+J+J\beta+C_1-C_2$ or $0<J\leq 1/2(A+S-C_1+C_2)$& $0\leq\beta\leq 1$ or $1/2(A+S-C_1+C_2)<J<A+S-C_1+C_2$& $0\leq\beta\leq (A-J+S-C_1+C_2)/J$ or $J=A+S-C_1+C_2$ & $\beta=0$. When condition *b* is satisfied, there is only one stable point (1, 1, 1), i.e., consumers' real complaints, the mediation platform's positive handling, and the e-commerce platform's positive handling become a stable strategy combination. When condition *c* is satisfied, there is only one stable point (1, 0, 1), to avoid the real consumer complaint, mediation platform negative handling, e-commerce platform positive handling become a stable strategy combination, should improve the credibility and influence of mediation platform to the

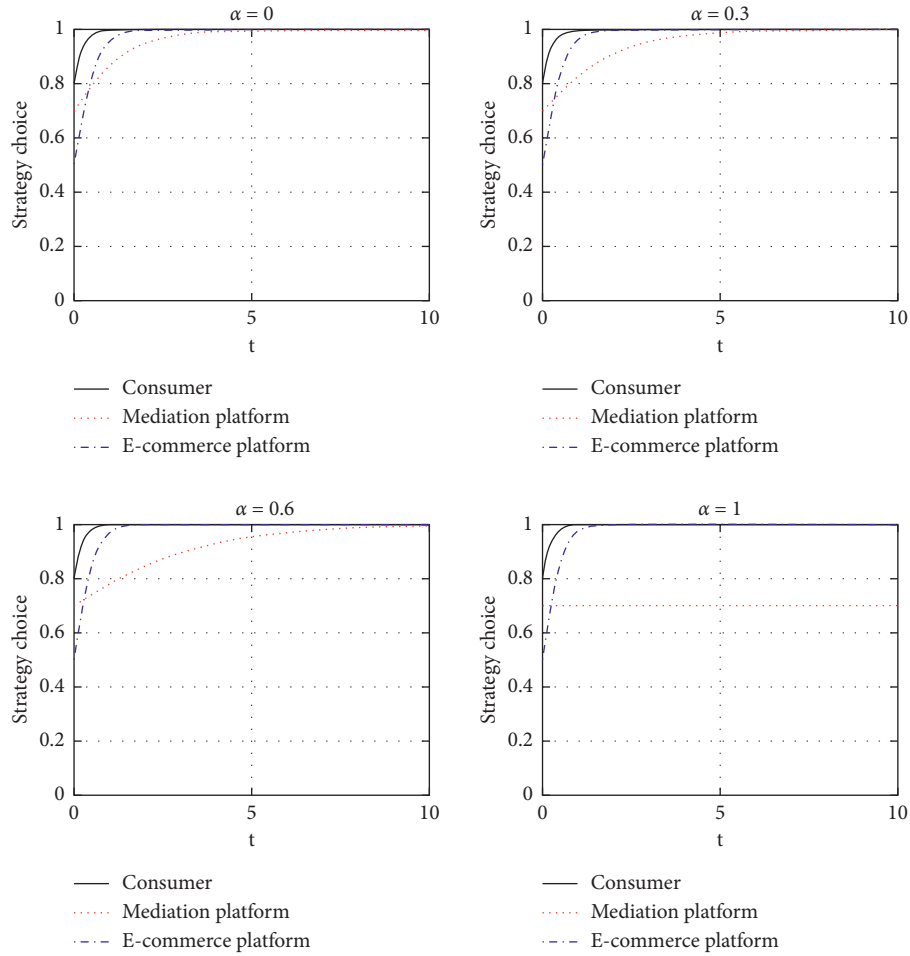

Figure 5: Influence of the probability of the e-commerce platform being enrolled in the mediation platform.

consumer and e-commerce platform, at least should meet $D_1 \geq -D_2 + T_1 - T_2$.

4. Numerical Analysis

In this section, numerical values are brought in for simulation to analyze the effect of the relevant parameters on the process.

Numerical values are given in conjunction with the actual situation, and simulation is performed using MATLAB 2020b. The 'sky-eye search' data shows that there are over 3.78 million e-commerce related enterprises in China, but most e-commerce enterprises are relatively small, and the probability of the e-commerce platform is in the mediation platform is low, so assume that $\alpha = 0.3$. When consumers make a distortion complaint, The measures taken by the mediation platform are only to dismiss the complaint and ban the relevant account, so the punishment for consumers' complaints is small, so let $S = 0.5$. According to the actual situation let $p = 0.8$, $q = 0.7$, $g = 0.5$.

4.1. Influence of the Probability of the E-Commerce Platform Being Enrolled in the Mediation Platform. The probability of the e-commerce platform being enrolled in the mediation platform are dissatisfied, so that $\alpha = \{0, 0.3, 0.6, 1\}$, then the game subject strategy evolution process and the impact results, as shown in Figure 5.

As can be seen from Figure 5, the probability of the e-commerce platform being enrolled in the mediation platform mainly has a greater impact on the mediation platform and a smaller impact on the consumer and e-commerce platform. As the probability of the e-commerce platform entering the mediation platform increases, the mediation platform will take positive measures to deal with the settled e-commerce platform. Due to the limited resources and energy of the mediation platform, the mediation platform will call more resources to serve the settled e-commerce platform. Therefore, the probability of positively dealing with complaints against nonsettled platforms will be reduced.

4.2. Influence of the Probability of Consumer Being Dissatisfied with the Outcome When the E-Commerce Platform Is Handled Negatively. The probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively is dissatisfied, so that $\beta = \{0, 0.2, 0.6, 1\}$ and, then the game subject strategy evolution process and the impact results, as shown in Figure 6.

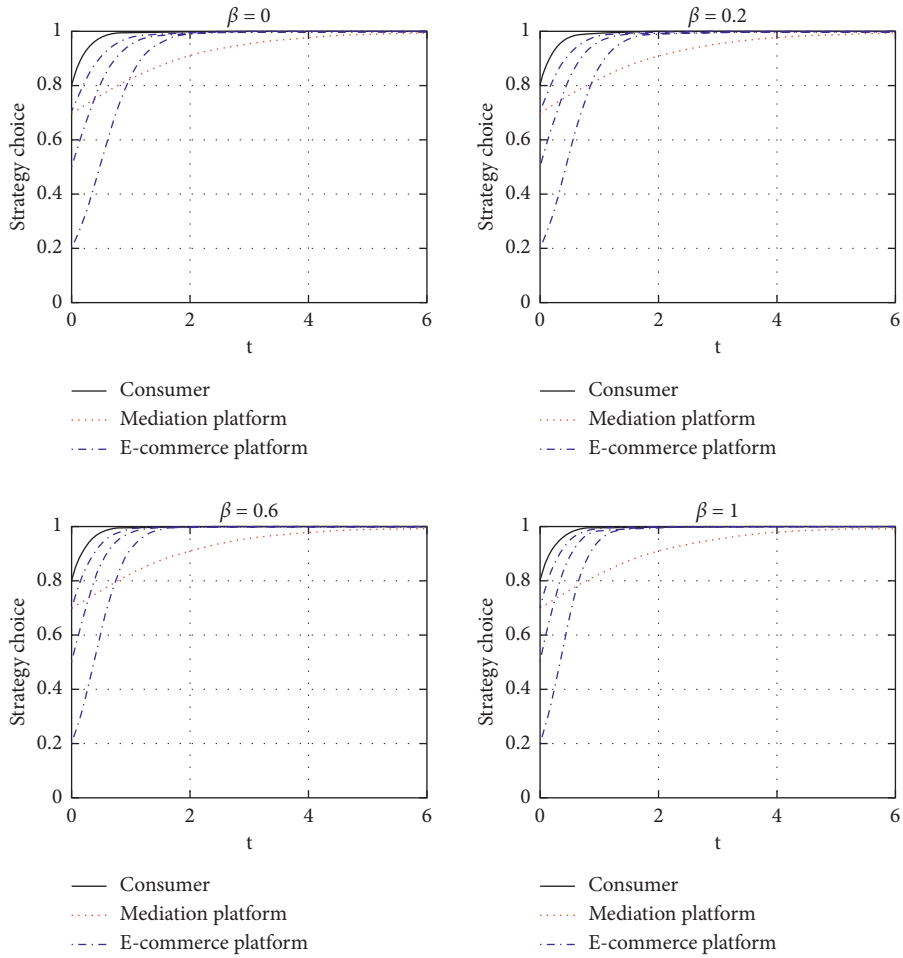

Figure 6: Influence of t the probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively.

As can be seen from Figure 6, the probability of consumers being dissatisfied with the outcome when the e-commerce platform is handled negatively has a greater impact on the strategy choice of the e-commerce platform. With the increase of the probability that consumers are dissatisfied with the processing results when the e-commerce platform handles negatively, the probability that the e-commerce platform chooses to handle positively will increase. This is because consumers' dissatisfaction with the complaint handling results will reduce consumers' trust in the e-commerce platform and affect the reputation of the e-commerce platform, thus forcing the e-commerce platform to positively handle consumer complaints and restore the reputation of the e-commerce platform. Improving consumers' awareness of rights protection can effectively inhibit the negative handling of consumer complaints by the e-commerce platform.

4.3. Influence of Factors Leading to the Loss of E-Commerce Platform Reputation on the Choice of E-Commerce Platform Strategy. Loss of reputation of the e-commerce platform due to negative reports on the mediation platform and consumer's dissatisfaction with the result of processing are changed, so that $N_2 = \{0, 1, 1.5, 2, 2.5, 3\}$ and $X_2 = \{0, 0.5, 0.9, 1.5, 3, 8\}$, then the process of e-commerce platform strategy evolution and the impact results, as shown in Figure 7.

As can be seen from Figure 7, the evolution rate of the e-commerce platform towards positively handling consumer complaints increases with the increase of reputation loss of the e-commerce platform caused by negative reports of mediation platforms. Consumers' dissatisfaction with the handling results leads to increased reputation loss of the e-commerce platform, which can promote the evolution of the e-commerce platform to positively handle consumer complaints. It can be seen that the greater the impact on the reputation loss of the e-commerce platform, the more the e-commerce platform tends to choose to positively deal with consumer complaints. This is because the negative reports of the mediation platform, the low ranking of the list and other behaviors, and consumers' dissatisfaction with the processing results will hurt the reputation of the e-commerce platform. To recover customers lost due to bad reputation, the e-commerce platform will positively and quickly deal with consumer complaints, recover lost customers, and reestablish a good platform image. Therefore, improving the

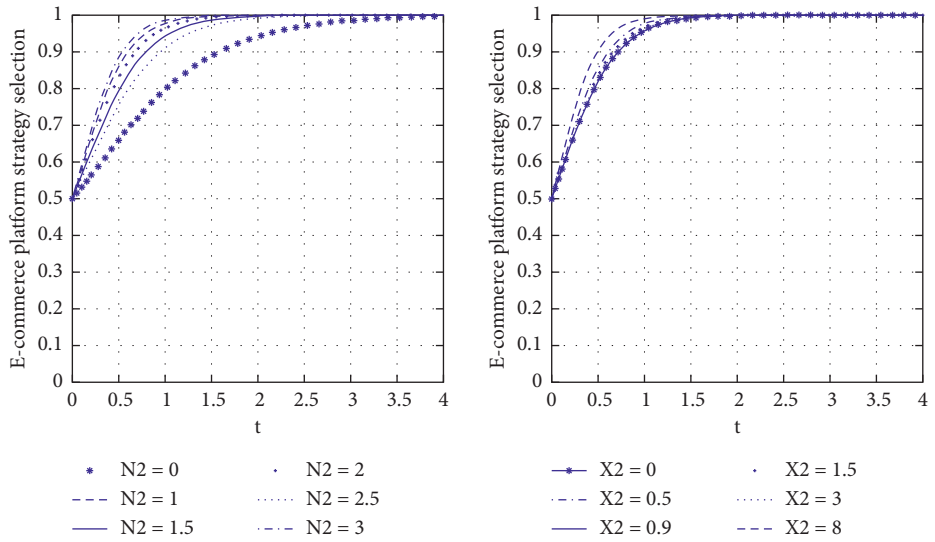

Figure 7: Influence of factors leading to the loss of e-commerce platform reputation on the choice of e-commerce platform strategy.

influence of consumers and mediation platforms on the e-commerce platform can improve the enthusiasm of the e-commerce platform to deal with consumer complaints, to build a better relationship between consumers and the e-commerce platform.

4.4. Influence of Strategy Choice of Game Subjects. The probability of each game subject's strategy choice is changed, then the process of strategy evolution and influence results of the consumer, mediation platform, and e-commerce platform, as shown in Figure 8.

As can be seen from Figure 8, changing the probability of consumers' real complaint, the probability of mediation platform's positive handling and the probability of e-commerce platform's positive handling yields unstable equilibriums $(1, q, 1)$ and $(0, 0, g)$, and the system exists a combination of evolutionarily stable strategies (consumer's distorted complaint, mediation platform's negative handling, e-commerce platform's negative handling), (consumer's real complaint, mediation platform's positive handling, e-commerce platform's positive handling), (consumer's real complaint, mediation platform's negative handling, e-commerce platform's positive handling). Therefore, consumers themselves should improve their awareness of safeguarding their rights. If they are not satisfied with consumption, they should positively complain. The mediation platform itself should strengthen the supervision and review of consumers and the e-commerce platform to promote the settlement of the e-commerce platform. Improve the credibility and influence of the mediation platform, to increase the trust of the e-commerce platform and consumers in the mediation platform, so that the mediation platform can better urge the e-commerce platform to deal with consumer complaints. The e-commerce platform should improve the awareness of after-sales service and consumer satisfaction, to improve the reputation of the platform and attract more consumers.

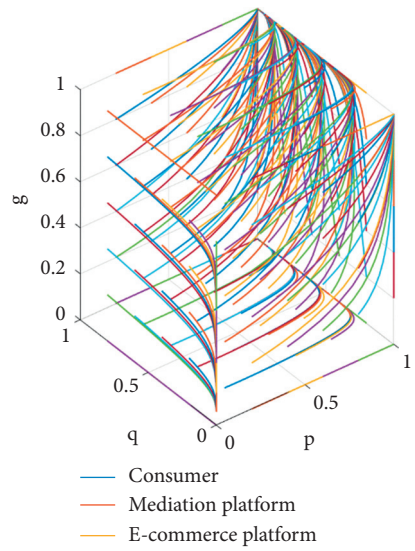

Figure 8: Influence of strategy choice of game subjects.

5. Conclusion

The e-commerce dispute mediation platform is introduced, and the evolutionary game model with the consumer, mediation platform, and e-commerce platform as the main subjects is constructed, while the probability of the e-commerce platform being enrolled in the mediation platform and the probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively are introduced to be more realistic. The stability analysis of each game subject shows the influencing factors of each subject's strategy choice, and the influence of the main influencing factors on the strategy choice of the game subject is discussed through numerical simulation and emulation. The main conclusions of the study are as follows:

(i) The rate of consumer real complaint can be increased when the probability of the mediation platform and

e-commerce platform positively handling complaint increases, the penalty for consumer distortion complaint is higher, the real complaint cost of the consumer is lower, and the distorted complaint cost of the consumer is higher. (ii) The probability of the mediation platform positively handling consumer complaints increases with the increase in the probability of consumers' real complaints and the increase in the impact of the mediation platform's handling strategies on their reputation. (iii) With the increase in the probability of consumer's true complaint and the mediation platform's positive handling, the increase in the probability of the e-commerce platform being enrolled in the mediation platform, the lower positive handling cost of e-commerce platform, the increase in the reputational impact of consumers on the e-commerce platform, the increase in the loss of reputation of the mediation platform due to negative handling of a real complaint by the mediation platform, and the increase in the mediation platform on the impact of e-commerce platform reputation, the e-commerce platform tends to choose the positive handling strategy.

For the e-commerce platform to positively handle consumer complaints, and thus make the entire e-commerce industry sustainable, the behavior of all three parties - the consumer, the mediation platform, and the e-commerce platform - must be positive and honest. (i) Consumers should have a sense of integrity and not make exaggerated or even false complaints; consumers themselves should also raise their awareness of their rights, legally defend their rights, and positively pursue secondary complaints if they are not satisfied with the results of the complaint mediation. (ii) The e-commerce platform should improve the awareness of after-sales service and positively deal with consumer complaints. The e-commerce platform should also be positively stationed in the mediation platforms and urge themselves to positively deal with consumer complaints through a series of services of the mediation platforms. (iii) Improving the credibility and influence of the mediation platforms is an important part of motivating the e-commerce platform to positively handle consumer complaints. Therefore, to improve the credibility and influence of the mediation platforms, the mediation platforms themselves should increase the supervision and review of consumers and the e-commerce platform, and positively promote the "exposure desk", "case study", "e-commerce rating", "list" and other operations. The mediation platforms can positively promote the consumer rating system, increase the service and publicity for the resident merchants, promote the entry of the e-commerce platform, urge the e-commerce platform to deal with consumer complaints, increase the docking and cooperation with social media, and constantly optimize the system to simplify the procedures for consumer complaints, etc. At present, the mediation platforms' punishment for consumers who complain about distortion is relatively small and is simply a blocking process. The mediation platforms need to improve supervision and punishment efforts and impose a certain degree of punishment on consumers who complain about distortion and on the e-commerce platform that deals with it negatively.

This paper addresses the evolutionary game among the consumer, mediation platform, and e-commerce platform. In fact, for the e-commerce platform with merchants on board, they also need to interface with merchants, and some complaints need to be handled by merchants; in reality, consumers who are not satisfied with the processing results may make secondary complaints; e-commerce ratings need to consider feedback time, consumer ratings and other factors, but they are not considered in this study. Subsequent studies can be conducted around this.

Appendix

Proof of Proposition 1. Let $R(q,g) = -J + Jq + S - J\beta + g(J - Jq + J\beta) + A - C_1 + C_2$, $\partial R(q,g)/\partial q = (1-g)J > 0$, $\partial R(q,g)/\partial g = J(1-q) + J\beta > 0$, $R(q,g)$ is positively correlated with q, g. Under $0 \le q_0 \le 1$ and $0 \le g_0 \le 1$, when $q > q_0, g > g_0$, $R(q,g) > 0$, $F(p)|_{p=1} = 0$, $F\prime(p)|_{p=1} < 0$, at $p = 1$ stable; when $q < q_0, g < g_0, R(q,g) < 0$, $F(p)|_{p=0} = 0$, $F\prime(p)|_{p=0} < 0$, at $p = 0$ stable; when $q = q_0, g = g_0, R(q,g) < 0$, $F(p) = 0$, $F'(p) = 0$, Stability is uncertain. End of proof. □

Proof of Corollary 1. Under $i < 1/e$, $\partial V_{p1}/\partial S = \partial V_{p1}/\partial C_2 = 1 + \ln i/J > 0$, $\partial V_{p1}/\partial C_1 = -1 + \ln i/J < 0$. When $S\uparrow$, $C_1\downarrow$ or $C_2\uparrow$, $V_{p1}\uparrow$. End of proof. □

Proof of Corollary 2. From Proposition 1, $q_0\uparrow$, $q < q_0$, the stable strategy for the consumer is distortion complain. $\partial q_0/\partial J = (S + A - C_1 + C_2)/[(1-g)J^2]$, $V_{p1}/\partial\beta = (S + A - C_1 + C_2)/(J\beta + J\beta^2)$. When $S + A - C_1 + C_2 < 0$, $\partial q_0/\partial J < 0$, $\partial V_{p1}/\partial\beta > 0$. When $S + A - C_1 + C_2 > 0$, $\partial q_0/\partial J > 0$, $\partial V_{p1}/\partial\beta < 0$. When $S + A - C_1 + C_2 = 0$, $\partial q_0/\partial J/ = \partial V_{p1}/\partial\beta = 0$.If change J does not affect q_0. If change β does not affect V_{p1}. □

Proof of Proposition 2. When $\alpha = 1$, $F(q) = 0$, $F'(q) = 0$, mediation platform selects complaint handling strategy uncertainty. Let $Q(p) = p(D_1 + D_2) - T_1 + T_2$, $\partial Q(p)/\partial p = D_1 D_1 + D_2 > 0$, $p\uparrow$, $Q(p)\uparrow$. Under $p_1 < 0$, $Q(p) > 0$ is constant, $F(q)|_{q=1} = 0$, $F\prime(q)|_{q=1} < 0$, mediation platform stabilizes the choice of positive handling strategy. When $p_1 > 1$, $Q(p) < 0$ is constant, $F(q)|_{q=0} = 0$, $F\prime(q)|_{q=0} < 0$, mediation platform stabilizes the selection of negative handling strategy. Same reason, under $0 \le p_1 \le 1$, when $p > p_1$, $Q(p) > 0$, $F(q)|_{q=1} = 0$, $F\prime(q)|_{q=1} < 0$, the mediation platform stabilizes the choice of positive handling strategy; when $p < p_1$, $Q(p) < 0$, $F(q)|_{q=0} = 0$, $F\prime(q)|_{q=0} < 0$, the mediation platform stabilizes the selection of negative handling strategy; when $p = p_1$, $Q(p) = 0$, $F(q) = 0$, $F\prime(q) = 0$, the mediation platform chooses an uncertain complaint handling strategy. End of proof. □

Proof of Corollary 3. $\partial V_{p1}/\partial D_1 = -(2(T_1 - T_2)^2/(D_1 + D_2)^3) < 0$, $\partial V_{p1}/\partial D_2 = -(2(T_1 - T_2)^2/(D_1 + D_2)^3) < 0$. When $D_1\uparrow$ or $D_2\uparrow$, $V_{p1}\uparrow$. □

Proof of Corollary 4. When $0 \le (T_1 - T_2)/(D_1 + D_2) \le 1$, $\partial p_1/\partial T_1 = 1/(D_1 + D_2) > 0$, $\partial p_1/\partial T_2 = -1/(D_1 + D_2) < 0$. When $T_1 \downarrow$ or $T_2 \uparrow$, $p > p_1$, mediation platform stabilizes the choice of positive handling strategy. End of proof. □

Proof of Proposition 3. Let $W(p,q) = pa + (1-p)(1-q)b$, $\partial W(p,q)/\partial p = a + (1-q)b$, $\partial W(p,q)/\partial q = (1-p)b$. Because $a + (1-q)b > 0$, $(1-p) > 0$, $(1-q) > 0$, $(1-\alpha) > 0$, $Q_1 > Q_2$, therefore $\partial W(p,q)/\partial p > 0$, $\partial W(p,q)/\partial q > 0$. That is, $W(p,q)$ is positively correlated with p and q. Under $0 \le a/[a + (1-q)b] \le 1$ and $0 \le pa/[(1-p)b] \le 1$, when $p > p_2$ and $q > q_2$, $W(p,q) > 0$, $F(g)|_{g=1} = 0$, $F\prime(g)|_{g=1} < 0$, stable choice of positive handling strategy for e-commerce platform; when $p < p_2$ and $q < q_2$, $W(p,q) < 0$, $F(g)|_{g=0} = 0$, $F\prime(g)|_{g=0} < 0$, stable choice of negative handling strategy for e-commerce platform; when $p = p_2$, and $q = q_2$, $W(p,q) = 0$, $F(g) = 0$, $F'(g) = 0$, uncertainty of complaint handling strategy for e-commerce platform. End of proof. □

Proof of Corollary 5. It follows from Proposition 3 that $p_2 \downarrow$, $p > p_2$ increased probability of the e-commerce platform choosing aggressive handling strategy. Under $0 \le a/a + (1-q)b \le 1$, because $0 \le q \le 1$, $Q_1 > Q_2$, it follows from Corollary 5 that $-L_1 + L_2 + N_1 + N_2 + \beta X_1 + \beta X_2 > 0$, therefore $(\partial p_2/\partial \alpha) = -(1-q)(Q_1 - Q_2)[N_1 + N_2 + \beta(X_1 + X_2)]/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \le 0$ $\partial p_2/\partial L_1 = (1-q)(1-\alpha)^2(Q_1 - Q_2)/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \ge 0$, $\partial p_2/\partial L_2 = -(1-q)(1-\alpha)^2(Q_1 - Q_2)/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \le 0$, $/\partial Q_1 = (1-q)(1-\alpha)[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta(X_1 + X_2)]/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \ge 0$, $\partial p_2/\partial Q_2 = -(1-q)(1-\alpha)[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta(X_1 + X_2)]/\left[\begin{array}{c}(1-\alpha)(L_2 - L_1) + N_1 + N_2 \\ +\beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)\end{array}\right]^2 \le 0$, $\partial p_2/\partial X_1 = \partial p_2/\partial X_2 = -(1-q)(1-\alpha)(Q_1 - Q_2)\beta/\left[\begin{array}{c}(1-\alpha)(L_2 - L_1) + N_1 \\ +N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)\end{array}\right]^2 \le 0$, $\partial p_2/\partial N_1 = \partial p_2/\partial N_2 = -(1-q)(1-\alpha)(Q_1 - Q_2)/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \le 0$, $\partial p_2/\partial \beta = -(1-q)(1-\alpha)(Q_1 - Q_2)(X_1 + X_2)/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + (-1+q)(-1+\alpha)(Q_1 - Q_2) + \beta(X_1 + X_2)]^2 \le 0$. $L_1 \downarrow$, $q \downarrow$, $Q_1 \downarrow$, $\alpha \uparrow$, $L_2 \uparrow$, $N_1 \uparrow$, $N_2 \uparrow$, $Q_2 \uparrow$, $X_1 \uparrow$, $X_2 \uparrow$, $\beta \uparrow$, then $p_2 \downarrow$. End of proof. □

Data Availability

The data used to support the findings of this paper are included within the article (Numerical Analysis section).

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Controlling Shareholders' Equity Pledge and Listed Companies' Stock Repurchase

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Based on the unbalanced panel data of China's A-share listed companies from 2013 to 2021, this paper empirically examines the influence of controlling shareholders' equity pledge on the listed companies' stock repurchase. It is found that listed companies will stabilize the share price through stock repurchase to prevent the risk of control right transfer due to stock price decline. There is a positive correlation between equity pledge and stock repurchase. Moreover, this positive correlation is more significant among nonstate-owned listed companies and listed companies in the eastern region. Further research shows that the positive influence of equity pledge on stock repurchase is more significant under a good information environment and good corporate governance. However, the earnings management behavior of listed companies has no significant influence on the positive influence of equity pledge on stock repurchase.

1. Introduction and Literature Review

The essence of equity pledge is the pledge of the rights to the underlying loan. The target of the pledge is the stocks held by the pledgor, and the pledgor is generally the borrower. Equity pledge is not a new product of the capital market. China's pledge guarantee system can be traced back to the Guarantee Law of the People's Republic of China, which came into effect on October 1, 1995. Article 75 of the Guarantee Law stipulates stocks that can be transferred by law, and it is a right to pledge. Article 223 of the Property Law of the People's Republic of China also stipulates that transferable stocks that the debtor or a third party has the right to dispose of can be pledged. The Guarantee Law and Property Law are the fundamental laws to be observed in equity pledge.

The specific practices of equity pledge in China indicate that regulators are gradually relaxing the constraints of equity pledge to better serve the development of the capital market [1]. Before 2013, the equity pledge in China was mainly handled through intermediaries such as commercial banks and trusts. As equity pledge is a nonstandard business, the setting of contract terms is quite flexible, which is determined by the pledgor and the pledgee through negotiation. If a securities company pledges its stocks or certificates of securities investment funds, it needs to be more detailed. Along with the generally active capital market, on-floor equity pledge, a convenient financing tool, is widely favored by brokers and shareholders of listed companies. During this period, the scale of equity pledge market also expanded dramatically. However, with the sharp fluctuations in the capital market and frequent equity pledge plunge, the risk of equity pledge has become increasingly prominent. Thus, regulators had to focus on controlling the risk of on-floor pledge. On September 8, 2017, Shanghai Stock Exchange, Shenzhen Stock Exchange, and CSDC issued the Measures for the Trading, Registration and Settlement of Equity Pledge and Repurchase (2017 Amendment for Trial Implementation) to solicit public opinions on the amendments. The SASAC also issued the Guidelines on Risk Management of Equity Pledge and Repurchase Transactions by Securities Companies (Draft for Public Comments) on the same day. On March 12, 2018, the revised version of the above Methods and Guidelines was officially implemented. This new regulation puts forward stricter and more detailed requirements for the risk control of on-floor pledge.

Since the formal promulgation of the Guarantee Law in 1995, equity pledge has been institutionally recognized for the first time. Existing studies have demonstrated that the controlling shareholders will choose to pledge equity when the stock price is overvalued, but the stock price will not remain high all the time, and the wrong pricing will be closer to the true value. However, the equity pledge itself has a negative effect on the stock price of listed companies. During the duration of the pledge contract, listed companies may also have some incidents that have negative impacts on the stock price [2, 3]. As a result, the stock price may also have a downward tendency. However, controlling shareholders fear the decline in the stock price, which may cause the transfer of control rights and the collapse of the stock price. However, this is not what controlling shareholders expect. Therefore, the significance of maintaining the stock price stability for controlling shareholders is evident [4].

China actively promotes the construction of a multilevel capital market to drive sustained and healthy economic development. A key of this construction is to make the financiers with different risk levels and the fund providers with different risk tolerance and preference levels match quickly, that is, find risk-matched counterparties and complete transactions efficiently. The equity pledge market is a part of multilevel capital market, which was dominated by commercial banks before 2013 (with a market share of 80% in 2007). In May 2013, Shenzhen Stock Exchange issued the Measures for the Trading, Registration and Settlement of Equity Pledge and Repurchase (Trial). Thus, brokers gradually became the main body of the market (with a market share of 70% in 2018). They have significantly stimulated the development of this market because their transactions of equity pledge are more convenient than commercial banks. Although the stocks of listed companies as pledge objects are more liquid than fixed assets, the stocks of many listed companies are riskier than fixed assets [5]. Recently, large fluctuations in the capital market have led to a more frequent stock pledge plunge. This has caused many pledgors to suffer losses and provided a large amount of provision for diminution in value. Moreover, whether the pledge risk matching represents the equilibrium of China's stock pledge market is particularly important because the major risk mismatch between the pledgor and the pledgee will damage the sustainability and stability of the market and lead to systemic financial risks [6].

To maintain the stability of stock prices, regulators have issued a large number of policies to prevent systemic financial risks caused by equity pledge. The New Pledge Regulations promulgated in March 2018 further restricted the upper limit of equity pledge ratio and strictly controlled the use of funds [7]. However, the development of equity pledge business grows vigorously. Meanwhile, the research and exploration of equity pledge in domestic academic circles are making robust progress. Although fruitful research results have been achieved, it is urgent to strengthen the analysis of the influencing factors and economic consequences of equity pledge academically, which is of essential reference and exploration value for listed companies, investors, and regulators.

Although equity pledge provides financing convenience for controlling shareholders by using the liquidity and valuation convenience of listed companies' stocks, the pledgor cannot effectively monitor the actual use of funds obtained from the controlling shareholders' equity pledge. For stock repurchase, the United States has carried out many studies, forming a wealth of research results, but there are not many related studies in domestic academic circles. Based on the political, economic, and institutional differences, it is also of great significance to study the stock repurchase in China. Song et al. [8] empirically studied the impact of equity pledge on stock repurchase and found that listed companies have the motivation to publish their stock repurchase plans and provide support for stock prices in order to alleviate the financial pressure caused by equity pledge and maintain control right [9]. The market will have a positive reaction to the stock repurchase plans, but the excess return on stock repurchase with equity pledge is lower than the excess return without pledge [10]. The actual purpose of controlling shareholders' equity pledge is to alleviate their own financial difficulties, cash out, or increase the leverage of control rights. The willingness of large shareholders to pledge stocks is positively correlated with the wrong pricing of the company's stocks and the credit policy, indicating the existence of temporal behavior of large shareholders' equity pledge [11]. When pledging stocks, controlling shareholders can maintain or defend the stock price in various ways by themselves or by asking the listed company to reduce the risk of control right transfer. These methods may include reducing the levy on them, promoting listed companies to capitalize development costs or manage actual earnings to boost profits, using the dividend policy of listed companies to manage market value, requiring listed companies to conceal bad news, promoting listed companies to engage in tax avoidance, inhibiting innovative investment of listed companies, and increasing strategic charitable donations of listed companies [12].

Different from Song et al. [8], this study employs the actual data of stock repurchase to study the relationship between equity pledge and stock repurchase. The reason for choosing the actual data of stock repurchase is that listed companies are not required to make repurchases as planned after the stock repurchase plan is issued, and listed companies can choose to either repurchase, partially repurchase, or not repurchase. In the United States, the entire process from the issuance of a stock repurchase plan to the completion of its implementation can take up to three years [13]. In the market, there are many cases of not repurchasing after issuing the stock plan. Studies have found that the average repurchase completion rate of US listed companies is nearly 73%. Only 60% of listed companies complete their stock repurchase plan in full, and another 10% complete less than 5% of their stock repurchase plan. The completion rate of Japan's stock repurchase plan is higher than that of the United States, reaching 77% [14, 15]. It is found that the stock repurchase plan in the US market is used as a tool to raise the stock price, but the listed companies are not aware of it. In history, there has never been a record of punishment for listed companies not repurchasing after issuing the stock

repurchase plan. In this case, investors may feel cheated and believe that the stock repurchase announcement is not credible. According to the signal theory, paying a high price is an effective signal because it is the only way to effectively distinguish those companies that are truly undervalued from others. However, when the stock repurchase is implemented, listed companies use free cash flow to buy stocks, which has a high cost for listed companies with financing constraints. Therefore, the implementation of stock repurchase is a more effective signal than the announcement of stock repurchase.

To sum up, it can be seen that existing studies are still insufficient and fail to expose the relationship and internal influence mechanism between equity pledge and stock repurchase from the perspective of stock repurchase plan implementation. Therefore, based on the sample data of China's A-share listed companies from 2013 to 2021, this paper profoundly discusses the relationship and internal mechanism between equity pledge and stock repurchase from the perspective of stock repurchase plan implementation. The innovations of this paper are as follows. First, proceeding from the actual repurchase behavior of listed companies, this paper finds that one of the motives of stock repurchase is equity pledge, which enriches the related literature on stock repurchase. Secondly, this paper also investigates what kind of changes the dividend policy of stock repurchase will have in equity pledge, which supplements the related literature on dividend policy of equity pledge.

2. Theoretical Analysis and Hypothesis

As mentioned earlier, brokers have been allowed to enter the equity pledge market of listed companies since May 2013. Subsequently, China's stock pledge market has developed rapidly. Pledgors have made equity ledge to obtain funds from pledgees through off-floor pledge and on-floor pledge, respectively, and pledged the stocks of listed companies they held.

Controlling shareholders' equity pledge is an act in which the controlling shareholders of listed companies guarantee their stocks of listed companies as the collateral for obtaining funds for themselves or others. Equity pledge provides a convenient and fast financing mode for the controlling shareholders who are short of funds. Creditors are usually willing to lend to borrowers with equity pledge as guarantees because stocks are the expression of the ownership of listed companies. When listed companies go bankrupt, they also mean the claim of surplus value. Moreover, the stock price is clearly visible, making it easier for creditors to make the valuation [16].

However, equity pledge is not without risks. Creditors will stipulate the warning line and liquidation line in the pledge contract for their own interests and guarantee the safety of funds. If the market value of the pledge is lower than the warning line, the borrower should supplement the pledge. If the market value is lower than the liquidation line, the pledged stock may be forced to liquidate through either block trade or competitive bidding [17]. Forced liquidation will lead to a downward spiral of stock prices, resulting in more stocks of controlling shareholders being sold. When a certain number of stocks are sold and the remaining stocks of the controlling shareholders can no longer control the listed company, the risk of control right transfer will occur [18]. For controlling shareholders, the control right is of high value. Therefore, it becomes the choice of controlling shareholders to maintain the control right and reduce the risk of control right transfer.

Studies have found many ways for listed companies with equity pledge to maintain stock prices, and the shareholders will increase their holdings to convey positive information about the company to the market [19]. In the meantime, they will also use their own control right to change the information disclosure behavior of listed companies [20]. It is also found that listed companies also beautify accounting statements by earnings management, especially the upward earnings management [21, 22]. However, as a way of market value management, both short-term and long-term stock repurchase can play a role in increasing market value. This is because stock repurchase can not only improve the abovementioned companies' net profit per share but also increase the market demand for stocks as a kind of buying behavior, thus managing the supply value [23]. Furthermore, when the stock price is undervalued, stock repurchase also has a signal effect [24].

Therefore, the controlling shareholders of equity pledge have the incentive to repurchase stocks for market value management. The controlling shareholders have the will to manage market value and also the ability to manage market value. In addition, the market value management is to enhance the market value of listed companies, and the management team can obtain the recognition of their management ability from the high market value of listed companies and enhance the management reputation, which is consistent with the management team's goal. To sum up, this paper puts forward hypothesis 1.

H1 : With other things being equal, controlling shareholders' equity pledge is positively correlated with the listed companies' stock repurchase.

3. Research Design

3.1. Sample Selection and Data Sources. This paper selects the sample data of China's A-share listed companies from 2013 to 2021. It should be noted that the reason why the starting point of the sample is 2013 is as follows. First, before 2013, listed companies rarely conducted stock repurchase. Second, in 2013, the on-floor equity pledge was released, and securities companies were allowed by regulators to participate in the stock pledge business as fund providers. In addition, this paper excludes the ST-rated samples, insolvent samples, samples belonging to the financial industry, and samples with missing data. Finally, 15,567 companies of 3,331 listed companies are obtained, and the annual observation values constitute the unbalanced panel data. All the data in this paper are from the CSMAR Economic and Financial Database. At the same time, all continuous variables are winsorized at 1% and 99% quantiles to eliminate the influence of extreme outliers on the research results.

3.2. Variable Explanation and Description

3.2.1. Explained Variable: Stock Repurchase. This paper selects the actual stock repurchase data of listed companies as the explained variable. The reason for choosing the actual implementation data of stock repurchase instead of the stock repurchase plan published is that listed companies do not need to carry out stock repurchase according to the original plan after the stock repurchase plan is published but have different choices. Moreover, the practice of listed companies' repurchase is unknown. The implementation of stock repurchase is that listed companies use free cash flow to buy stocks. Therefore, the explained variables in this paper are, respectively, the dummy variable of stock repurchase (Rpurchase1) and the stock repurchase scale (Rpurchase2). If the listed company implements the stock repurchase in the year, Rpurchase1 is 1; otherwise, it takes 0. The stock repurchase scale (Rpurchase2) is calculated by the annual stock repurchase amount/market value of listed companies *100%. The larger the value, the larger the stock repurchase scale of the company.

3.2.2. Core Explanatory Variable: Controlling Shareholders' Equity Pledge. This paper uses two methods to measure controlling shareholders' equity pledge: (1) The dummy variable of controlling shareholders' equity pledge (Pledge1). If the listed company has the equity pledge at the end of the accounting year, it is 1; otherwise, it is 0. (2) Year-end pledge ratio of controlling shareholders (Pledge2), which is calculated by the year-end number of stocks pledged by controlling shareholders of listed companies/the number of stocks held by controlling shareholders.

3.3. Control Variable. Considering the factors affecting the listed companies' stock repurchase, the following control variables are selected to effectively restrain the influence of possible factors by referring to the existing literature. The control variables include company size (size), financial leverage (Lev), return on equity (Roe), growth (Growth), cash ratio (Cash), board independence (board), 1 person serving 2 positions (dual), and equity nature (Soe). In addition, this paper also controls the dummy variable of year, Year, and the dummy variable of industry, Industry, respectively. See Table 1 for the definition and detailed description of the above variables.

3.4. Model Setting. To test hypothesis H1, that is, the influence of controlling shareholders' equity pledge on listed companies' stock repurchase, this paper sets the following regression model:

$$\begin{aligned} \text{Rpurchase}_{i,t+1} = {} & \alpha_0 + \alpha_1 \text{Pledge}_{i,t} + \alpha_2 \text{Controls}_{i,t} \\ & + \sum \text{Year} + \sum \text{Industry} + \varepsilon_{i,t}. \end{aligned} \tag{1}$$

To effectively reduce the influence of endogenous factors, the core explanatory variables and control variables in this paper are treated with one-period lag, and the repurchase is conducted.

4. Analysis of Empirical Results

4.1. Descriptive Statistical Analysis. Table 2 shows the results of descriptive statistical analysis. From the explained variables, the average value of Rpurchase1 is 0.185, which indicates that 18.5% of listed companies repurchase stocks during the sample period. The average value of Rpurchase2 is 0.458, which indicates that listed companies repurchase 45.8% of the market value. The minimum value is 0, and the maximum value is 15.27, which indicates that there is a huge gap between different listed companies in the stock repurchase scale. From the core explanatory variables, the average value of Pledge1 is 0.528, which indicates that 52.8% of the controlling shareholders participate in the equity pledge business during the sample period. The average value of Pledge2 is 0.499, which indicates that 49.9% of controlling shareholders carry out the equity pledge. The minimum value is 0, and the maximum value is 16.25, which indicates that the ratio of controlling shareholders' equity pledge in different listed companies varies largely in different years. From the control variables, the difference is also significant. In addition, multicollinearity tests are carried out in this paper, and the average VIF is 5.69, suggesting that there is no significant collinearity problem in the samples.

4.2. Correlation Analysis. Table 3 presents the statistical results of correlation analysis. From the dummy variable of controlling shareholders' equity pledge, the correlation coefficient between Rpurchase1 and Pledge1 is 0.221, which is significantly positive at the level of 1%. It indicates that whether the controlling shareholders' equity is pledged is positively correlated with whether the stock repurchase is carried out. Meanwhile, the correlation coefficient between Rpurchase1 and Pledge2 is 0.152, which is significantly positive at the level of 1%. It indicates that the ratio of controlling shareholders' equity pledge is positively correlated with whether the stock repurchase is carried out. From the ratio of controlling shareholders' equity pledge, the correlation coefficient between Rpurchase1 and Pledge2 is 0.186, which is significantly positive at the level of 1%. It indicates that the ratio of controlling shareholders' equity pledge is positively correlated with whether the stock repurchase is carried out. Moreover, the correlation coefficient between Rpurchase2 and Pledge2 is 0.134, which is significantly positive at the level of 1%. It indicates that the ratio of controlling shareholders' equity pledge is positively correlated with the ratio of stock repurchase. The above results basically verify the validity of hypothesis 1, which needs to be further tested and demonstrated.

4.3. Analysis of Multiple Regression Results. Will the listed companies whose controlling shareholders pledge their stocks manage their market value in the way of stock repurchase? In order to verify the prediction of hypothesis 1, this paper carries out empirical tests, and the specific results are demonstrated in Table 4.

Panel A presents the regression results when the core explanatory variable is the dummy variable of equity pledge.

Table 1: Variable description.

Variable	Definition	Symbol	Description
Explained variable	Dummy variable of stock repurchase	Rpurchase1	If the company implements the stock repurchase in the year, Rpurchase1 is 1; otherwise, it is 0
	Stock repurchase scale	Rpurchase2	Annual stock repurchase amount/market value of listed companies *100%
Core explanatory variable	Dummy variable of controlling shareholders equity pledge	Pledge1	If the company has equity pledge at the end of the accounting year, it is 1; otherwise, it is 0
	Year-end pledge ratio of controlling shareholders	Pledge2	Year-end number of stocks pledged by controlling shareholders of listed companies/the number of stocks held by controlling shareholders
Control variable	Company size	Size	Year-end total assets; take the natural logarithm
	Financial leverage	Lev	Total liabilities/total assets
	Return on equity	Roe	Net profit/equity
	Growth	Growth	Growth rate of business revenue compared with the previous period
	Cash ratio	Cash	Cash/total assets
	Board independence	Board	Number of independent directors/board size
	1 person serving 2 positions	Dual	If the chairman and general manager hold concurrent positions, the value is 1; otherwise, it is 0
	Nature of equity	Soe	If the listed company is a state-owned enterprise, the value is 1; otherwise, it is 0

Table 2: Descriptive statistics.

Variable	N	Mean	Sd	min	p25	p50	p75	Max
Rpurchase1	15567	0.185	0.388	0	0	0	0	1
Rpurchase2	15567	0.458	1.426	0	0	0	0	15.27
Pledge1	15567	0.528	0.499	0	0	1	1	1
Pledge2	15567	0.499	0.243	0	0	1	8	16.25
Lev	15567	0.428	0.198	0.0603	0.269	0.422	0.578	0.863
Growth	15559	0.380	0.881	−0.674	−0.0113	0.153	0.452	5.987
Roe	15555	0.0733	0.102	−0.491	0.0385	0.0775	0.121	0.306
Soe	15233	0.347	0.476	0	0	0	1	1
Dual	15567	0.280	0.449	0	0	0	1	1
Board	15566	37.60	5.398	33.33	33.33	36.36	42.86	57.14
Asset	15567	22.53	1.317	20.20	21.59	22.33	23.29	26.50

Table 3: Correlation analysis.

Variable	Rpurchase1	Rpurchase2	Pledge1	Pledge2	Lev	Growth	Roe
Rpurchase1	1						
Rpurchase2	0.674***	1					
Pledge1	0.221***	0.152***	1				
Pledge2	0.186***	0.134***	0.495***	1			
Lev	−0.063***	−0.036***	−0.040***	0.025***	1		
Growth	−0.023***	−0.031***	0.00600	0.0110	0.094***	1	
Roe	0.029***	0.024***	−0.045***	−0.068***	−0.137***	0.032***	1
Soe	−0.232***	−0.150***	−0.483***	−0.307***	0.279***	0.036***	−0.047***
Dual	0.082***	0.046***	0.155***	0.089***	−0.129***	−0.017**	0.0120
Board	0.020**	0.00400	0.027***	0.020**	0.00100	0.017**	−0.0110
Asset	−0.00800	0.038***	−0.155***	−0.0110	0.575***	0.026***	0.072***
	Soe	Dual	Board	Asset			
Soe	1						
Dual	−0.299***	1					
Board	−0.045***	0.118***	1				
Asset	0.417***	−0.200***	0.016**	1			

Table 4: Results of baseline regression.

Panel A core explained variable: dummy variable of equity pledge				
Variable	(1) Rpurchase1	(2) Rpurchase1	(3) Rpurchase2	(4) Rpurchase2
Pledge1	0.1464***	0.0603***	0.3688***	0.1001***
	(16.607)	(6.678)	(11.196)	(3.040)
Lev		−0.0538		−0.4159**
		(−1.231)		(−2.560)
Growth		0.0128***		0.0603***
		(3.280)		(4.226)
Roe		0.1687***		0.4439***
		(4.170)		(2.985)
Soe		−0.0039		0.1068
		(−0.114)		(0.797)
Dual		−0.0183		−0.0476
		(−1.289)		(−0.971)
Board		−0.0007		−0.0002
		(−0.685)		(−0.069)
Asset		0.2009***		0.6259***
		(20.175)		(18.279)
Constant	0.1075***	−4.3050***	0.2631***	−13.4894***
	(23.113)	(−19.538)	(15.138)	(−17.906)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	15567	15212	15567	15212
R-squared	0.023	0.088	0.009	0.048
F	275.8	90.39	125.4	57.54
Panel B core explained variable: equity pledge ratio				
Pledge2	0.0062***	0.0026***	0.0190***	0.0086***
	(10.651)	(5.237)	(9.131)	(4.639)
Lev		−0.0518		0.4010**
		(−1.190)		(−2.479)
Growth		0.0117***		0.0568***
		(2.974)		(−3.969)
Roe		0.1591***		0.3944***
		(3.926)		(2.684)
Soe		−0.0035		0.1185
		(−0.099)		(0.874)
Dual		−0.0196		−0.0485
		(−1.367)		(−0.987)
Board		−0.0007		−0.0004
		(−0.738)		(−0.108)
Asset		0.1985***		0.5915***
		(19.979)		(17.149)
Constant	0.1446***	−4.2367***	0.3339***	−12.7276***
	(38.365)	(−19.171)	(24.625)	(−16.726)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	15567	15212	15567	15212
R-squared	0.027	0.089	0.016	0.051
F	113.5	78.67	83.37	56.53

Note. The *t*-test value is in brackets, using company-level clustering robust standard error; *, **, and ** are significant at the level of 10%, 5%, and 1%, respectively.

The explained variable in column (1) and column (2) is the dummy variable of stock repurchase. From column (1), it can be seen that the regression coefficient of Pledge1 is 0.1464, which is significantly positive at the level of 1%. Column (2) is the regression result after adding control variables. The regression coefficient of Pledge1 is 0.0603, which is significantly positive at the level of 1%. This shows that the average annual listed companies' stock repurchase with controlling shareholders' equity pledge is 6.03% higher than that of listed companies without controlling shareholders' equity pledge. Column (3) and column (4) are the regression results that the explained variable is the stock

repurchase ratio. The results in column (3) indicate that equity pledge increases the stock repurchase ratio. From the results of column (4) after adding control variables, it can be seen that the ratio of stock repurchase amount of listed companies with controlling shareholders' equity pledge to market value is significantly higher than that of listed companies without equity pledge. In short, listed companies with equity pledge will increase the stock repurchase ratio in the next year, which is consistent with the expectation of hypothesis 1.

Panel B introduces the regression results when the core explanatory variable is the ratio of equity pledge. Column (5) and column (7) are regression results without adding control variables. The explained variable of column (5) and column (6) is the dummy variable of stock repurchase. The explained variable of column (7) and column (8) is the stock repurchase ratio. It can be seen from column (6) that the regression coefficient of Pledge2 is 0.0026, which is significantly positive at the level of 1%, indicating that there is a positive correlation between the ratio of controlling shareholders' equity pledge and whether the stock repurchase is carried out. The regression coefficient of Pledge2 in column (8) is 0.0086, which is significantly positive at the level of 1%, indicating that there is a positive correlation between the ratio of controlling shareholders' equity pledge and the ratio of listed companies' stock repurchase. Thus, hypothesis 1 is verified.

From the perspective of control variables, company size, return on equity, and growth have a significant positive correlation with stock repurchase, while financial leverage has a significant negative correlation with stock repurchase.

5. Robustness Test

5.1. Propensity Score Matching. Propensity score matching is an effective method to alleviate systematic differences. According to the control variables in this paper, 1 : 1 matching is made on whether there is controlling shareholders' equity pledge. The regression results after matching are shown in Table 5. After the propensity score matching, both the dummy variable of equity pledge and the equity pledge ratio still have a significant positive impact on stock repurchase.

5.2. Alternative Explanatory Variable and Explained Variable. First of all, the new proxy variable Pledge3 is adopted as the core explanatory variable, which is obtained by dividing the year-end pledge quantity by the total stock capital. The regression results are shown in column (1) and column (2) of Table 6. It can be seen that Pledge3 has a significant positive influence on whether to carry out the stock repurchase.

Secondly, Rpurchase3, the natural logarithm of the stock repurchase amount, is taken as the proxy variable of the new explained variable. It can be seen from Table 6 that the regression coefficients of the dummy variable of equity pledge and equity pledge ratio to Rpurchase3 are 0.5951 and 0.5668, respectively, both of which are significantly positive at the level of 1%. The above results are consistent with the initial test results.

6. Further Analysis

6.1. Controlling Shareholders' Equity Pledge and Listed Companies' Stock Repurchase: The Motivation of Stock Price Rising. According to the previous hypothesis, equity pledge is that listed companies tend to adopt the market value management method of stock repurchase to raise the stock price. Therefore, it can be expected that when listed companies are faced with serious risk of control right transfer, the controlling shareholders will have a stronger motivation to boost the stock price through stock repurchase. Therefore, this paper further carries out heterogeneity analysis by group according to the equity nature and regional differences.

6.1.1. Equity Nature, Controlling Shareholders' Equity Pledge, and Listed Companies' Stock Repurchase. According to the equity nature, this paper divides the samples into two groups of state-owned listed companies and nonstate-owned listed companies and carries out the regression by group. Table 7 shows the results of regression by group.

The core explanatory variable of Panel A is the dummy variable of equity pledge. The regression results show that the regression coefficient and t value of column (3) are significantly larger than those of column (1), which indicates that whether there is an equity pledge in nonstate-owned listed companies has a significantly greater positive impact on the repurchase decision than state-owned listed companies. Moreover, the regression coefficient and t value of column (4) are significantly larger than those of column (2), which indicates that the stock repurchase scale of nonstate-owned listed companies with equity pledge is significantly larger than that of state-owned listed companies, which once again verifies the motivation of stock repurchase to boost stock price. The core explanatory variable of Panel B is the equity pledge ratio. From column (5) and column (7), it can be seen that the influence of state-owned listed companies' equity pledge ratio on whether to carry out the stock repurchase is not particularly significant compared with that of nonstate-owned listed companies. However, it can be seen from column (8) that the regression coefficient and significance of the influence of the nonstate-owned listed companies' equity pledge ratio on the stock repurchase scale are significantly higher than those of state-owned listed companies, which further verifies the motivation of stock repurchase.

The reason is that the above-mentioned nonstate-owned companies tend to use stock repurchase to boost the stock price. This is because the nonstate-owned listed companies face a greater risk of control right transfer, while the pledge behavior of state-owned listed companies is strictly regulated. When the pledged stocks fall below the "liquidation line," they cannot be forced to liquidate, which requires the approval of the regulators, thus restricting the transfer of state-owned stocks. In addition, the controlling shareholders of state-owned listed companies have strong social and political relationships, so they use political resources when the equity pledge crisis occurs.

Table 5: Regression results of propensity score matching.

Variable	(1) Rpurchase1	(2) Rpurchase2	(3) Rpurchase1	(4) Rpurchase2
Pledge1	0.1601***	0.2199***		
	(6.500)	(2.964)		
Pledge2			0.1108***	0.1675***
			(2.774)	(4.066)
Constant	−3.9705***	−3.9444***	−12.7738***	−12.1484***
	(−17.632)	(−17.504)	(−16.777)	(−15.924)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	15567	15212	15567	15212
R-squared	0.077	0.077	0.043	0.045
F	59.95	51.54	40.81	39.97

Note. The *t*-test value is in brackets, using company-level clustering robust standard error; *, **, and ** are significant at the level of 10%, 5%, and 1%, respectively.

Table 6: Regression results of alternative explanatory variable and explained variable.

Variable	(1) Rpurchase1	(2) Rpurchase2	(3) Rpurchase3	(4) Rpurchase3
Pledge1			0.5951***	
			(17.270)	
Pledge2				0.5668***
				(16.456)
Pledge3	0.1868***	0.1863***		
	(18.369)	(18.393)		
Constant	−3.0108***	−3.0096**	−3.0609***	−3.0576***
	(−2.774)	(−2.468)	(−4.154)	(−3.919)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	15567	15212	15567	15212
R-squared	0.086	0.087	0.047	0.053
F	125.4	55.74	83.37	55.47

Note. The *t*-test value is in brackets, using company-level clustering robust standard error; *, **, and ** are significant at the level of 10%, 5%, and 1%, respectively.

6.1.2. Regional Differences, Controlling Shareholders' Equity Pledge, and Listed Companies' Stock Repurchase. According to the provinces and municipalities where the listed companies are registered, this paper divides the samples into the eastern region group and the western region group and carries out tests by group to demonstrate the influence path of listed companies' equity pledge on stock repurchase under different marketization levels. See Table 8 for the test results by group.

The core explanatory variable of Panel A is the dummy variable of equity pledge. It can be seen that the regression coefficient and significance in the eastern region are significantly higher than those in the noneastern region, which suggests that listed companies registered in eastern provinces and municipalities directly under the Central Government will participate more in stock repurchase to prevent the risk of control right transfer caused by equity pledge. Similarly, in order to prevent control right transfer, listed companies with a higher ratio of controlling shareholders' equity pledge in the eastern region will increase the stock repurchase scale compared with listed companies in the noneastern region. The core explanatory variable of Panel B is the equity pledge ratio. It can be observed that listed companies in the eastern region with a higher proportion of controlling shareholders' equity pledge are more inclined to carry out stock repurchase to prevent the risk of control right transfer and manage the market value.

6.2. Mechanism Test

6.2.1. Controlling Shareholders' Equity Pledge, Information Environment, and Listed Companies' Stock Repurchase. According to the previous theoretical analysis, listed companies attempt to convey information to external investors through stock repurchase to raise the stock price. Then, the better the information environment is, that is, the more comprehensively the information is conveyed (the lower degree of information asymmetry), the more the information about stock repurchase can be perceived by investors. Meanwhile, listed companies with controlling shareholders' equity pledge will be more active in stock repurchase. In this paper, the analysts' attention is used as the proxy variable of enterprise information environment to test the mechanism.

Table 7: Regression results of equity nature, controlling shareholders' equity pledge, and listed companies' stock repurchase.

Panel A core explained variable: dummy variable of equity pledge				
	Soe = 1		Soe = 0	
Variable	(1) Rpurchase1	(2) Rpurchase2	(3) Rpurchase1	(4) Rpurchase2
Pledge1	0.0054	0.0433	0.0621***	0.0606***
	(0.457)	(0.984)	(5.363)	(3.409)
Lev	−0.1513***	−0.6337***	−0.0496	−0.4267**
	(−2.782)	(−2.763)	(−0.876)	(−2.034)
Growth	−0.0107***	−0.0225*	−0.0083	−0.0749***
	(−3.187)	(−1.745)	(−1.321)	(−3.280)
Roe	−0.0115	−0.0741	−0.2304***	−0.5836***
	(−0.278)	(−0.542)	(−4.156)	(−2.773)
Dual	0.0283	0.0565	−0.0263	−0.0568
	(1.451)	(0.936)	(−1.446)	(−0.887)
Board	−0.0001	0.0014	−0.0005	−0.0001
	(−0.098)	(0.359)	(−0.346)	(−0.016)
Asset	0.1000***	0.2752***	0.2403***	0.7619***
	(7.697)	(6.802)	(18.542)	(16.972)
Constant	−2.1888***	−5.9816***	−5.0450***	−16.0454***
	(−7.327)	(−6.429)	(−17.741)	(−16.541)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	5,274	5,274	9,938	9,938
R-squared	0.034	0.017	0.107	0.059
F	10.01	7.801	97.23	58.45
Panel B core explained variable: equity pledge ratio				
Pledge2	0.0034**	0.0114*	0.0018***	0.0064***
	(1.972)	(1.851)	(3.684)	(3.317)
Lev	−0.1454***	−0.6190***	−0.0450	−0.4004*
	(−2.685)	(−2.705)	(−0.796)	(−1.911)
Growth	−0.0104***	−0.0211	−0.0074	−0.0727***
	(−3.108)	(−1.644)	(−1.168)	(−3.175)
Roe	−0.0168	−0.0913	−0.2254***	−0.5252**
	(−0.409)	(−0.669)	(−4.063)	(−2.522)
Dual	0.0287	0.0572	−0.0277	−0.0566
	(1.463)	(0.946)	(−1.517)	(−0.881)
Board	−0.0001	0.0014	−0.0006	−0.0004
	(−0.083)	(0.371)	(−0.402)	(−0.076)
Asset	0.0974***	0.2692***	0.2429***	0.7212***
	(7.644)	(6.720)	(18.884)	(15.925)
Constant	−2.1338***	−5.8546***	−5.0746***	−15.1642***
	(−7.286)	(−6.358)	(−17.807)	(−15.370)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	5,274	5,274	9,938	9,938
R-squared	0.038	0.019	0.106	0.060
F	10.15	7.854	84.33	58.01

Note. The *t*-test value is in brackets, using company-level clustering robust standard error; *, **, and ** are significant at the level of 10%, 5%, and 1%, respectively.

From column (1) and column (2) of Table 9, it can be seen that the estimated coefficients of the interactive term between the dummy variable of the controlling shareholders' equity pledge and analysts' attention are 0.0014 and 0.0034, respectively, both of which are significantly positive, indicating that the higher the analysts' attention is, the greater the possibility that the listed companies with equity pledge will carry out stock repurchase. From column (3) and column (4), it can be seen that the estimated coefficients of the interactive term between the ratio of controlling shareholders' equity pledge and analysts' attention are still significantly positive. It suggests that the smoother the information environment, the more obvious the motivation of listed companies to convey confidence to investors through stock repurchase to maintain the stock price and prevent the risk of control right transfer caused by equity pledge.

6.2.2. Controlling Shareholders' Equity Pledge, Corporate Governance, and Listed Companies' Stock Repurchase.

Table 8: Regression results of regional differences, controlling shareholders' equity pledge, and listed companies' stock repurchase.

Panel A core explained variable: dummy variable of equity pledge				
	East = 1		East = 0	
Variable	(1) Rpurchase1	(2) Rpurchase2	(3) Rpurchase1	(4) Rpurchase2
Pledge1	0.0691***	0.0818***	0.0383***	0.0375**
	(6.057)	(3.923)	(2.782)	(2.011)
Lev	−0.0476	−0.4357**	−0.0710	−0.3675
	(−0.863)	(−2.157)	(−1.070)	(−1.366)
Growth	−0.0098**	−0.0510***	−0.0175***	−0.0749***
	(−2.035)	(−2.974)	(−2.957)	(−2.930)
Roe	−0.2215***	−0.6644***	−0.0531	0.0271
	(−4.261)	(−3.294)	(−0.884)	(0.159)
Soe	0.0044	0.1770	−0.0214	−0.0592
	(0.106)	(1.014)	(−0.325)	(−0.338)
Dual	−0.0175	−0.0262	−0.0167	−0.0961
	(−1.064)	(−0.482)	(−0.593)	(−0.874)
Board	−0.0004	−0.0003	−0.0013	0.0005
	(−0.341)	(−0.077)	(−0.820)	(0.082)
Asset	0.2126***	0.6478***	0.1661***	0.5680***
	(18.031)	(16.537)	(9.431)	(8.077)
Constant	−4.5611***	−13.9197***	−3.5376***	−12.3249***
	(−17.523)	(−16.194)	(−9.089)	(−7.950)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	10,893	10,893	4,319	4,319
R-squared	0.096	0.051	0.068	0.042
F	75.63	48.92	17.81	11.62
Panel B core explained variable: equity pledge ratio				
Pledge2	0.0028***	0.0091***	0.0019*	0.0073*
	(5.116)	(4.382)	(1.903)	(1.856)
Lev	−0.0470	−0.4253**	−0.0662	−0.3476
	(−0.856)	(−2.119)	(−0.997)	(−1.283)
Growth	−0.0086*	−0.0474***	−0.0166***	−0.0714***
	(−1.787)	(−2.754)	(−2.796)	(−2.768)
Roe	−0.2104***	−0.5995***	−0.0475	0.0501
	(−4.032)	(−2.999)	(−0.793)	(0.300)
Soe	0.0087	0.2062	−0.0286	−0.0862
	(0.210)	(1.170)	(−0.433)	(−0.486)
Dual	−0.0181	−0.0251	−0.0188	−0.1035
	(−1.092)	(−0.459)	(−0.665)	(−0.940)
Board	−0.0005	−0.0006	−0.0013	0.0004
	(−0.384)	(−0.140)	(−0.839)	(0.071)
Asset	0.2111***	0.6037***	0.1634***	0.5549***
	(18.040)	(15.559)	(9.284)	(7.649)
Constant	−4.5093***	−12.9540***	−3.4661***	−11.9981***
	(−17.365)	(−15.148)	(−8.864)	(−7.502)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	10,893	10,893	4,319	4,319
R-squared	0.096	0.055	0.069	0.043
F	68.36	49.63	14.93	10.48

Note. The *t*-test value is in brackets, using company-level clustering robust standard error; *, **, and ** are significant at the level of 10%, 5%, and 1%, respectively.

When there are problems in the governance mechanism of listed companies, controlling shareholders may damage the value of listed companies through "hollowing out" and information manipulation. Therefore, the less negative information the company hides, the more willing the controlling shareholder is to convey information to the market through stock repurchase, in order to maintain the stock price. This paper uses the equity balance degree to measure the level of corporate governance.

As can be seen from column (1) and column (2) of Table 10, the estimated coefficients of the interactive term between the dummy variable of the controlling shareholders'

Table 9: Estimated results of controlling shareholders' equity pledge, information environment, and listed companies' stock repurchase.

Variable	(1) Rpurchase1	(2) Rpurchase2	(3) Rpurchase1	(4) Rpurchase2
Pledge1	0.0458***	0.0574*		
	(3.992)	(1.743)		
Pledge2			0.0028***	0.0083***
			(4.388)	(3.387)
Analyst	−0.0018***	−0.0114***	−0.0010	−0.0098***
	(−2.654)	(−5.099)	(−1.525)	(−4.063)
Pledge1×Analyst	0.0014*	0.0034**		
	(1.701)	(2.124)		
Pledge2×Analyst			0.0073***	0.0079**
			(3.679)	(2.117)
Lev	−0.0560	−0.4419***	−0.0554	−0.4292***
	(−1.283)	(−2.728)	(−1.275)	(−2.658)
Growth	−0.0131***	−0.0635***	−0.0121***	−0.0602***
	(−3.341)	(−4.399)	(−3.078)	(−4.159)
Roe	−0.1491***	−0.2669*	−0.1361***	−0.2167
	(−3.585)	(−1.733)	(−3.270)	(−1.427)
Soe	−0.0042	0.0898	−0.0071	0.0971
	(−0.122)	(0.672)	(−0.203)	(0.717)
Dual	−0.0182	−0.0469	−0.0196	−0.0476
	(−1.282)	(−0.962)	(−1.373)	(−0.974)
Board	−0.0006	−0.0001	−0.0007	−0.0003
	(−0.664)	(−0.041)	(−0.741)	(−0.085)
Asset	0.2035***	0.6535***	0.2022***	0.6195***
	(20.123)	(18.092)	(20.084)	(17.159)
Constant	−4.3459***	−13.9942***	−4.3089***	−13.2577***
	(−19.451)	(−17.695)	(−19.276)	(−16.697)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	15,212	15,212	15,212	15,212
R-squared	0.089	0.051	0.090	0.053
F	73.72	46.64	63.42	45.57

Note. The *t*-test value is in brackets, using company-level clustering robust standard error; *, **, and ** are significant at the level of 10%, 5%, and 1%, respectively.

equity pledge and equity balance degree are significantly positive. Similarly, in column (3) and column (4), the estimated coefficients of the interactive term between the ratio of controlling shareholders' equity pledge and equity balance degree are still significantly positive, which indicates that the higher the corporate governance level of listed companies, the greater the positive impact of equity pledge on listed companies' stock repurchase.

6.2.3. Controlling Shareholders' Equity Pledge, Earnings Management, and Listed Companies' Stock Repurchase. Studies have found that earnings management can beautify the financial statements of enterprises and increase the net profit per share, so earnings management is used by listed companies to prevent control right transfer. Moreover, the equity pledge will affect listed companies' choice between accrual earnings management and stock repurchase. In this paper, the earnings management of enterprises is measured by the nonoperational accrued profits calculated by the modified Jones model.

From Table 11, it can be seen that the interaction term between the dummy variable of equity pledge and earnings management and the interaction term between equity pledge ratio and earnings management are not significant, which shows that listed companies will not adopt earnings management to reduce stock repurchase under equity pledge.

7. Research Conclusions and Policy Implications

Based on the data on controlling shareholders' equity pledge and China's A-share listed companies' stock repurchase from 2013 to 2021, this paper empirically tests the influence and internal mechanism of controlling shareholders' equity pledge on listed companies' stock repurchase. It is found that listed companies will stabilize the stock price through stock repurchase to prevent the risk of control right transfer caused by stock price decline. First, there is a positive correlation between equity pledge and stock repurchase, which is more significant among nonstate-owned listed companies and listed companies in the eastern region. Further research shows that the positive impact of equity pledge on stock repurchase is more significant under the condition of a good information environment and good corporate governance. However, the earnings management

Table 10: Test results of controlling shareholders' equity pledge, corporate governance, and listed companies' stock repurchase.

Variable	(1) Rpurchase1	(2) Rpurchase2	(3) Rpurchase1	(4) Rpurchase2
Pledge1	0.0461***	0.0709		
	(3.510)	(1.568)		
Pledge2			0.0026***	0.0090***
			(3.433)	(3.064)
Balance	0.0032	0.1089*	0.0086	0.1287**
	(0.194)	(1.847)	(0.554)	(2.233)
Pledge1 × Balance	0.0187**	0.0343***		
	(2.301)	(2.678)		
Pledge2 × Balance			0.0000**	0.0005**
			(2.071)	(2.171)
Lev	−0.0521	−0.3699**	−0.0486	−0.3536**
	(−1.186)	(−2.263)	(−1.110)	(−2.168)
Growth	−0.0129***	−0.0618***	−0.0118***	−0.0583***
	(−3.308)	(−4.349)	(−3.000)	(−4.078)
Roe	−0.1667***	−0.4211***	−0.1577***	−0.3744**
	(−4.131)	(−2.844)	(−3.901)	(−2.563)
Soe	−0.0075	0.0771	−0.0050	0.0950
	(−0.215)	(0.571)	(−0.141)	(0.693)
Dual	−0.0186	−0.0464	−0.0194	−0.0463
	(−1.305)	(−0.946)	(−1.353)	(−0.946)
Board	−0.0006	0.0002	−0.0007	−0.0000
	(−0.646)	(0.044)	(−0.714)	(−0.007)
Asset	0.1996***	0.6099***	0.1975***	0.5762***
	(19.593)	(17.807)	(19.397)	(16.771)
Constant	−4.2755***	−13.2355***	−4.2219***	−12.5060***
	(−19.103)	(−17.583)	(−18.843)	(−16.555)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	15,212	15,212	15,212	15,212
R-squared	0.088	0.049	0.089	0.051
F	73.05	46.67	63.41	46.06

Note. The *t*-test value is in brackets, using company-level clustering robust standard error; *, **, and ** are significant at the level of 10%, 5%, and 1%, respectively.

Table 11: Estimated results of controlling shareholders' equity pledge, earnings management, and listed companies' stock repurchase.

Variable	(1) Rpurchase1	(2) Rpurchase2	(3) Rpurchase1	(4) Rpurchase2
Pledge1	0.0601***	0.0979***		
	(6.500)	(2.859)		
Pledge2			0.0024***	0.0080***
			(4.782)	(4.251)
REM	0.0170	0.1325	−0.0199	0.0449
	(0.675)	(1.464)	(−0.964)	(0.590)
Pledge1×DA	−0.0487	−0.1016		
	(−1.299)	(−0.955)		
Pledge2×DA			0.0005	0.0028
			(0.274)	(0.503)
Lev	−0.0803*	−0.4710***	−0.0793*	−0.4584***
	(−1.801)	(−2.734)	(−1.780)	(−2.664)
Growth	−0.0108***	−0.0609***	−0.0096**	−0.0576***
	(−2.774)	(−4.154)	(−2.468)	(−3.919)
Roe	−0.1675***	−0.4229***	−0.1625***	−0.3867**
	(−4.066)	(−2.692)	(−3.962)	(−2.500)
Soe	−0.0070	0.0972	−0.0067	0.1092
	(−0.200)	(0.756)	(−0.191)	(0.840)
Dual	−0.0095	−0.0357	−0.0106	−0.0371
	(−0.640)	(−0.702)	(−0.714)	(−0.728)

Table 11: Continued.

Variable	(1) Rpurchase1	(2) Rpurchase2	(3) Rpurchase1	(4) Rpurchase2
Board	−0.0010	−0.0008	−0.0010	−0.0009
	(−1.051)	(−0.210)	(−1.082)	(−0.233)
Asset	0.1868***	0.5951***	0.1863***	0.5668***
	(18.369)	(17.270)	(18.393)	(16.456)
Constant	−3.9705***	−12.7738***	−3.9444***	−12.1484***
	(−17.632)	(−16.777)	(−17.504)	(−15.924)
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
Observations	14,244	14,244	14,244	14,244
R-squared	0.077	0.043	0.077	0.045
F	59.95	40.81	51.54	39.97

Note. The *t*-test value is in brackets, using company-level clustering robust standard error; *, **, and ** are significant at the level of 10%, 5%, and 1%, respectively.

of listed companies has no significant impact on the positive impact of equity pledge on stock repurchase. In addition, this paper also tests the robustness of propensity score matching, alternative explanatory variables, and explained variables. All of them prove that the conclusions of this paper are reliable.

The research conclusion of this paper has important practical significance and experience enlightenment. First of all, China's stock repurchase began in 2005, but there are many restrictions. In 2018, China's regulators revised relevant laws and regulations to encourage stock repurchase, aiming to correct the stock price and guide the stock price to the actual price. However, the China Securities Regulatory Commission and other institutions should strengthen supervision of stock repurchase to prevent listed companies from covering up the actual financial situation through stock repurchase and abusing stock repurchase to drive up stock prices. In addition, it is necessary to strengthen the information environment and corporate governance of listed companies, reduce the degree of information asymmetry of listed companies, and effectively monitor controlling shareholders' behaviors, such as opportunism.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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Research Article

Research on the Impact of Digital Finance on the Green Development of Chinese Cities

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This paper takes 286 prefecture-level Chinese cities from 2011 to 2019 as research objects. It empirically examines the influence of digital finance on green development by using the EBM model, two-way fixed effect model, and instrumental variable method. It is found that digital finance can significantly promote the green development of Chinese cities, and this conclusion is still valid after the robustness tests, such as the instrumental variable method dealing with endogeneity and two-sided winsorization. The mechanism analysis results suggest that only the breadth of digital finance can significantly promote green development in the internal mechanism of digital finance, but the effect of coverage depth and digitization degree is not significant. The external mechanism of industrial structure upgrading assumes the mediating role of digital finance in improving the level of green development. The heterogeneity analysis results show that digital finance has a stronger impact on green development in the central and western cities and small-scale cities. This paper contributes to the study of the relationship between digital finance and green development and puts forward relevant suggestions.

1. Introduction

China's current economic development has moved towards the path of high-quality development. It has become a critical issue to realize the transformation of the speed-oriented economy to the quality-oriented economy. China's rapid economic growth since the reform and opening-up has been realized in an extensive development mode with high pollution and high energy consumption, which has brought serious impacts on China's energy resources and ecological environment. Economic transformation has now become a critical path. The *2021 Sustainable Development Report* released by the Institute for Sustainable Development Goals, Tsinghua University, points out that China's sustainable development index is 72.1, ranking 57th among 165 countries in the world. In September 2020, President Xi Jinping attended the United Nations General Assembly and proposed that China need to reach peak carbon dioxide emissions by 2030 and strive to achieve carbon neutrality by 2060. This implies that the economic and social development mode emphasizing reducing carbon emissions and promoting green development has become the focus.

Finance is the bloodline of the modern economy, and digital finance is a financial innovation that combines traditional finance with technologies such as big data and artificial intelligence. The development of digital finance has addressed the problems such as information asymmetry, provided crucial financial support, supported the development of real economy such as small- and medium-sized enterprises, reduced costs for the development of high-tech and low-carbon clean enterprises, and made the information of enterprises more transparent, thus making the utilization of funds easy to be monitored and helping prevent and eliminate risks. There have been many studies on the role of digital finance and the influencing factors of green development, but there are few studies on the relationship between digital finance and green development. Some scholars find that digital finance can improve the green total factor productivity [1–3]. However, they mainly proceed from the perspectives of factor distortion, resource mismatch,

innovation, and entrepreneurship. Their measurement models all adopt the SBM model, only considering the nonradial relationship between the input and output. However, both radial and nonradial relationships exist in actual production. The omission of this factor may lead to deviation in the measurement [4]. Therefore, this paper uses the panel data of 286 Chinese cities from 2011 to 2019, employs the mixed distance function, EBM model, to measure the green total factor productivity, and matches it with the digital inclusive finance index. On this basis, it uses cartographic visualization, two-way fixed effect model, instrumental variable method, and mediating effect model to examine the relationship and mechanism between digital finance and green development and further explores the heterogeneity.

The possible contributions of this paper are as follows. Firstly, the existing studies seldom conduct research from the perspective of the internal and external mechanisms of digital finance. This paper studies the internal and external mechanisms and verifies their existence in different ways. Secondly, the existing studies on digital finance and the green total factor productivity mainly adopt the SBM model, only considering nonradial function. This paper adopts mixed distance function, EBM model, which can better reduce the error in measurement. Thirdly, this paper uses the number of urban telephones in 1984 as an instrumental variable to identify the causal relationship between digital finance and green development, which helps alleviate the endogenous problems related to the research of digital finance and green development.

This paper is arranged as follows. The second part presents the theoretical analysis and shows that digital finance has a positive effect on green development. The third part introduces the empirical model of this paper and measures the green total factor productivity. The fourth part verifies that digital finance can promote green development and further tests its mechanism and heterogeneity. The fifth part further discusses the empirical results of this paper and proposes policy suggestions.

2. Theoretical Basis and Research Hypotheses

Green development is a way of economic growth and social development aiming at efficiency, harmony, and sustainability. As the theme of progress and development in the new era, it not only inherits the goal of sustainable development, but also innovates the theory of sustainable development in China. Green development possesses three characteristics, namely, systematic coordination, global sharing, and social practice. Jiang Nanping and others [5] argue that the core of green development is the combination and efficient utilization of resources and environmental energy, the common development of economy and society, and the harmonious coexistence between man and nature. The joint research group of the World Bank and the Development Research Center of the State Council believes that economic growth should be moderate, rather than excessively relying on resources, carbon emissions, and environmental damage. Green development is creating new green products, technologies, and investment. Hu Angang and others [6] think that the main characteristics of green development are moderate consumption, low energy consumption, low emission, and the continuous expansion of ecological resources, coordinating the three systems of economy, nature, and society.

Financial development can significantly affect green development, which has been supported by many studies. Financial factor cluster has a significant spatial spillover effect on green development, and this effect embodies significant characteristics of spatial decline. Financial cluster also influences green development through capital support, resource allocation, and innovation [7]. Huang Jianhuan and others [8] think that the enterprise supervision effect plays a substantial role in the influence mechanism of financial development on green development, while the green financial effect is not strong. In terms of industry, Guo Wei and Si Menghui [9] conclude that financial cluster has an inverted "U" shape relationship with green total factor productivity in manufacturing industry, and it mainly generates the influence through improving technological capabilities. Some researchers believe that financial development can reduce the green total factor productivity. For example, Ge Pengfei and others [10] find that financial development can reduce the green total factor productivity by using the cross-border panel data of the "Belt and Road Initiative," while fundamental innovation and application innovation can mitigate the negative effect.

With the development of Alipay and other platforms, the development speed of digital finance in China is extremely rapid, which has caused tremendous impacts on people's life. In terms of the studies on the impact of digital finance, many researchers have studied the macro and micro effects of digital finance. Yi Hang and Zhou Li [11] find that digital finance can significantly improve residents' consumption and play a more prominent role in the "vulnerable" groups in rural areas and central and western cities, thus proving the inclusive characteristics of digital finance. Qian Haizhang and others [12] think that digital finance has a significant impact on China's economic growth, and its mechanism is to drive the development of innovation and entrepreneurship. Song Min and others [13] put forward that financial technology can empower enterprises, reduce information asymmetry, improve the relationship between banks and enterprises, and ease financing constraints and other issues, thus improving the total factor productivity of enterprises. Tang Wenjin and others [14] state that digital finance has a nonlinear influence on the industrial structure upgrading by using the panel data of prefecture-level Chinese cities. In terms of the literature on the relationship between digital finance and environmental governance, Fang Lin and Yang Siying [15] think that financial technology can reduce urban pollution, presenting a significant emission reduction effect. Zheng Wanteng and others [16] argue that digital finance can significantly control environmental pollution, and its primary mechanism is to promote social development, industrial upgrading, and green technology innovation. Based on the previous literature, this paper puts forward the following hypotheses:

(i) H1 : Digital finance can promote green development.

(ii) H2 : Digital finance can promote green development through industrial structure upgrading.

3. Research Design

3.1. Model Specification.

$$\text{lngtfp}_{it} = \alpha_0 + \alpha_1 \text{lndfi}_{it} + \alpha_2 \text{controls}_{it} + \varphi_i + \pi_t + \varepsilon_{it}. \quad (1)$$

In this model, subscript *i* indicates city identification and year identification. lngtfp represents the explained variable, the green total factor productivity. lndfi represents the core explained variable, digital finance. "controls" represents a series of control variables. φ_i represents the city fixed effect. π_t represents the year fixed effect. α_0 represents the intercept term of the equation. ε_{it} represents the random disturbance term that varies with individuals and time. The empirical model adopted in this paper is a two-way fixed effect model, which can alleviate endogenous problems caused by factors such as missing variables.

3.2. Data Sources and Variable definitions. This paper uses the balanced panel data of 2,574 observations in 286 cities from 2011 to 2019 for empirical research. The primary data sources are the CSMAR Database, China Urban Statistical Yearbook, and Institute of Digital Finance Peking University. All the variables related to prices are deflated while taking the year 2010 as the base year.

Explained variable (lngtfp): the existing methods to measure green development are mainly divided into index system method and model efficiency method. The index system method mainly uses a variety of indexes to measure development performance. Chen et al. [17] employ 32 indexes to systematically evaluate the interprovincial industrial green development level in China from four aspects: industrial green output, innovation, efficiency, and policy. The model efficiency method mainly utilizes data envelopment analysis. Feng et al. [18] measure the development status through the green development performance index from the perspective of regions and evaluate the green development status of more than 40 regions in the world based on the expert scoring and data envelopment method. There are also studies using the methods such as stochastic frontier method and exponential method [19, 20]. In this paper, DEA software is used to measure the green total factor productivity of Chinese cities through the EBM model considering the undesirable output and Malmquist-Luenberger productivity index method. The year 2010 is defined as the base period, and then the green total factor productivity is measured. Finally, the logarithmic value is taken as the explained variable in this paper.

The indexes for calculating green total factor productivity are as follows. 1. Input indexes: in this paper, input elements include labor, capital, and energy. The number of employees in state-owned units and private units in various prefecture-level cities is taken as labor input indexes. The sum of household electricity consumption and industrial electricity consumption in the whole city is used to measure the energy input. The capital input is measured by the perpetual inventory method, in which the depreciation rate is set at 10.96%. 2. Output indexes: output indexes are divided into desired output and undesirable output. The desired output is constant-price GDP and green coverage of built-up areas, while the undesirable output is industrial smoke, industrial sulfur dioxide, and industrial wastewater. To reduce the efficiency reduction caused by too many variables, this paper uses entropy method to synthesize three indexes of undesirable output into one index.

Core explanatory variable (lndfi): referring to the research of Guo Feng et al., this paper uses the digital inclusive finance index published by the Institute of Digital Finance Peking University to measure the development of digital finance in Chinese cities. Its logarithmic value is taken as the core explanatory variable to reduce the influence of heteroscedasticity [21].

Control variables: referring to the existing literature, this paper introduces a series of economic and social control variables. Economic development level (LNP GDP) is represented by the logarithmic value of per capita GDP. Human capital level (edu) is represented by the proportion of college students to urban population. Urban scale (lnurban) is represented by the logarithmic value of population density. Foreign investment level (fdi) is represented by the ratio of actual foreign direct investment to GDP adjusted by exchange rate. Financial development level (finance) is represented by the proportion of year-end loan balance in financial institutions to GDP. Descriptive statistics of related variables are shown in Table 1. The mean value of the green total factor productivity (gtfp) is 1.05, indicating that the green total factor productivity of Chinese cities is on the rise from 2011 to 2019. The standard deviation of human capital (edu) of cities is large, suggesting that the human capital level of Chinese cities is quite different. In addition, the characteristics of each variable in this paper are similar to those in previous studies.

To observe the evolution of the green total factor productivity and digital finance more intuitively, this paper visualizes it in Figure 1 with Stata15.0. In terms of the green total factor productivity, it can be seen from the comparison between 2011 and 2019 that the maximum and minimum values increase substantially, especially in the northeast, central, and western cities. The deeper color indicates that its absolute value increases, and its ranking also rises substantially. For digital finance, the minimum value increases from 17.02 to 199.54, and the maximum value increases from 86.51 to 321.65, indicating that the overall development of digital finance is also improving. In addition, the color of digital finance in the central region is obviously deepened, indicating that digital finance in the central region is developing at a fast speed.

4. Empirical Results and Economic Explanations

This part tests the previous hypotheses. Before the empirical analysis, it is necessary to conduct multicollinearity test on the model. The results show that the vif values are all less

Table 1: Descriptive statistics.

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
Gtfp	2574	1.05	0.07	0.846	1.361
Lngtfp	2574	0.046	0.066	-0.168	0.308
Dfi	2574	165.493	65.451	17.02	321.65
Lndfi	2574	5.001	0.515	2.834	5.773
Lnpgdp	2574	10.692	0.578	8.773	13.056
Edu	2574	1.842	2.413	0.005	14.001
Lnurban	2574	5.731	0.93	1.629	7.968
Fdi	2574	0.017	0.018	0	0.199
Finance	2574	0.997	0.642	0.118	9.622

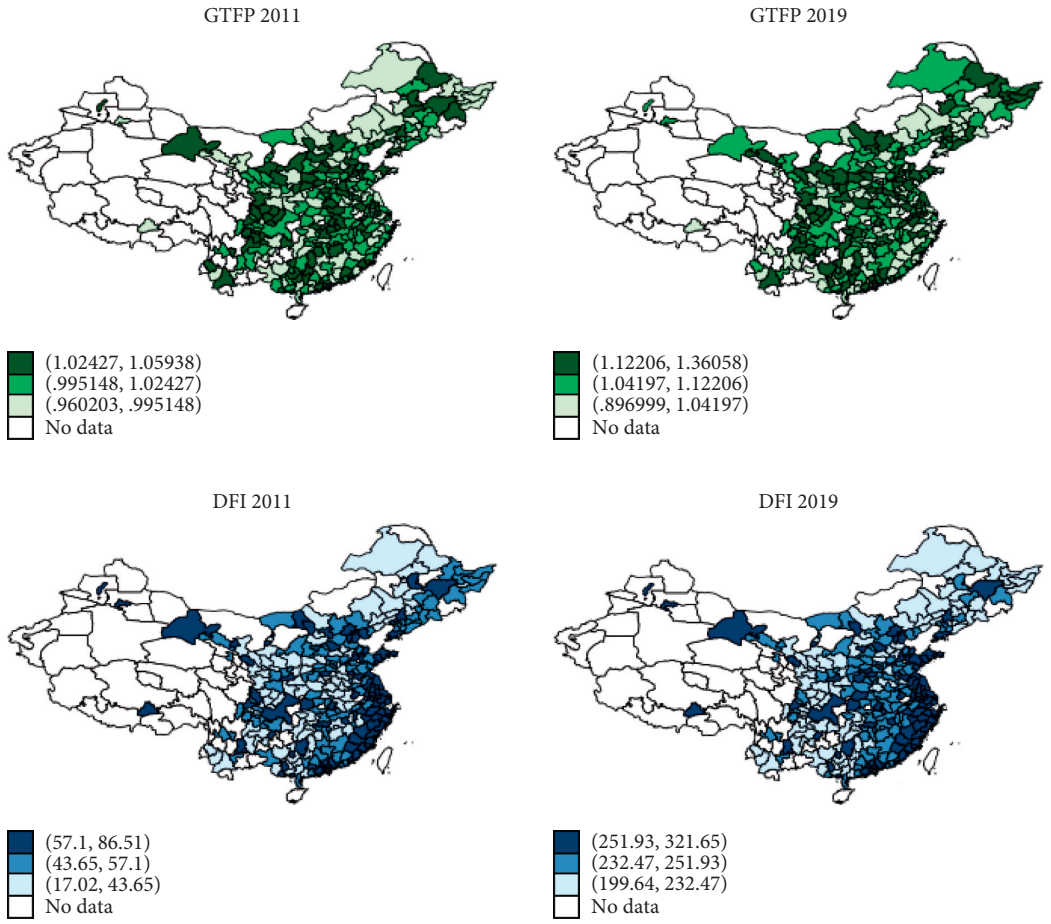

Figure 1: Spatial and temporal evolution of green development and digital finance.

than 2.08, far less than 10, indicating that there is no multicollinearity in the empirical model of this paper. In addition, it also passes the F test, LM test, and Hausman test, confirming that it is reliable to choose the fixed effect model, as demonstrated in Table 2.

Table 2: Multicollinearity test.

Variable	Edu	Lnpgdp	Finance	Lndfi	Fdi	Lnurban	Mean vif
VIF	2.08	1.72	1.71	1.43	1.21	1.15	1.55

4.1. Baseline Regression. Firstly, this paper examines the relationship between digital finance and urban green development. The corresponding results are summarized in Table 3. In this paper, the two-way fixed effect model is taken as the baseline model, and stepwise regression is carried out by adding control variables step by step to verify the robustness of the results. In Columns (1) to (6), the coefficients of digital finance (lndfi) are all positive and significant at the level of 1%, which indicates that digital finance has the green growth effect and significantly promotes the green total factor productivity. Among them, the coefficient of digital finance in Column (6) is 0.0377, indicating that the logarithm of green total factor productivity increases by

Table 3: Influence of digital finance on green development.

	(1) Lngtfp	(2) Lngtfp	(3) Lngtfp	(4) Lngtfp	(5) Lngtfp	(6) Lngtfp
Lndfi	0.0356***	0.0373***	0.0397***	0.0401***	0.0386***	0.0377***
	(0.0109)	(0.0110)	(0.0111)	(0.0111)	(0.0111)	(0.0111)
Lnpgdp		−0.0072	−0.0083	−0.0097*	−0.0106**	−0.0079
		(0.0053)	(0.0053)	(0.0053)	(0.0054)	(0.0053)
Edu			0.0071***	0.0071***	0.0071***	0.0065***
			(0.0022)	(0.0022)	(0.0022)	(0.0022)
Lnurban				0.0486***	0.0488***	0.0488***
				(0.0130)	(0.0129)	(0.0128)
Fdi					0.0920	0.0984
					(0.0807)	(0.0804)
Finance						0.0061***
						(0.0018)
_Cons	−0.1319**	−0.0628	−0.0765	−0.3418***	−0.3274***	−0.3572***
	(0.0546)	(0.0735)	(0.0737)	(0.1021)	(0.1022)	(0.1016)
Year fe	Yes	Yes	Yes	Yes	Yes	Yes
City fe	Yes	Yes	Yes	Yes	Yes	Yes
N	2574	2574	2574	2574	2574	2574
R^2	0.7274	0.7276	0.7289	0.7303	0.7305	0.7312

Note. *, ** and *** are significant at the level of 10%, 5%, and 1%, respectively. The robust standard error is within the brackets. Same below.

3.77% for every 1 unit increase in the logarithm of digital financial index. Digital finance relies on big data, artificial intelligence, and other means to improve the efficiency of information matching, lower service costs, and optimize the distribution of production factors. Moreover, the transparency of its information makes it easier to distinguish between green industries and green companies, laying a solid foundation for the improvement of green development. Then, hypothesis 1 is preliminarily verified.

For control variables, the coefficient of human capital (edu) is 0.0065, which is significant at the level of 1%, indicating that the improvement of urban human capital can significantly improve the urban green total factor productivity. The coefficient of urban scale (lnurban) is 0.0488, which is significant at the level of 1%, indicating that the increase of urban population density can improve the level of green total factor productivity. Finally, the coefficient representing the level of traditional finance (finance) is 0.0061, which is significant at the level of 1%. It suggests that digital finance does not play a role of substitution, and traditional finance can still have an impact on green development.

4.2. Endogenous Treatment and Robustness Test

4.2.1. Instrumental Variable Method. Even if the two-way fixed effect model is adopted, endogenous problems may still exist in this study. To address this concern, this paper refers to the practice of Huang Qunhui and others [22] and uses the number of telephones per 10,000 households in various regions in 1984 as an instrumental variable method. It is because the historical data can meet the exogeneity, and the development of communication technology and digital finance in history also meets the relationship. This variable is the cross-sectional data, which cannot match the panel data, so the mean value of digital finance in each region except itself in the previous year is taken as the trend item with dynamic changes. After multiplying it by the number of telephones owned by every 10,000 households in 1984, the instrumental variable of this paper is obtained.

Column (1) of Table 4 reports the regression results of the instrumental variable. The coefficient of digital finance (lndfi) is 0.2361, which shows that the impact of digital finance on green total factor productivity is still significant at the positive level of 1% after considering endogenous problems, which is basically consistent with the previous results of baseline model. They all pass the K–P rk LM test and K–P rk Wald F test, showing that the selection of the instrumental variable is reasonable and valid.

4.2.2. Control Macro Factors. The fixed effect model adopted in this paper is the year-city two-way fixed effect. Because each region may have different characteristics that change at any time, the two-way fixed effect model may not be rigorous enough. Therefore, this paper takes the interaction term of year and province into the model and considers the characteristics of the region changing with time to further test the conclusions. The corresponding results are presented in Column (2) of Table 4. The coefficient of digital finance is 0.0358, which is significant at the level of 1%, indicating that the previous conclusion is robust.

4.2.3. Eliminate Interference Factors. ① Winsorization treatment: considering that the development levels of cities are quite different, there may be abnormal values in each variable. To eliminate the influence of abnormal values on the results of this paper, the variables undergo the winsorization treatment of 1% on both sides, and the corresponding results are reported in Column (3) of Table 4. The coefficient of digital finance is 0.0435, slightly higher than the result of baseline regression, and still

Table 4: Endogenous treatment and robustness test.

	(1) Instrumental variable method	(2) Control macro factors	(3) Winsorization	(4) Exclude the abnormal year
	Lngtfp	Lngtfp	Lngtfp	Lngtfp
Lndfi	0.2361***	0.0358***	0.0435***	0.0366***
	(0.0612)	(0.0112)	(0.0123)	(0.0108)
Lnpgdp	−0.0238***	−0.0113**	−0.0064	−0.0069
	(0.0072)	(0.0057)	(0.0058)	(0.0057)
Edu	0.0068***	0.0063***	0.0069***	0.0074***
	(0.0024)	(0.0022)	(0.0022)	(0.0023)
Lnurban	0.0537***	0.0497***	0.0538***	0.0412**
	(0.0133)	(0.0130)	(0.0158)	(0.0174)
Fdi	0.0191	0.0948	0.0325	0.0350
	(0.0795)	(0.0802)	(0.1073)	(0.0971)
Finance	0.0052***	0.0058***	0.0157***	0.0063***
	(0.0018)	(0.0018)	(0.0040)	(0.0018)
c.year#c.prov		0.00003		
		(0.0000)		
K–P rk LM p-value	0.0000			
K–P rk wald F statistic	131.076 [16.38]			
_Cons		−2.9121	−0.3816***	−0.3208***
		(1.7734)	(0.1039)	(0.1227)
Year fe	Yes	Yes	Yes	Yes
City fe	Yes	Yes	Yes	Yes
N	2288	2574	2574	2288
R^2	0.0273	0.7315	0.7332	0.7223

significant at the level of 1%. Meanwhile, the coefficient and significance of other variables do not change significantly. Therefore, it can be considered that the previous conclusion is robust. ② Exclude the abnormal year: the P2P platform went bankrupt in 2018, which had a great impact on the development of digital finance. Therefore, this paper excludes that year and makes the regression again. The corresponding results are shown in Column (4). Among them, the coefficient of digital finance is 0.0366, which is significant at the level of 1%, basically consistent with the previous result. The above results show that the previous conclusions are robust and reliable.

4.3. Internal and External Mechanisms of Digital Finance Influencing Green Development. Digital finance must have its unique mechanisms when it plays a role in green development, but what are its internal and external mechanisms? How do these mechanisms work? To answer these questions, this paper divides the mechanisms into internal mechanism and external mechanism for research.

4.3.1. Internal Mechanism. The Institute of Digital Finance Peking University measures the digital inclusive finance from the coverage breadth, depth, and digitization degree and then synthesizes these three indexes into the digital inclusive finance, which facilitates the research on its internal mechanism. Table 5 shows the regression results of the internal mechanism of digital finance. The results in Columns (1) and (2) demonstrate that the coverage breadth of digital finance has a positive influence on the green total factor productivity, and it is significant at the level of 1%, indicating that the "inclusive feature" of digital finance plays a significant role in the growth of green total factor productivity. Columns (3) to (6) present the results of the depth and digitization degree of digital finance. Their estimation coefficients are also positive, but they have not passed the statistical significance test, indicating that the depth and digitization degree of digital finance do not play a significant role in green growth. The above results suggest that the expansion of its coverage breadth promotes green development, but its depth and digitalization degree need to be further explored to better contribute to green development.

4.3.2. External Mechanism. The secondary industry mainly refers to the industrial sector. In the process of China's rapid economic development, some industries, especially heavy industries, emit a large number of pollutants such as carbon dioxide and sulfur dioxide, which adversely affects the green and low-carbon development mode. According to the research of Xu Xianchun and others [23], the upgrading industrial structure promotes green development, and the promotion effect of digital finance on the industrial structure upgrading has been effectively verified. To test the role of the industrial structure upgrading, this paper refers to the research of Gan Chunhui and others, adopts the ratio of the tertiary industry to the secondary industry to express the industrial structure upgrading, and uses the mediating effect model to conduct the study [24].

Table 5: Internal mechanism of digital finance influencing green development.

	(1) Lngtfp	(2) Lngtfp	(3) Lngtfp	(4) Lngtfp	(5) Lngtfp	(6) Lngtfp
Lncov	0.0157***	0.0166***				
	(0.0048)	(0.0049)				
Lnuse			0.0111	0.0102		
			(0.0075)	(0.0074)		
Lndig					0.0013	0.0025
					(0.0042)	(0.0042)
Lnpgdp		−0.0087		−0.0048		−0.0053
		(0.0054)		(0.0053)		(0.0053)
Edu		0.0063***		0.0057***		0.0059***
		(0.0022)		(0.0022)		(0.0022)
Lnurban		0.0473***		0.0490***		0.0485***
		(0.0129)		(0.0128)		(0.0129)
Fdi		0.1106		0.1292		0.1383*
		(0.0808)		(0.0815)		(0.0809)
Finance		0.0061***		0.0063***		0.0065***
		(0.0018)		(0.0018)		(0.0018)
_Cons	−0.0312	−0.2341***	−0.0092	−0.2526***	0.0397*	−0.2068**
	(0.0239)	(0.0901)	(0.0375)	(0.0975)	(0.0214)	(0.0925)
Year fe	Yes	Yes	Yes	Yes	Yes	Yes
City fe	Yes	Yes	Yes	Yes	Yes	Yes
N	2574	2574	2574	2574	2574	2574
R^2	0.7272	0.7310	0.7261	0.7297	0.7257	0.7294

$$\begin{aligned} \text{lngtfp}_{it} &= \alpha_0 + \alpha_1 \text{lndfi}_{it} + \alpha_2 \text{controls}_{it} + \varphi_i + \pi_t + \varepsilon_{it} \\ \text{indurs}_{it} &= \beta_0 + \beta_1 \text{lndfi}_{it} + \beta_2 \text{controls}_{it} + \varphi_i + \pi_t + \varepsilon_{it} \\ \text{lngtfp}_{it} &= \gamma_0 + \gamma_1 \text{lndfi}_{it} + \gamma_2 \text{indurs}_{it} + \gamma_3 \text{controls}_{it} + \varphi_i + \pi_t + \varepsilon_{it}. \end{aligned} \tag{2}$$

Among them, the subscript i indicates city identification and year identification. "indurs" indicates the mediating variable in this paper, the industrial structure upgrading. The definitions of other variables are consistent with the previous ones. For the mediating effect model, firstly, if the coefficient of α_1 is significant and positive, it will be regarded as passing the test. In the second step, if the coefficient β_1 is significant and positive, it shows that digital finance can significantly affect the industrial structure upgrading. In the third step, if the coefficient of γ_2 is significant and positive, it means that it passes the mediating effect test. In addition, if only one of β_1 and γ_2 passes the significance test, the bootstrap method is needed to perform the Sobel test.

Table 6 reports the results of external mechanism test. The coefficient of α_1 is proved to be significant and positive, so they will not be elaborated here. In Column (2), the coefficient of digital finance (lndfi) is 0.1693, which is significant at the level of 1%, indicating that digital finance can significantly promote the urban industrial structure upgrading. Next, the coefficient of γ_2 is further tested and found to be 0.0123, which is significant at the level of 1%, indicating that the industrial structure upgrading can significantly promote the urban green development. The above results demonstrate that the industrial structure upgrading plays the mediating role in digital finance influencing urban green development. The coefficients of digital finance in the third Column are significant and positive. It suggests that there are other mediating roles, and the industrial structure upgrading bears part of the mediating roles. The rapid development of digital finance lowers the threshold for obtaining funds, and its information matching mechanism enables more small- and medium-sized enterprises to obtain funds, thus providing essential support for the upgrading and development of the tertiary industry, promoting the industrial structure upgrading and accelerating the process of urban green development. Thus, hypothesis 2 is verified.

4.4. Heterogeneity Analysis

4.4.1. Heterogeneity of Region. Due to the huge differences in the economic and social development levels in different regions of China, there are great differences in resource endowments and development stages between the eastern region and other regions. Meanwhile, there are also great differences in their green development levels. In this context, this paper divides cities into eastern, central, and western cities to further explore the heterogeneity of the impact of digital finance on green development. The corresponding results are displayed in Column (1) and Column (2) of Table 7. It can be observed that the coefficient of digital finance in the eastern region is 0.0306, which is positive but not significant. The coefficient of digital finance in the central and western cities is 0.0390, which is positive and

Table 6: External mechanism of digital finance influencing green development.

	(1) Lngtfp	(2) Indurs	(3) Lngtfp
Lndfi	0.0377***	0.1693***	0.0356***
	(0.0111)	(0.0564)	(0.0111)
Indurs			0.0123***
			(0.0045)
Lnpgdp	−0.0079	−0.4208***	−0.0027
	(0.0053)	(0.0576)	(0.0054)
Edu	0.0065***	0.0162	0.0063***
	(0.0022)	(0.0132)	(0.0022)
Lnurban	0.0488***	0.1528*	0.0469***
	(0.0128)	(0.0897)	(0.0124)
Fdi	0.0984	0.4020	0.0935
	(0.0804)	(0.4625)	(0.0805)
Finance	0.0061***	0.0573*	0.0054***
	(0.0018)	(0.0311)	(0.0017)
_Cons	−0.3572***	3.6666***	−0.4023***
	(0.1016)	(0.7295)	(0.1015)
Year fe	Yes	Yes	Yes
City fe	Yes	Yes	Yes
N	2574	2574	2574
R^2	0.7312	0.8982	0.7322

Table 7: Heterogeneity of digital finance influencing green development.

	(1) Eastern cities Lngtfp	(2) Central and western cities Lngtfp	(3) Large-scale cities Lngtfp	(4) Small-scale cities Lngtfp
Lndfi	0.0306	0.0390***	0.0349**	0.0418***
	(0.0208)	(0.0143)	(0.0169)	(0.0160)
Lnpgdp	0.0029	−0.0107	−0.0073	−0.0090
	(0.0088)	(0.0073)	(0.0083)	(0.0074)
Edu	0.0098**	0.0050*	0.0108***	−0.0017
	(0.0039)	(0.0027)	(0.0027)	(0.0036)
Lnurban	0.0386	0.0484***	0.0629***	0.0356
	(0.0438)	(0.0136)	(0.0183)	(0.0224)
Fdi	0.0136	0.1744*	0.0445	0.1717
	(0.1405)	(0.0932)	(0.1060)	(0.1231)
Finance	0.0184***	0.0049***	0.0057*	0.0075***
	(0.0070)	(0.0017)	(0.0032)	(0.0022)
_Cons	−0.4221	−0.3131***	−0.4866***	−0.2542*
	(0.3088)	(0.1172)	(0.1545)	(0.1461)
Year fe	Yes	Yes	Yes	Yes
City fe	Yes	Yes	Yes	Yes
N	972	1602	1286	1286
R^2	0.7502	0.7186	0.7275	0.7387

significant at the level of 1%, indicating that the digital financial development in the central and western cities enhances the level of urban green development. This is consistent with the conclusion of the previous internal mechanism test that digital finance mainly plays a role in increasing the green total factor productivity through its inclusive feature. The reason why it does not have a significant role in the eastern region may be that the traditional finance there is developed enough to meet the supply of factors that promote green growth. Moreover, in the first Column, the coefficient of traditional finance is positive, which is also proved by the fact that it is significant at the level of 1%.

4.4.2. Heterogeneity of City Size. According to the median of the population density in cities, this paper divides cities into large-scale cities and small-scale cities and further explores the heterogeneity. The corresponding results are shown in Columns (3) and (4) of Table 7. It can be seen that digital finance plays a significant role in promoting green development in both large-scale cities and small-scale cities. The difference lies in that the significance of digital finance in large-scale cities is only 5%, while that in small-scale cities is 1%. The coefficient of digital finance in small-scale cities is 0.0418, greater than 0.0349. Therefore, for small-scale cities, the significance and coefficient of digital finance prove that it can play a stronger role, which is also consistent with the

previous research findings that the inclusive feature of digital finance plays a significant role.

5. Conclusion

This paper attempts to explore the current situation of green development in Chinese cities from the perspective of green development and digital finance and further investigate how digital finance affects green development. In this paper, the panel data of 286 Chinese cities from 2011 to 2019 is employed. Moreover, the two-way fixed effect model, instrumental variable method, and mediating effect model are adopted for the empirical test. The main conclusions are as follows. First, digital finance can significantly improve the green development of Chinese cities. After using the number of telephones in 1984 as an instrumental variable and employing the robustness test method, such as winsorization, the conclusion is still robust and reliable. Second, digital finance promotes the green development level of Chinese cities through coverage breadth (internal mechanism) and industrial structure upgrading (external mechanism). Third, digital finance has a stronger effect on driving green development in the central and western cities, as well as small-scale cities.

Currently, there are few literatures on the relationship between digital finance and urban green development. This paper provides valuable empirical evidence for studying the relationship between them. Furthermore, this paper puts forward the following suggestions. First, we should vigorously explore its market depth and develop the digitalization degree. The breadth of digital finance plays a significant role in the green total factor productivity. However, the roles of depth and digitalization degree have not been highlighted. Hence, it is necessary to explore the role of digital finance and further reveal the green dividend brought by the development of digital finance. Second, we should put forward the policy of digital financial empowering the real economy according to local conditions. The central and western cities and small-scaled cities are the key beneficiaries of digital finance. Based on local resource endowments and production conditions, digital finance should play the role of empowering the real economy, speeding up the industrial structure upgrading, easing the financing constraints of enterprise development, reducing resource mismatch, and contributing to improving green development.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis on Regional Characteristics of Economic Growth Based on Total Factor Productivity

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In this paper, we adopt stochastic frontier model of translog production function to measure the total factor productivity growth rate of 13 cities in Jiangsu province from the year 2000 to 2020 and study the characteristics of the contribution rates of capital, labor, and total factor productivity in driving economic growth. The study shows that, firstly, the explanatory power of the model could be increased by 35.9% after 6 effect variables, such as urban economic development level, have been taken into consideration when two-step method has been adopted to explore the model parameters of stochastic frontier; secondly, there is an obviously positive correlation between the 4 variables, urban economic development level, urban size, level of opening up to the outside world and infrastructure construction, and production efficiency, while there is a negative correlation between economic structure and production efficiency, and the research input intensity has an uncertain effect on production efficiency; thirdly, the TFP growth trend of urban economy of the province shows a similar "W" trend, technical progress becomes the first element in affecting total factor productivity, and the negative growth in technical efficiency and scale efficiency result in a dramatic decline in growth rate of TFP; fourthly, among all the elements contributing to urban economic growth, capital has the greatest contribution, TFP takes the second place, and labor element takes the last. The double difference between capital and TFP appears to be the major cause in forming regional difference of urban economy. The regional differences of TFP concerning infrastructure advantage, position advantage, factor advantage, and policy advantage are the key factors in urban economic gap. At the end of this study, we propose some policy suggestions.

1. Introduction

In neoclassical economics, the increase in production factor input and technical progress are elements that can affect economic growth [1]. In the background of resource constrain, the mode of economic development that inputting factors increase economic growth cannot be kept on because of marginal decline of factors [2]. The fact that economic growth of China has declined since the year 2012 proves that the factor-driving mode cannot realize economic sustainable growth [3]. Total factor productivity (TFP) is an important tool for finding source of economic growth and is a major indicator in evaluating economic growth driving to force structure. Yu and Li [4] also pointed that promoting urban economic TFP has become an important direction when considering transforming economic growth driving to force structure. The relevant literature at present mainly concerns the measure and constitution of TFP, influential factors, and spatial differences. There are prominent differences in measurement and decomposition of TFP due to study methods and data time, and there is no convergence concerning TFP influential degree due to differences in factor choice and clustering method of TFP [5, 6]. A deep analysis on spatial characteristics of driving force of economic growth is conductive for realizing the reasons for the gap in regional economic growth and for clarifying whether the gap in economic development is more due to the differences in TFP or the accumulation of production factors.

At present, scholars in foreign countries use a wide range of TFP analysis and have conducted in-depth research on the impact of economic growth and obtained enlightening conclusions. Many valuable conclusions have been drawn from the research methods, research perspectives, and research paradigms. In terms of research methods, scholars used different methods to measure TFP and analyzed the determinants of growth rate. For instance, in his book, *Green Productivity: Applications in Malaysia's Manufacturing*, Ahmed [7] used a method to calculate the actual total factor productivity per unit of labor growth by internalizing the pollutant emissions other than the inputs in the traditional production function. Jreisat et al. [8] used DEA based on nonparametric method to evaluate and review the productivity changes of 14 banks operating in the Egyptian market from 1997 to 2013. It is found that the Egyptian Banking Industry as a whole shows a decline in productivity, which is mainly due to technological progress. Based on the unbalanced panel data of 1994, 2004, and 2014, Mariyono [9] used stochastic frontier transcendental logarithmic production function to estimate TFP of Indian rice production. He found that the main sources of TFP growth of rice production were technological change and allocation efficiency effect, and the contribution rate of technical efficiency was low. Moreover, Mariyono [10] evaluated the implications of and assessed the economic and sustainable impact of environmentally friendly technological packages introduced into agribusiness players in the centre of chili-producing regions of Indonesia and found that the packages of technologies improved economic and sustainability performance of agribusiness resulting from efficient use of agrochemicals and water resource and increased the production. Dhandhalya and Tarpara [11] analyzed the return on investment and the source of productivity of Gujarat peanut researched from 1990 to 1991 and from 2011 to 2012 and constructed the total output, total input, and TFP index by using the Tornqvist-Theil index technology and using two outputs and ten inputs. In terms of research perspectives, scholars analyzed the growth of TFP from different perspectives. Fuglie and Wang [12] compared the growth of agricultural TFP in developed countries, developing countries, and transition countries from a national perspective and found that the overall growth of agricultural TFP in developed countries was strong. The developing countries represented by China maintained extremely high TFP growth of the past from 1991 to 2009, and TFP growth in coastal areas was significantly higher than that in inland areas. Ahmed [13] estimated TFP index of tourism industry and divided it into three parts: input change rate, output change rate, and frontier change. The author provided the efficiency measurement of 101 tourism destinations. Afzal [14] focused on estimating total factor productivity growth in Pakistan's economy and particularly in the agriculture sector, covered total factor productivity growth period from 1973 to 2020, and found that TFP has been the lowest in the agriculture sector as compared to other sectors as per findings of the study. Malik [15] examined the output and total factor productivity (TFP) growth by estimating a stochastic frontier production function for a panel of Middle East and North Africa (MENA) countries and to decompose TFP growth into technical change, technical efficiency, and scale efficiency. In terms of research paradigms, Benzaquen [16] focused on the impact of manufacturing industry (shipbuilding industry) on economic growth. He took Peru's large shipbuilding industry from 1969 to 1990 as an example, obtained TFP of an industry through quantitative empirical analysis, and further studied that the evolution of Peru's shipbuilding activities coincided with the growth and decline period of Peru's GDP. Ivanic and Martin [17] discussed the impact of factor productivity on global poverty across industries (agriculture, industry, and services) and found that the improvement on agricultural productivity usually has a greater poverty reduction effect than that of industry or services in poor countries. Wang and Xu [18] studied the direct and spatial impacts of China's human capital structure on regional GTFP and found that the different levels of human capital have different effects on GTFP and that some types of human capital (such as tertiary-level educational human capital) promote local GTFP, while other types (such as primary-level educational human capital) inhibit it.

Among all economic plates in Chinese regional economy, the annual average economic growth rate of Jiangsu province sustains more or less 10%, and Jiangsu province is the second strongest economy in China, developing a "Jiangsu Model" in economic and social development. Nevertheless, according to the literature at home and abroad, there are few literature pieces to calculate the contribution rate of capital, labor, and TFP in economic growth and take measures to improve the contribution rate of TFP. Further, relevant literature focusing on TFP of Jiangsu cities is scarce. This paper will fill the research gap in the field of urban TFP in Jiangsu province and explore the mechanism of influencing factors on production efficiency and evolution trend of the urban TFP growth rate in the year between 2000 and 2020 of urban economy in Jiangsu province. In order to enhance the driving force of economic growth, each part of this paper is arranged as follows: the first part is to test the applicability of stochastic frontier model and give the specific form. The second is to estimate and analyze the production efficiency of 13 cities in Jiangsu. (There are 13 cities in Jiangsu province, which is divided into three regions: Southern Jiangsu, Central Jiangsu, and Northern Jiangsu. Southern Jiangsu includes five cities such as Nanjing, Suzhou, Wuxi, Changzhou, and Zhenjiang, Central Jiangsu includes three cities such as Nantong, Taizhou, and Yangzhou, and Northern Jiangsu includes five cities such as Yancheng, Huai'an, Lianyungang, Suqian, and Xuzhou.) The third is to decompose the TFP growth rate of 13 cities, calculate the capital contribution rate, labor contribution rate, and TFP contribution rate in the economic growth power structure of Southern Jiangsu, Central Jiangsu, and Northern Jiangsu, and analyze the spatial characteristics of urban economic growth power on this basis. Conclusions and policy recommendations are given in the last part. The main innovations of this paper are as follows: Firstly, we put our emphasis on studying the influential elements and constitution of growth rate of TFP in Jiangsu urban economy and the evolution trend of TFP

growth rate, while adopting the transcendental logarithmic stochastic frontier model and panel data of 13 cities in Jiangsu. Secondly, we calculate the contribution rate of capital, labor, and TFP to urban economic growth and explore the major influential factor of forming regional gap in terms of urban economic development, so as to provide new thinking in increasing urban TFP growth rate and promoting transformation of driving force for urban economy.

2. Analytical Framework and Methods

2.1. The Estimation and Decomposition of TFP Based on SFA. Based on [1] residual method, TFP is considered to be the residual which equals output growth minus input factors growth. In this method, producer is considered to realize the optimal productive efficiency, and the growth of TFP comes from technical progress, taking no account of technical invalid item and stochastic disturbance. Farrell [19] put forward the idea of frontier analysis efficiency, in which the interference stochastic factors had on output was taken into account, and this idea was of prominently practical significance. Battese and Coelli [20] established a time-varying stochastic frontier production functions model while adopting panel data and a time-varying stochastic frontier production function model (BC95 model) while adding environment variable. In this paper, the TFP of urban economy in transitional period is comparatively objective, which is calculated by adopting the frontier model of transcendental logarithmic production function, in which model of the interference effect on output from stochastic factors is taken into account, the assumption of constant substitution elasticity is relaxed, and the applicability and concrete form could be verified through a series of tests.

2.2. Estimation of Production Function and Decomposition of TFP. At present, models which are applicable to panel data stochastic frontier model are time-varying stochastic frontier production function model by [20] and time-varying stochastic frontier production function which includes model environment variable by [21]. The concrete forms of models by [20] are as follows:

$$Y_{it} = f(X_{it}, t; \beta)\exp(v_{it} - u_{it}) i = 1, 2, \ldots, I; \quad t = 1, 2, \ldots, T, \tag{1}$$

$$\mu_{it} = \mu_i \exp(-\eta(t - T)) \sim i\ dd\ N^{+}\left(\mu, \sigma^2\right). \tag{2}$$

In this model, the functional expression (1) is the stochastic frontier production function, and the functional expression (2) is the time-varying technical inefficiency function. In this model, Y_{it} means economic output of i city in the year t, X_{it} input vector of i city in the year t, β solve-for parameter, η time-varying parameter of technical efficiency, $v_{it} - \mu_{it}$ combination of error items (ε_{it}), v_{it} stochastic disturbance term, which measures the degree of nonefficiency of the system and follows standard normal distribution, μ_{it} the error terms of technical loss, which reflects the degree of technical nonefficiency and follows zero cutoff half-normal distribution, and η solve-for parameter, with $\eta > 0$, $\eta = 0$, $\eta < 0$ meaning technical inefficiency decreases progressively, sustains stability, and increases progressively, respectively. Krugman [22] thought that TFP was composed of technical progress, transformation in scale effect, transformation in allocation efficiency, and transformation in technical efficiency. We take the derivation of t from the production function and drop the subscript for brevity:

$$\begin{aligned}\dot{Y} = \frac{\partial \ln f(Y)}{\partial t} = \frac{\partial \ln f(X, t; \beta)}{\partial t} \\ + \frac{\partial \ln X_j}{\partial X_j} \sum_j \frac{\partial \ln f(X, t; \beta)}{\partial \ln X_j} \frac{\mathrm{d}X_j}{\mathrm{d}t} - \frac{\partial U}{\partial t}.\end{aligned} \tag{3}$$

From the above decomposition formula, we can get

$$\dot{\mathrm{TFP}} = \dot{\mathrm{TEC}} + \mathrm{TP} + \mathrm{SE}, \tag{4}$$

$$\begin{aligned}\mathrm{TP}_{it} &= \frac{\partial \ln Y_{it}}{\partial t} = \beta_t + \beta_{it} t + \beta_{Lt} \ln L_{it} + \beta_{Kt} \ln K_{it}, \\ \mathrm{TEC}_{it} &= E[\exp(-u_i) | (v_i - u_i)], \\ \mathrm{SE} &= (E - 1) \sum_j \frac{E_j}{E} \dot{X}_{ij}, \text{ where } j = K, L, \\ E_K &= \beta_K + \beta_{KK} \ln K + \beta_{KL} \ln L + \beta_{Kt} t, \\ E_L &= \beta_L + \beta_{LL} \ln L + \beta_{KL} \ln K + \beta_{Lt} t.\end{aligned} \tag{5}$$

In the above formulas, $\dot{TFP}$, $\dot{TEC}$, TP, and SE represent, respectively, the growth rate of TFP, the change rate of production efficiency, the rate of technological progress, and the improvement of scale efficiency. X_{ij} represents the growth rate of the input j of i province and j is K or L. E presents elasticity of scale, $E = E_K + E_L$.

2.3. Decomposition of Contribution Rate of Factors to Economic Growth. Formerly, many scholars used the TFP change rate to economic growth rate as the contribution rate to measure economic growth of TFP, but some scholars such as Yu Yongze pointed out that, for China, whose economic growth rate is comparatively high, the abovementioned way could result in major measurement error; thus, in this paper, we adopt the approximate decomposition of the following production function, with $f(X_{it})_t$ meaning output level when input factor is X_{it} in t period, and X_{it} the input of factor i in t period, $i = 1, 2, 3, \ldots; t = 1, 2, \ldots$.

$$\mathrm{d}f(X_{it}) = \sum_{i=1}^{n} \mathrm{d}f_{X_i}(X_i) + \mathrm{d}f_{\mathrm{TFP}}(X_i). \tag{6}$$

When the period changes from t to $t+1$, economic growth can be approximately decomposed as follows:

$$\frac{f\left(X_{i,t+1}\right)_{t+1} - f\left(X_{i,t}\right)_t}{f(X_{it})} \approx \sum_{i=1}^{n} \frac{f\left(X_{i,t+1}\right)_t - f\left(X_{i,t}\right)_t}{f\left(X_{i,t}\right)_t} + \frac{\mathrm{TFP}_{t+1} - \mathrm{TFP}_t}{\mathrm{TFP}_t}. \tag{7}$$

Though formula (7) is approximate decomposition, the remaining shares small share in economic growth, and we

will no longer conduct a study on it in this paper. We set $P_{X_{i,t+1}}$ and $P_{\mathrm{TFP}_{t+1}}$ as contribution rate to economic growth of X_i and TFP, respectively, when the period is $t+1$, and their percentage terms can be expressed as formulas (8) and (9), respectively.

$$P_{X_{i,t+1}} = \frac{\left(f\left(X_{i,t+1}\right)_{t+1} - f\left(X_{i,t}\right)_t / f\left(X_{i,t}\right)_t\right)}{\left(\sum_{i=1}^{n}\left(f\left(X_{i,t+1}\right)_t - f\left(X_{i,t}\right)_t / f\left(X_{i,t}\right)_t\right) + \left(\mathrm{TFP}_{t+1} - \mathrm{TFP}_t / \mathrm{TFP}_t\right)\right)} \times 100, \tag{8}$$

$$P_{\mathrm{TFP}_{t+1}} = \frac{\left(\mathrm{TFP}_{t+1} - \mathrm{TFP}_t / \mathrm{TFP}_t\right)}{\left(\sum_{i=1}^{n}\left(f\left(X_{i,t+1}\right)_t - f\left(X_{i,t}\right)_t / f\left(X_{i,t}\right)_t\right) + \mathrm{TFP}_{t+1} - \mathrm{TFP}_t / \mathrm{TFP}_t\right)} \times 100. \tag{9}$$

2.4. Variable Selection and Management. We choose output data, input data, and factor cost data of 13 cities in Jiangsu province from the year 2000 to 2020 as the study sample, with all the variables limited to urban area.

2.4.1. Data of Gross Output. Data of gross output are from the public data of *Jiangsu Statistical Yearbook*. We use urban GDP to measure urban gross economic output and take the year 2000 as the base period to measure urban economic output with urban gross value of production, and then we deflate the annual normal GDP of all the prefecture-level city and get the real output.

2.4.2. Data of Capital Sum (K). The calculation of physical capital stock in base year of every city is the core for calculation of capital stock. In view that it is very difficult to collect capital stock in base year of every city, in this paper, we take the ratio of GDP in 2000 of every city to the GDP of Jiangsu in 2000 as the weight, distribute the capital stock of Jiangsu in 2000 proportionately to every city, and then calculate the physical capital stock of every city in base period.

$$\frac{\text{physical capital stock of every city in 2000}}{\text{physical capital stock of Jiangsu in 2000}} = \frac{\text{GDP of every city in 2000}}{\text{GDP of Jiangsu in 2000}}. \tag{10}$$

After we confirm the physical capital stock of base year, we can calculate annual physical capital stock of every city in Jiangsu with perpetual inventory method at constant price (in the year 2000) with 10.6% yearly depreciation. (Different scholars have different evaluation method for capital stock. In this paper, we adopt the rate of depreciation of 10.96% by [23] to evaluate the capital stock of all cities.)

2.4.3. Data of Labor. We choose arithmetic mean value of "employee numbers" at the end of the year $t-1$ and t as labor force input of the city in the year t.

2.4.4. Environment Variable. We choose PGDP, STRU, SCALE, OPN, RD, and ROD as the environment variables affecting production efficiency. We use per capita GDP to measure PGDP, proportion of secondary industry in GDP to measure urban STRU, the total urban population at the end of the year to show SCALE, the proportion of total exports in GDP to show OPN, with US dollar exchanged into RMB at current rate, regional research and development input intensity to show RD, and per capita paved road area to express proxy variable of ROD. Per capita GDP and total exports have been evaluated and deduced.

2.5. Model Test. We use likelihood ratio statistic to test the applicability of stochastic frontier model. For simplicity, we give the test result as follows directly. Table 1 is the test result of model hypothesis, which shows that the concrete form of translog stochastic frontier production function is as follows.

Table 1, the test result of model hypothesis, shows that the concrete form of translog stochastic frontier production function we adopt in this paper is as follows:

$$\begin{aligned} \ln Y_{it} = {} & \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_t t + \frac{1}{2}\beta_{KK}\left(\ln K_{it}\right)^2 + \frac{1}{2}\beta_{LL}\left(\ln L_{it}\right)^2 \\ & + \beta_{KL}\left(\ln K_{it}\right)\left(\ln L_{it}\right) + \beta_{Kt}\left(\ln \mathrm{K}_{it}\right)t + \beta_{Lt}\left(\ln L_{it}\right)t + \frac{1}{\beta_{tt}t^2 + \upsilon_{it} - \mu 2_{it}}. \end{aligned} \tag{11}$$

Table 1: Test result of model hypothesis.

Test	Hypothesis	LLF	LR	$\chi^2_{0.01}(j)$	conclusion
Test ①	H0: $\gamma = \mu = \eta = 0$	306.285	289.307	10.501	Refuse
Test ②	H0: $\beta_{KK} = \beta_{LL} = \beta_{KL} = \beta_{tK} = \beta_{tL} = \beta_{tt} = 0$	272.527	75.562	10.501	Refuse
Test ③	H0: $\beta_t = 0$	248.304	121.543	10.501	Refuse
Test ④	H0: $\beta_{tK} = \beta_{tL} = 0$	244.475	161.140	8.273	Refuse
Test ⑤	H0: $\eta = 0$	289.957	2.254	5.412	Refuse

3. Calculation and Analysis on Production Efficiency of Different Regions in Jiangsu

3.1. Multicollinearity Test and Estimation of SFA Model. To analyze the influence factors of production efficiency function, we adopt one-step method and two-step method to estimate the model, with model one corresponding to two-step method and model two one-step method. In model one, the multicollinearity of 6 influence factors will be tested. And the inefficiency regression model is as follows:

$$\mu_{it} = \delta_0 + \delta_1 \ln\mathrm{PGDP} + \delta_2 \ln\mathrm{STRU} + \delta_3 \ln\mathrm{CSCALE} + \delta_4 \ln\mathrm{OPEN} + \delta_5 \ln\mathrm{RD} + \delta_6 \ln\mathrm{ROD} + \phi_{it}. \quad (12)$$

Collinearity index is VIF = 3.45, and through multicollinearity test, the maximum value of variance inflation factor of influence factor is 7.72, less than 10, the reasonable value, which means that the applicability of the two-step model we use to estimate production function is good. In model two, we use the actual GDP of 13 cities as the output (y) and capital stock of all the past years (k) and labor force (l) as the factor input, add 6 efficiency influence variables, and adopt the software Frontier 4.1 for regression of stochastic frontier model of production function. We get the following result.

From Table 2 measurement results, the value of γ in model one is 0.997, which means that technical inefficiency results in producers deviating from the frontier. In model two, influence factor of technical nonefficiency item is added, and the value of γ is 0.639. On the whole, the explanatory power of model two increases by 35.9%. The growth rate of urban production efficiency in cities with high production level shows a Mathew's Effect, which means that cities in South Jiangsu that have advantages in infrastructure, positions, elements, and policies have the abilities to increase production efficiency. There is a negative correlation between the high class way of industry structure and production efficiency. The reason may be that during the process of pursuing high class the industry structure has sublated the negative sides, realizing the promotion of production efficiency, but resulting in decrease in scale effect of original industry. There is positive correlation between city scale and production efficiency, which means that the increase in city population promotes the urbanization level. High level in urbanization means advantages in industrial technology, labor to force, element reallocation, and policies. The efficient reallocation of resources at last promotes production efficiency. High level in opening up could promote the regional production efficiency. The promotion of production efficiency gives enterprises more chances and more confidence in participating in international competition. For export-oriented enterprises with high efficiency, the favorable reallocation of market shares, competitive advantages, and whole promotion of study effect during process of enterprise competition promote the regional production efficiency. In model one and model two, the coefficients of research and development input intensity of different regions are remarkably different, which shows that the correlation between research and development input intensity and production efficiency is not obvious. The constant improvement of city infrastructure has positive externality for urban economic development and production efficiency promotion. This is verified in this paper. It means that the constant improvement of infrastructure such as city roads could promote element efficiency in urban economics, decrease trade cost, and promote concentrated development of urban economics.

3.2. Calculation of TFP Growth Rate. In this paper, we use Frontier 4.1 to estimate SFA model. In equation (4), we get the value of decomposing indices of TE, TP, and SE from the year 2000 to 2020. In Figure 1, we have the TFP growth rate trend in South Jiangsu, Central Jiangsu, and North Jiangsu. From the change trend of the TFP growth rate, the TFP growth rate in the three regions of Jiangsu shows a changing trend of W and shows sharp decrease in 2008 and obvious rebounds in 2013 around. Around the year 2007, the TFP change trends of all cities in Jiangsu basically match each other, which shows that the urban economic efficiency in Jiangsu is affected greatly by macroeconomic situation and national policies.

4. The Decomposition and Spatial Characteristics of TFP Growth Rate of Jiangsu Cities

4.1. Decomposition of TFP in Jiangsu Cities. On the basis of measurement model two, we decompose TFP growth rate index and could get TFP growth rate and change rate of production efficiency, technical development, and scale efficiency improvement through calculation. Figure 2 shows the changing trend of TFP growth rate and its decomposition of cities in Jiangsu. From the time dynamic features of decomposition, the fluctuation range of scale efficiency improvement among 2000 and 2020 is low, except the peaks of wave of scale efficiency improvement appearing in 2003 and 2010; in other years the fluctuation rage of scale efficiency improvement shows slight reduction, which means

Table 2: Estimation result of stochastic frontier production model.

Major measurement models		Model one			Model two		
Variables	Coefficient	Estimated value	Standard deviation	T statistic	Estimated value	Standard deviation	T statistic
Intercept	β_0	17.827***	0.542	35.826	1.769***	0.531	3.647
ln$K$	β_K	0.776***	0.016	7.958	0.867***	0.034	27.192
ln$L$	β_L	0.122***	0.039	4.272	0.130***	0.026	5.786
T	β_t	0.073***	0.005	17.287	0.064***	0.008	10.254
0.5 * ln$K$ * ln$K$	β_{KK}	−0.088***	0.027	−3.951	−0.082***	0.020	−3.765
0.5 * ln$L$ * ln$L$	β_{LL}	−0.018	0.087	−1.005	−0.047	0.068	−0.920
ln$K$ * ln$L$	β_{KL}	0.231***	0.352	6.742	0.018***	0.030	6.834
t * ln$K$	β_{tK}	0.014**	0.007	2.373	0.004***	0.009	9.748
t * ln$L$	β_{tL}	−0.047***	0.011	−7.019	−0.002*	0.006	−1.827
0.5 * t^2	β_{tt}	−0.001***	0.003	−8.473	−0.003	0.001	−0.904
Constant term	δ_0	4.047**	1.521	2.430	8.657***	1.475	8.272
PGDP	δ_1	0.409***	0.030	12.427	0.124***	0.033	11.825
STRU	δ_2	−0.113	0.271	−0.570	−0.658**	0.241	−2.189
CSCALE	δ_3	0.099***	0.019	6.734	0.075***	0.012	5.728
OPEN	δ_4	0.064***	0.015	6.428	0.017*	0.014	1.859
RD	δ_5	−0.077**	0.028	−2.283	−0.120***	0.027	−3.950
ROD	δ_6	0.310***	0.037	10.507	0.342***	0.039	9.224
σ^2		0.188	0.005	28.375	0.017	0.003	9.892
Γ		0.997	0.002	755.492	0.639	0.028	547.548
M		0.847	0.075	9.425			
H		0.015	0.004	8.827			

Note: *, **, *** represent the value is remarkable at 10%, 5%, and 1%, respectively.

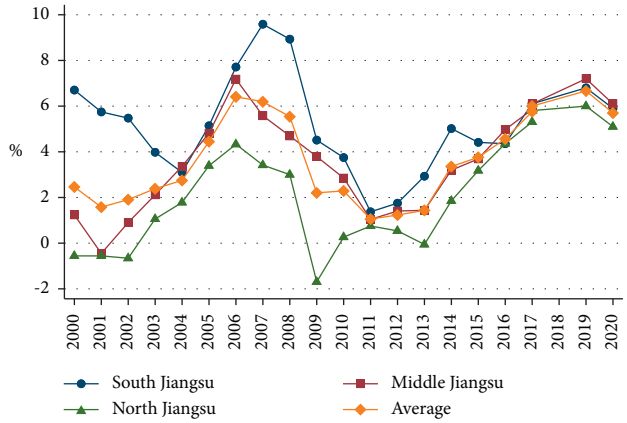

Figure 1: Variation diagram of TFP growth rate in regions of Jiangsu.

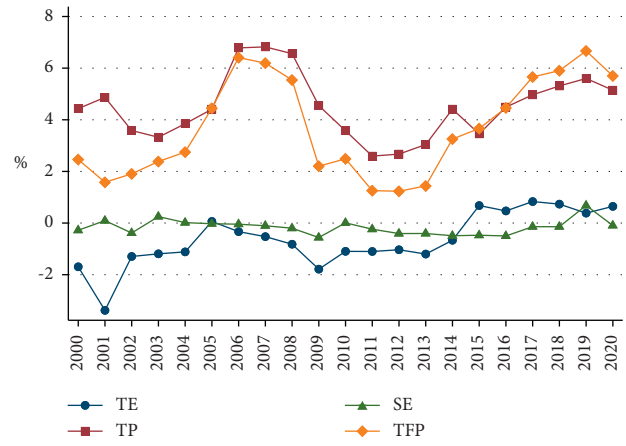

Figure 2: Diagram of provincial TFP growth rate and its decomposition.

that the investment expansion could result in decrease in marginal efficiency, that scale efficiency could be improved at certain degree, that the growth rate of production efficiency shows changes between ups and downs between the section of (−0.034, 0.008) and shows a zigzag growth trend, and that the growth rate of technical advance is remarkably higher than other elements, showing that all regions in economic development have strengthened technical import and promoted utilization efficiency. The growth rate of production efficiency and scale efficiency has less influence on TFP growth rate, and the contribution of improvement of scale efficiency to TFP growth rate fails to get the expected result. Through the analysis, we could conclude that technical advance is the major cause of TFP growth in cities of Jiangsu and that the changes of production efficiency growth rate and scale efficiency in low section offset the effect of technical advantage for economic efficiency.

4.2. Structure Features of TFP Growth Rate in Jiangsu Cities. Table 3 shows the accumulative change situation of city TFP growth rate, change rate of production efficiency, technical progress rate, and scale efficiency. From the changing trend of production efficiency, the accumulative changes of urban economic efficiency on different regions are remarkably different, and their common characteristic is that the TFP growth relies mainly on technical advance (TP). The TFP growth rate and decomposition structure index of South Jiangsu lie at the leading level in Jiangsu, which means that the economic development lies mainly on innovation-driven

Table 3: The accumulative change situation of TFP, TE, and SE in three regions of Jiangsu from 2000 to 2020.

	TFP	TE	TP	SE
South Jiangsu	5.209	−0.361	5.654	−0.084
Middle Jiangsu	3.672	−0.726	4.768	−0.370
North Jiangsu	2.218	−1.284	3.680	−0.178

development way. The TFP growth rates in Middle Jiangsu and North Jiangsu lie mainly on technical advance (TP), and their production efficiency (TE) and scale efficiency (SE) show negative growth, decreasing the TFP growth rate in the two regions. One reason why technical advance has not brought about an obvious promotion in production efficiency and scale efficiency may be that technical innovation promotes technical progress, which makes production technology frontier move forward, but could not ensure the efficient promotion of competition efficiency and scale efficiency of the whole industry. Besides, during the process of inviting investment appearing in Middle Jiangsu and North Jiangsu, many input elements are attracted and accumulated there, and the increasing intensity of element input, instead, results in the decrease in scale efficiency.

4.3. Time Characteristics of Driving Force of Jiangsu Urban Economic Development. From equations (8) and (9), we calculate the results in different periods of economic development contributions of different elements in provincial urban economic development as in Tables 4 and 5. In this paper, we will analyze the periodical characteristics of economic development driving force in different regions. The first period is from the year 2000 to 2004, in which the change of TFP growth rate is comparatively stable. In a whole, during this period, the contribution of capital, labor, and TFP to economic development is comparatively steady. The second period is from the year 2005 to 2008, in which the economic development experienced a new round of rapid development.

The influence of financial crisis in 2008 on economics began to show, and there appeared major fluctuation in urban TFP, but the contribution of TFP to economic development was higher by 5.841% than that in the first period. The third period is from the year 2009 to this day, the driving effects of capital input for urban economic development have been strengthened, and at the same time, the contribution of TFP to urban economic development shows sharp decrease. In the circumstances that our nation strongly initiates the policies of "developing new driving force for economic development," "mass entrepreneurship and innovation," and "vigorously transforming the pattern of economic growth and achieving high-quality development," after 2013, the contribution of TFP rebounded back a little.

4.4. Spatial Characteristics of Driving Force of Jiangsu Urban Economic Development

4.4.1. Economic Development Driving Force Features of South Jiangsu. The spatial characteristics of economic growth driving force in South Jiangsu are similar to that in the whole province, which are as follows: firstly, capital input is the main driving force for economic growth, which is below the average level of the whole province; secondly, the contribution level of labor forces is low, which shows a stable condition and grows up slowly in the second period; thirdly, the contribution of TFP to economic growth is lower than that of capital element, but higher than that of labor force. Comparing with the average level of the whole province, the contribution of TFP to economic growth is comparatively high in South Jiangsu but showed a sharp decrease after the year 2009 and bounced back in 2011, which was earlier than in other regions in Jiangsu.

4.4.2. Economic Development Driving Force Features of Middle Jiangsu. The economic growth driving force in Middle Jiangsu shows little difference compared to that of the whole Jiangsu province, which are as follows: firstly, capital input is also the major driving force for economic growth, whose contribution level to economic growth is close to that of the average level of the whole province, becoming the biggest driving force for economic growth in Middle Jiangsu; secondly, the contribution of labor force is comparatively low, a little more than the average level in the whole Jiangsu province in the third period, lower than the average level of the whole province in other periods; thirdly, the changing trend of TFP contribution to economic growth is basically the same as that of the labor force, a little lower than the average level of the whole province in the first two periods, and higher than that of the average level of the whole province in the third period. But it showed a sharp decrease after the financial crisis in 2008 and bounced back a little after 2013.

4.4.3. Economic Development Driving Force Features of North Jiangsu. The changing trend of economic growth driving force in North Jiangsu is shown as follows: firstly, the contribution of capital input is apparently higher than that of the average level of the whole province, being the biggest driving force for economic growth; secondly, the contribution of labor force is comparatively low, which is higher than that of the whole province; thirdly, the contribution of TFP to economic growth is apparently lower than that of the average level of the whole province, showed a sharp decrease after the financial crisis in 2008, and bounced back obviously in 2010 and 2013.

In a whole, the contribution of TFP to economic growth in South Jiangsu is the biggest among the three regions, and then is that in Middle Jiangsu, and the last one is that in North Jiangsu. One reason may lie in that in South and Middle Jiangsu there are more advantages in industrial base, technology, innovation, and talents. In the years from 2009 to 2012 after the financial crisis, due to sharp decrease in TFP in South Jiangsu, the contribution of TFP to economic growth deceased apparently, which was gentle in Middle Jiangsu, and little in North Jiangsu, the reason of which lies in that in South Jiangsu there are lots of export-oriented enterprises, and to lessen the shock from financial crisis, the

Table 4: The formation features of urban economic development driving force in Jiangsu province and South Jiangsu from 2000 to 2020.

year	Provincial average			South Jiangsu		
	Economic growth rate resulted from capital	Economic growth rate resulted from labor	Economic growth rate resulted from TFP	Economic growth rate resulted from capital	Economic growth rate resulted from labor	Economic growth rate resulted from TFP
	Capital contribution	Labor contribution	TFP contribution	Capital contribution	Labor contribution	TFP contribution
2000~2004	8.929	0.632	2.621	7.973	0.527	3.680
	73.296	**5.186**	**21.518**	**65.457**	**4.328**	**30.215**
2005~2008	9.368	0.722	3.800	8.163	0.677	5.050
	67.443	**5.198**	**27.359**	**58.770**	**4.872**	**36.358**
2009~2020	6.961	0.492	2.142	6.568	0.473	2.562
	72.748	**5.128**	**22.324**	**68.395**	**4.926**	**26.679**

Table 5: :The formation features of urban economic development driving force in Middle Jiangsu and North Jiangsu from 2000 to 2020.

year	Middle Jiangsu			North Jiangsu		
	Economic growth rate resulted from capital	Economic growth rate resulted from capital	Economic growth rate resulted from capital	Economic growth rate resulted from capital	Economic growth rate resulted from capital	Economic growth rate resulted from capital
	Capital contribution	Capital contribution	Capital contribution	Capital contribution	Capital contribution	Capital contribution
2000~2004	9.156	0.606	2.419	9.659	0.762	1.765
	75.175	**4.974**	**19.851**	**79.256**	**6.257**	**14.487**
2005~2008	9.484	0.698	3.708	10.456	0.791	2.643
	68.280	**5.028**	**26.692**	**75.279**	**5.693**	**19.028**
2009~2020	6.852	0.510	2.251	7.409	0.489	1.682
	71.278	**5.305**	**23.416**	**77.338**	**5.104**	**17.557**

government adopted economic stimulus policies to pull up the contribution of capital input, and this kind of extensive investment resulted in decrease in economic efficiency, bringing down the contribution of TFP to economic growth.

5. Conclusions and Suggestions

By adopting stochastic frontier transcendental logarithmic production function model, we explore the regional characteristics of economic growth driving force in cities of Jiangsu by calculating the production efficiency and TFP from the year 2000 to 2020 of the 13 cities in Jiangsu and decomposing the changes of TFP from production efficiency growth rate, technical progress rate, and scale efficiency. The study has filled the research gaps in the past, which did not use stochastic frontier model of translog production function to calculate TFP growth rate of a region. This paper also provides a new algorithm for measuring the driving force of regional economic growth such as the driving force of TFP.

5.1. Conclusions.

(a) We adopt two-step method to explore the stochastic frontier model parameter and find that the global explanatory power of the model is enhanced by 35.9% after the effect variable of the production efficiency is changed. The urban economic development level, urban size, opening-up degree, and infrastructure construction level can apparently promote the growth of production efficiency. There exists negative correlation with the economic structure and production efficiency. The effect of research and development input intensity on production efficiency is uncertain.

(b) There is significant regional heterogeneity in TFP growth rate of Jiangsu. The TFP growth rate for South Jiangsu is higher than that in other regions of Jiangsu province and takes the leading position. The growth trend of TFP in cities of Middle Jiangsu is close to that of the average level of the whole province. The TFP growth rate for North Jiangsu is in the third echelon. Fuglie [12] also confirmed that the growth rate of TFP in China's developed areas was faster than that in other developing areas. In decomposition of TFP, the contribution to technical progress of TFP growth rate is the biggest, showing a slow rising trend in the process of fierce changes. This view has been further verified in the relative literature. Mariyono [24] support that technical progress is the most important driving force for TFP growth. In 2009, the TFP showed a sharp decrease. The reason is that the decrease in elements results in the significant decline in TFP growth rate.

(c) The contribution of capital to the urban economic growth occupies the first position, and the TFP is the second, and labor element is the third. Clearly, economic growth style of Jiangsu urban economy is a classical capital input style, by which the input lies

in a leading position in urban economic development. Ahmed [7] reached similar conclusions in studying the productivity growth of manufacturing industry in Malaysia. Especially after the financial crisis in 2008, the government participated in urban infrastructure construction and carried out capital support projects for key industries by means of growing fiscal capacity, which made the contribution of capital to economic growth even more obvious [3, 6]. Besides, the fluctuation features of TFP have the similar trend to economic fluctuation features, and the TFP shows the same changing trend with that of economic development. Benzaquen [16] also got similar findings and believed that the evolution of TFP of the shipbuilding industry coincided with the GDP expansion and decline periods in Peru. From the data, the period in which the contribution to TFP is comparatively large is around the year 2007, when the economic development in China was in high growth period. However, with the constant progress of industrialization and urbanization, the marginal effect of capital is becoming less and less. At the same time, with the disappearing of demographic dividend, the resource allocation efficiency is low, and the conditions on which the traditional urban economy develops have changed, so the transformation of the economic development style which depends mainly on TFP is extremely urgent.

5.2. Policy Implication. In the future, to promote the total production efficiency and to transform the economic growth driving force in Jiangsu, we should work on the following points:

(a) Because urban economic scale, urban size, opening-up degree, and infrastructure level are conductive to the growth of production efficiency, cities should provide convenient infrastructure, cultivate more human resources, and attract more capital and technology to urban clusters, so as to realize high-quality urban development and drive the continuous improvement in production efficiency.

(b) In order to realize the positive and stable growth of total factor productivity, we must give full play to the basic advantages of Jiangsu's rich technological innovation resources and establish an innovation ecosystem suitable for high-quality development. We should encourage enterprises to carry out innovation and entrepreneurship activities, build a fair trading platform, encourage the industrialization of a large number of innovative achievements, and let innovators enjoy high returns. For the regional heterogeneity distribution of Jiangsu urban regional innovation factors, we should gather them in the urban areas with advantageous factors to control the investment of medium and low-end alternative industrial factors.

(c) The transformation of economic growth power mainly relied on TFP needs to improve the level of urban TFP growth rate of Jiangsu. At the same time, it makes up for the lack of TFP growth rate of Northern Jiangsu. Therefore, for the low growth rate of TFP in North Jiangsu, we must vigorously encourage enterprises to carry out independent innovation, build an industrialization platform for innovative achievements, continuously improve the role of technological progress in TFP growth, and realize innovation-driven urban economic growth in Jiangsu. North Jiangsu provides attractive policies in terms of resources, talents, and technology to attract high-quality innovation achievements in South Jiangsu, which can be industrialized in North Jiangsu, improve innovation elements and innovation ability in North Jiangsu, transfer them to urban clusters, and break the weakness for technological progress of North Jiangsu in TFP growth rate.

5.3. Limitations and Suggestions for Future Studies. Research limitations: the research objects are 13 cities in Jiangsu province of China. The research logic is rigorous and scalable, but the resource endowments are different from different provinces, and the research conclusions may be different. Especially in the provinces with serious pollution, how to bring the pollution emissions into the research model and get a more real TFP will be the focus of further research. Due to the lack of research on the dynamic characteristics of economic growth in 13 cities in Jiangsu province, there are few domestic confirmatory literature pieces, so we can only use foreign similar literature to confirm the reliability of the research conclusions.

Suggestions for future studies: when other scholars conduct similar research, we advise them to select areas with strong corroboration for research, compare with the research conclusions of other scholars, and further improve the reliability of research conclusions. When studying the total factor productivity of provinces with serious pollution, such as Hebei Province and Shanxi Province, it is suggested to learn from Ahmed's scheme (2008), internalize pollution emissions, and incorporate them into the research model, which may get a lower TFP contribution rate. If conditions permit, it is suggested to select DEA-Malmquist algorithm and super logarithm stochastic frontier production function method for confirmatory comparative research to improve the reliability of TFP calculation conclusion.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Fund Performance Evaluation Based on Bayesian Model and Machine Learning Algorithm

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Based on Bayesian method, this paper constructs a model for estimating fund performance evaluation, and uses machine learning algorithm to construct a sampler that can sample on the basis of conditional distribution. Sampling is used for stress test, so as to give the closeness of all possible test results and data results. The results show that performance evaluation is affected by many factors, and the resistance to risk plays an important role in the whole performance evaluation. At the same time, the Bayesian model in machine learning can quickly and accurately approach the statistical results, which is of great significance for predicting performance evaluation.

1. Introduction

As a financial innovation tool endowed with strong vitality and institutional advantages, funds have gained rapid development in recent years. How to reasonably evaluate the fund's business performance is of great importance to the general investors, fund managers and industry regulators. Fund performance evaluation is a complex issue. It involves not only objective and effective performance measurement standards, but also the sustainability of fund performance and performance attribution analysis [1–6]. From the current situation, the research on fund performance evaluation in China is still weak, not only in terms of theoretical research which is largely lacking market regulation is also relatively disorganized. And this is also true in empirical studies. In recent decades, theoretical research and practice at home and abroad have shown that quantitative analysis methods have been widely introduced into fund performance evaluation.

With the continuous development of modern mathematical finance theory, fund performance evaluation has been guided by theoretical studies with many empirical analyses. The results of the empirical analysis, in turn, validate the relevant financial theories and hypotheses. In fact, many controversial hypotheses in the field of financial performance evaluation, which can still be found in the field of fund performance evaluation. Foreign research on fund performance evaluation has a long history with a relatively sound theoretical system and a large number of empirical studies, while China is still basically in the development stage segment. This is because securities investment funds have been established in China for a relatively short period of time. Even the funds established around the world in the early 1990s have only a history of more than 30 years and are not standardized. Although they differ in their choice of metrics to measure risk (Sharpe Index uses all risks). Many evaluation models have a long history and are still widely used today. However, this theory has also met with strong opposition. Therefore, there is a need to select appropriate fund performance evaluation models to further develop the fund evaluation system [7–14].

For now, persistent attribution is another major aspect of research on performance evaluation. Domestic research on fund performance evaluation is still relatively scarce. From published articles and collected data, domestic research is still limited to the introduction of foreign theories and empirical studies, with more studies on a single theory or perspective, lacking holistic and systematic research, and lacking theoretical innovation.

With the synchronous growth of the number and scale of guidance funds, the management norms of government venture capital guidance funds by national and local government institutions at all levels have been gradually improved. On February 21, 2020, Government departments have issued government investment funds and improving the efficiency of financial investment, which puts forward higher requirements for strengthening government budget constraints, improving the use efficiency of financial funds, performance management and exit management. In order to comprehensively examine the policy guidance and investment operation effect of government venture capital guidance funds, Shandong, Henan and Zhejiang provinces have successively issued specific measures for the management of government investment funds and formulated the basic performance evaluation system of guidance funds. However, due to the unbalanced social and economic development in different regions and other factors, there are certain differences in the setting of performance evaluation indicators of guidance funds. Some government venture capital guidance funds even lack a normative description of the specific performance evaluation indicators and evaluation system of guidance funds, and have not established a sufficient and perfect fund performance evaluation system, As a result, there are great differences in fund use efficiency and performance of government venture capital guidance funds in different regions. Therefore, it is objectively necessary to establish a scientific, mature and operable performance evaluation system of government venture capital guidance fund that can fully reflect the allocation efficiency of government venture capital guidance fund, so as to fully activate the policy guidance effect of guidance fund. At present, performance evaluation can be systematically divided into three parts, as shown in Figure 1:

This paper focuses on the fund performance evaluation index system, which is based on the requirements of the Government Sector for the relevant performance evaluation policies of investment funds, and focuses on the realization of the fund policy objectives, the realization of the social benefit objectives and the standardized operation. In the process of designing the index system, on the basis of comprehensively investigating the basic characteristics of the fund performance evaluation index system launched in various pilot areas, the rows and columns of the matrix represent the total assets and benefits of the fund respectively. To test the performance of the network reconstruction method of row and column aggregation of the matrix composed of these fund data. Therefore, any stress test results will significantly depend on the method used to fill in the missing information. This paper proposes a new evaluation and testing method based on Bayesian model and machine learning algorithm.

2. Model Introduction

2.1. Bayesian Model

2.1.1. Basis of Bayesian Method. The concept of Bayesian method is relatively simple [15–20]. Generally, Bayesian reasoning uses a core tool called Bayesian theorem or Bayesian criterion. In fact, it is such a simple formula. We have basically learned this in probability. There are several basic objects in the formula, which we use θ Describe the parameters of the model. The model can be neural network, linear model or SVM. All parameters are used θ To describe; D is our training set; $\pi(\theta)$ Is a priori distribution, which is the description of the distribution of the model itself before we see the data; $p(D \mid \theta)$ Is the likelihood function, given a model θ The case describes the likelihood of this data. Our goal is to obtain this a posteriori distribution, which is to look at the distribution of the model itself after seeing the data. It can be expressed as follows:

$$p(\theta \mid D) = \frac{p(D \mid \theta)}{p(D)}. \tag{1}$$

What can Bayesian rule do in machine learning?

Prediction: m is a model class (for example, linear model in RD).

$$p(x \mid D, M) = \int p(x \mid \theta, D, M) p(\theta \mid D) \mathrm{d}\theta. \tag{2}$$

Due to the IID assumption, $p(x \mid \theta, D, M)$ is usually simplified to $p(x \mid \theta)$.

Model comparison:

M_1 is a model class (e.g., liner model in Rd), and M_2 is another model class (e.g., polynomial model with order p)

$$\begin{aligned} p(D \mid M_1) \geq ?\,(\text{or} \leq ?)\, p(D \mid M_2) p(D \mid M) \\ = \int p(D \mid \theta) p(\theta \mid M) \mathrm{d}\theta. \end{aligned} \tag{3}$$

First, the prediction problem. We use big M to describe model class, such as linear model and nonlinear model. There are many specific models in model class. We still use parameters θ express. Make a prediction for the new sample, such as calculating its likelihood, so that you can use the posterior distribution derived from the front to do an integral. This is the likelihood of the sample under a given model, which is the distribution of all possible models. In essence, an average is made. This idea is actually quite similar to many people's idea of integrated learning. We also make a weighted average for many models, but there may be infinite models in this place. We use probability distribution to describe it.

This likelihood function usually assumes that the test data and training data are independent when the model parameters are given, which is what we usually call the assumption of independent and identically distributed.

In addition to prediction, we can also compare different models and select models. For example, if we want to solve the classification problem, whether to choose a linear model or a deep learning nonlinear model is the problem of model selection. This problem can be described as follows: we use M_1 to represent a model class, which may be a linear model, and M_2 to represent another model class, which is a nonlinear model. In the case of the same data set D, we can compare which of the two quantities is large. This quantity is described. Under M_1, we observe a likelihood of the training

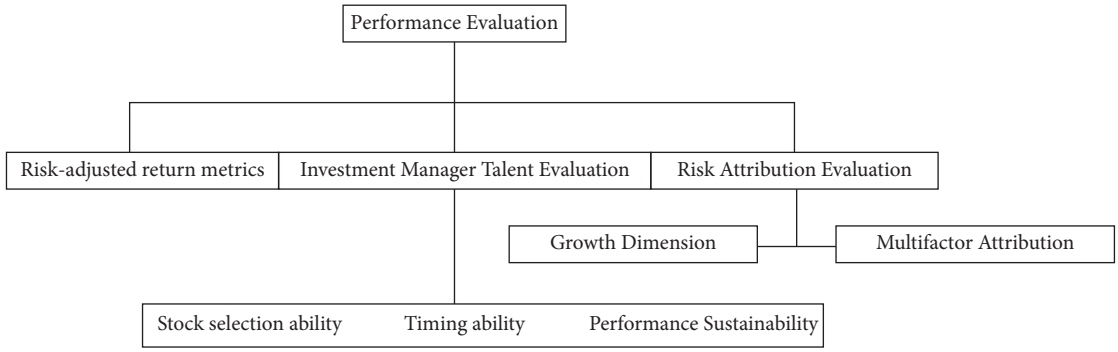

Figure 1: Current performance evaluation classification.

set, the other is the set of statistics in the case of M_2. Through this comparison, we can see which model I should choose. This is a basic rule for model selection using Bayesian method.

2.1.2. Why be Bayesian. One of many answers. Infinte exchangeability:

$$\forall n, \forall \sigma,\ p(x_1, \ldots, x_n) = p\left(x_{\sigma(1)}, \ldots, x_{\sigma(n)}\right). \tag{4}$$

De Finetti's theorem (1955): if $(x_1, x_2, \ldots)$ are infinitely exchangeable, then $\forall n$

$$p(x_1, \ldots x_n) = \int \coprod_i p(xi \mid \theta)\pi(\theta)\mathrm{d}\theta. \tag{5}$$

For some random variable $\theta = \{x_1, x_2, \ldots\}$

This has a basic property called infinite exchangeability. If your data has n samples, if they are exchanged in any order, the joint distribution of these data does not change, that is, what we usually say is independent of the sequence, then its joint distribution can be written in the form of Bayesian—there is a model and corresponding distribution, you can describe the whole distribution in the form of integral. If you draw it graphically, given this model, the data is completely independent. We call it conditional independence, which is a very important concept in the probability graph model.

It is worth noting that the exchangeability is a little wider than the independent and identically distributed previously. The exchangeable data cannot be independent and identically distributed. In addition, this theorem only tells you that it exists, but the latter problem is that we don't know what the specific model should be, such as linear model and nonlinear model, and what kind of model to describe, which is the problem to be solved by statistical modeling.

Where does a priori come from?

The main choice is through the following. Objective priors which are nonstatistically informative priors. Subjective a priori—a priori should reflect our thoughts and trends as much as possible.

Hierarchical a priori—multi-level a priori.

Empirical priors—some parameters for learning priors from the data.

$$p(\theta \mid \alpha)\alpha = \operatorname{argmax} p(D \mid \alpha). \tag{6}$$

Pros: robust-overcomes some limitations of misspecification

Cons: double counting of evidence/overfitting

There is a technology called "hierarchical priority." There is a basic assumption that the parameters in π are called hyperparameters. The farther away it is from my data generation model, the weaker the impact. In fact, using this basic assumption, we can build multi-layer prior.

It can be seen from this that Bayesian itself is a multilayer representation, which is essentially the same as the multi-layer representation of deep learning, but it is completely described in the way of probability. Of course, there are some approximate methods. Do some empirical priority and estimate it through data. The advantage is that the calculation is relatively simple. The disadvantage is that if you use the training data many times, you will get some over fitting problems.

How to calculate the integral?

Recall that:

$$p(D \mid M) = \int p(D \mid \theta)p(\theta \mid M)\mathrm{d}\theta. \tag{7}$$

This can be a very high dimensional intergral.

If we consider latent variable, it leads to additional dimensions to integrated out

$$p(D \mid M) = \int\int p(D, H \mid \theta)p(\theta \mid M)\mathrm{d}\theta\mathrm{d}H. \tag{8}$$

No matter in the most basic Bayesian operation or in multi-layer a priori, integral operation will be used repeatedly, which is the most annoying thing when using Bayesian method, because the integral here is not like the unary or binary simple integral operation when we learn calculus. The integral here may be a very high-dimensional integral. Suppose we use a linear model. When the feature is 100 dimensions, I'm the integral of 100 dimensions. If it is higher dimensions, such as thousands and thousands of dimensions, the integral is higher dimensions. There are very important calculation problems, The first point is the basic theoretical problem. The concept of Bayesian method I mentioned earlier is very simple, and its core is Bayesian

theorem. Bayesian theorem has existed for more than 250 years. It has some limitations. How can we reunderstand it from the perspective of basic information processing criteria and make more flexible reasoning.

The second point is about calculation. With the model and reasoning framework, how can I do efficient calculation and high-precision calculation.

Third, how to model different scenes. When applying Bayesian method to different scenarios, you have to understand your problem and find the appropriate model.

Bayesian theorem or Bayesian reasoning is a criterion of information processing. In information theory, we have a channel with input and output. In Bayesian reasoning, our input is a priori distribution and a likelihood function, and the output is a posteriori distribution. With this view, we can make many extensions. You can think that my input and output can remain unchanged, but I can replace the criteria of information processing. I can remove the criterion of information processing here and make it more universal than classical Bayes. The Bayesian method is organically combined with the machine learning framework based on risk minimization. Machine learning has deeply studied risk minimization and related optimization tools. Under our framework, Bayesian reasoning can be integrated to obtain a more flexible information processing criterion.

2.2. Machine Learning. In machine learning and pattern recognition, we are familiar with the loss function optimization problem. For example, if I want to do classification, I want to train the neural network. The first item is a loss function, which measures the error rate in the training set; The second term is the regularization term we want to add. The purpose is to protect the model from over fitting and divergence. This is a basic framework. These things are basically out of touch with Bayes in machine learning and will not be discussed together with Bayes [21–27].

First, establish learning objectives in machine learning

$$\min_{\theta} l(\theta; D) + r(\theta). \tag{9}$$

Loss functions of our predictive task.

2.2.1. Recap of SVMs. SVM learn a single decision boundary. As shown in the figure.

Here we give a simple example to show the application of Bayesian method in machine learning, such as linear SVM. Its purpose is to find a linear plane to distinguish different categories. As shown in Figure 2:

The first strategy is an averaging model and the second is a stochastic model. The two are theoretically related. With this different treatment, the understanding is achieved by dividing it up in space. With this loss function, optimisation can be carried out directly. We can understand this classifier as a division of the linear space, at its simplest, on a two-dimensional space, by straight lines. It is also understood as template matching, where each category can be seen as a template for one of the categories. The score for each category is, in effect, the element and template match for calculation. Through the loss function, also called the cost function, which is used to measure the degree of match, the aim is to minimise the loss function during the training process. From a Bayesian perspective, this is the SVM approach [28–31].

2.2.2. Bayesian SVMs. The overall optimization problem

$$\min_{q(\theta)} KL(q(\theta)\pi(\theta)) + C \cdot l(q(\theta); D). \tag{10}$$

Strategy #1 (averaging model):

$$l(q; D) = \sum_{i} \max\left(0, 1 - y_i x_i^T \hat{\theta}\right) \hat{\theta} = E_{q(\theta)}[\theta]. \tag{11}$$

Strategy #2 (Gibbs/stochastic model):

$$l(q; D) = \sum_{i} E_{q(\theta; D)}\left[\max\left(0.1 - y_i x_i^T\right)\right]. \tag{12}$$

With the above problems, how to solve them? The first average model can be solved by convex optimization. When the model is linear, if the a priori is Gaussian, your a posteriori distribution is still Gaussian. This actually degenerates to traditional SVMs. You can also use kernel method to expand the nonlinear model, which is OK.

SOLVE Bayesian SVMs.

Strategy #1(Averaging model):

If the prior is normal $\pi(\theta) = N(0, 1)$, we have the solution:

$$q(\theta) \propto \pi(\theta) \exp\left(\sum_{i} a_i y_i x_i^T\right) = N\left(\sum a_i y_i x_i, I\right), \tag{13}$$

where a_i are the solution of the dual problem.

For the second, given a priori, the general solution can be obtained.

Bayesian view can bring some additional benefits. Consistent with the idea of representation learning in deep learning, in Bayesian SVM, we can consider implicit variables or add many layers of implicit variables to learn the distribution of these implicit variables. The above is the coupling of Bayesian model in machine learning. Relevant evaluation indicators will be introduced in the next section.

The application of Bayes' theorem to machine learning to accomplish the task of model prediction and selection is machine learning from a Bayesian perspective. Since Bayesian theorems heavily involve the dependence of various explicit and hidden variables, they are usually described visually by probabilistic graphical models. Bayesianism treats the unknown parameters as random variables, and the uncertainty of the parameters before learning is described by the prior probability, while the uncertainty after learning is described by the posterior probability, and the elimination of uncertainty in between is where machine learning comes into play.

Unlike frequencyism, the output of Bayesian learning is not simply the optimal estimate $\widehat{\theta}$, but a probability distribution $p(\theta)$ about the parameters, thus giving more

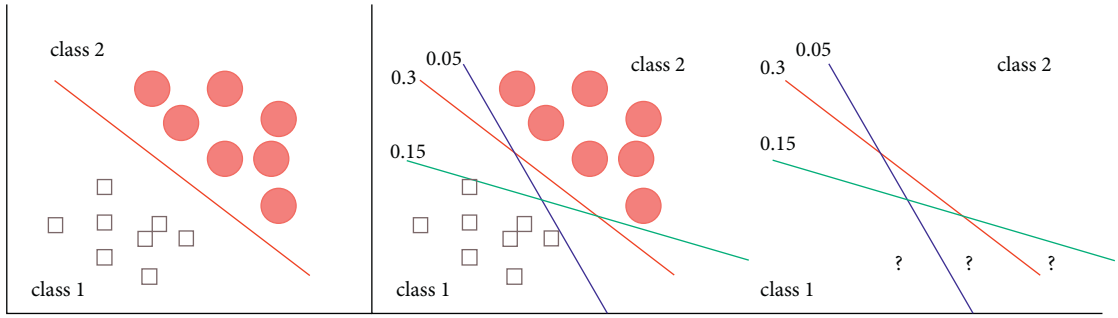

Figure 2: Different types of linear plane classification.

complete information. In the prediction problem, Bayesian learning also gives not just a most probable outcome, but a complete picture of all outcomes and their probabilities in the form of probability distributions.

In addition to providing more complete information in prediction, Bayesian learning also has its advantages in model selection. In Bayesianism, the so-called different models are actually parametric representations of different probability distributions, using parameters with their own prior distributions, but what all models have in common is that they all generate training datasets, and the task of model selection is to pick the best one from these probability distributions.

2.3. Indicators for Fund Performance Evaluation. The most traditional and direct method of fund performance evaluation is to understand the net value and return on investment of the fund.

(1) NAV of net assets of fund units

Deduct various expenses and liabilities from the total assets of the fund, and the balance is the net assets of the Fund:

$$\text{NAV} = \frac{\text{net assets of the fund}}{\text{number of fund units issued}}. \tag{14}$$

(2) Return on investment of the fund

$$R = \frac{(\text{NAV1} - \text{NAV0} + C)}{\text{NAV0}}, \tag{15}$$

where C is the fund interest distribution or dividend.

The above two indicators measure the return of the fund. As a rational investor, we should also consider the risk of return. Therefore, we introduce three risk adjusted return indicators:

2.3.1. Introduction to Sharp Index. William sharp, an American economist, published the performance of funds and proposed to measure the fund performance by the excess return brought by the fund's total risk (including systematic risk and nonsystematic risk), which is the sharp index. Sharp index measures the performance of the fund by the ratio of the average return of the fund portfolio exceeding the standard deviation of the risk-free return to the fund return in a certain evaluation period. The calculation formula is:

$$S_p = \frac{(r_p - r_f)}{\sigma_p}, \tag{16}$$

where S_p is the index, r_p is the actual return of the fund portfolio, and r_f is the risk-free return, σ P is the standard deviation corresponding to the fund yield. The theoretical basis of sharp index is the capital asset model (CAPM model), which takes the capital market line (CML) as the evaluation basis.

2.3.2. Introduction to Treynor Index. The Treynor index uses the method of comparing the average risk return of the portfolio with its systematic risk over a period of time to evaluate the performance of the investment fund.

$$T_p = \frac{(r_p - r_f)}{\beta_p}, \tag{17}$$

where T_p is the T index; β_p Represents the risk factor associated with the fund system. The capital asset pricing model is also the theoretical foundation of the Treynor performance index, but it is evaluated on the basis of the security market line (SML), where all asset portfolios fall on the SML when the market is in equilibrium, i.e., the slope of the SML represents the Treynor index of the market portfolio. When the Treynor index of a fund portfolio exceeds the slope of the SML, the portfolio is above the SML line, suggesting that it outperforms the market; conversely, when the Treynor index of a fund portfolio falls below the SML line, the investment fund portfolio underperforms the market. As a result, the higher the Treynor performance index, the better.

2.3.3. Jensen Index. The additional return on fund inputs expresses the value of fund information. It is also a measure of the fund's performance. Its calculation formula is

$$J_p = r_p - \left[r_f + b_p\left(r_m - r_f\right)\right]. \tag{18}$$

A positive value indicates that the evaluated fund is higher than the market average level and has good investment performance; a negative value indicates that the evaluated fund is higher than the market average level and

has good investment performance; The examined fund outperforms the market in terms of investment performance and is higher than the market average. A negative rating implies that the fund manager's stock picking expertise is poor, that he or she cannot go beyond the index, and that the evaluated fund's overall performance is bad in comparison to the market. If it is 0, it suggests that fund managers' stock selection ability is broad and can only be in accordance with the index.

3. Data Analysis Based on Coupling Model

In order to better understand the linear regression of the model, the relevant data are analyzed and studied. Here, Changxin healthcare industry (163001. Of) is selected as the research object of the fund. The market portfolio is approximated by CSI 300 index and the risk-free interest rate is approximated by 3-month Shibor. The research period is 2016 in order to assess the fund's performance throughout that time. First, as an example, consider the net present value of the shunt fund in the third quarter, as indicated in Figures 3 and 4:

Figures 3 and 4 show the significant growth rate of open-end stocks and the high overall return. This is crucial for performance evaluation. Under normal circumstances it is worth choosing open-end stocks. A detailed analysis of the fund companies is shown in Figure 5.

As can be seen in Figure 5, the average absolute value of the fund managers is in an upward phase, with some funds having large gains. In terms of net selection returns in terms of combined returns and value-at-risk, it is possible to select the top tier of funds among the above funds. The high rate of return in the case of taking the same risk, these are more important in the performance assessment. The performance of the funds in 2016 is measured based on the above indicators and their performance is shown in Table 1.

Here, through three linear regression in machine learning, in the H-M model, if β_2 is most greater than 0, which means that the fund charger will take the initiative to raise when the market rises β Value to follow the bull market and lower in the falling bear market β In the C-L model, when the market rises, use β_1. Measure the systematic risk of fund portfolio. When the market falls, use β_2 measure the systematic risk of the fund portfolio, and finally pass $\beta_1 - \beta_2$ to judge the timing ability of fund managers. As shown in Table 2:

From the regression results, we can see that under the three models, alpha is significantly different from 0, but the sign is negative, which can be considered that the fund manager's stock selection ability is under the market. In the T-M model, beta2 was significantly greater than 0; And H-M model, beta2 was not significant; In the C-L model, beta1 and beta2 are significant, and beta1 is significantly greater than beta2. In conclusion, it can be considered that the timing ability of the fund manager is significantly above the market.

In the analysis of beta value, only one factor of market risk is considered, but it is often necessary to analyze the source of fund performance more carefully, so there is a multifactor attribution analysis model. In this part, we will consider the attribution analysis of four factors: reversal (turnover), beta, volatility (standard deviation) and size (fund size). Using the past time series for rolling regression, we can get the exposure degree of the fund on these factors every day, which is summarized in the exposition_ In factor. From the observation results, the performance of the fund is mainly attributed to the volatility factor and partly to the reversal factor as shown in Table 3:

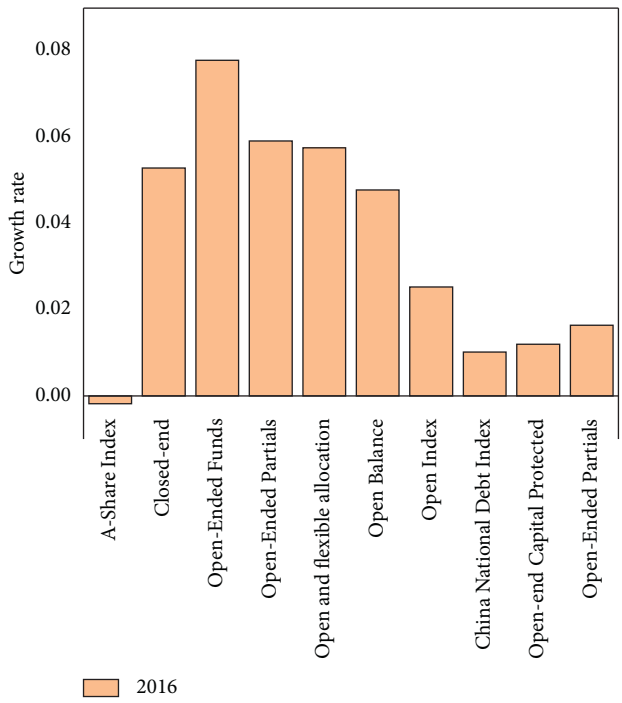

Figure 3: Fund growth rate.

Using the past time series for rolling regression, we can get the exposure degree of the fund on these factors every day, which is summarized in the exposition_ In factor. From the observation results, the performance of the fund is mainly attributed to the volatility factor and partly to the reversal factor. As shown in Figure 6:

Profitability, risk resistance and risk adjusted return indicators. Among them, stage return and Jason alpha are commonly used for profitability, volatility (standard deviation), loss ratio (frequency of net loss in the stage), average loss (mean value of loss when loss occurs) and leverage are commonly used for anti risk ability, and Sharpe ratio, sotino ratio, information ratio, uplink capture rate, downlink capture rate are commonly used for risk adjusted indicators. After analyzing the above indicators, we can get the following results as shown in Figures 7 and 8:

With the above Figures 7 and 8, we can clearly understand that the impact of risk tolerance on fund performance evaluation is very important. Therefore, we understand that it is necessary to reasonably improve the evaluation through machine learning and related training algorithms. More accurate prediction estimation of fund trend is trained by

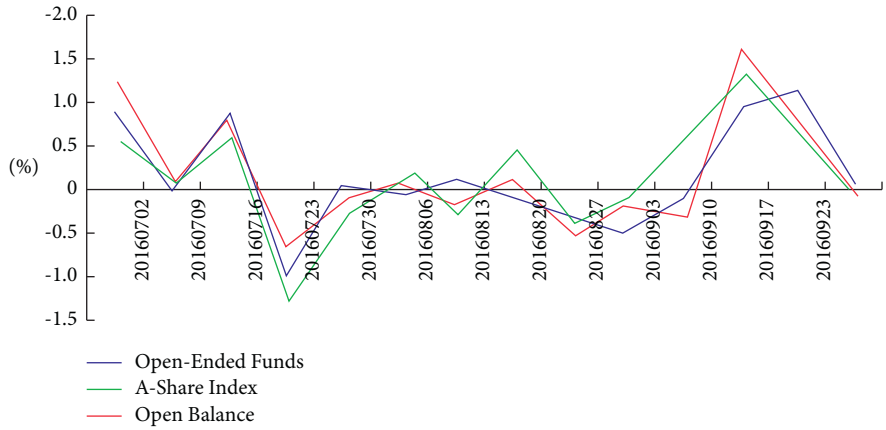

Figure 4: Average fund NAV growth and A-share market returns by week.

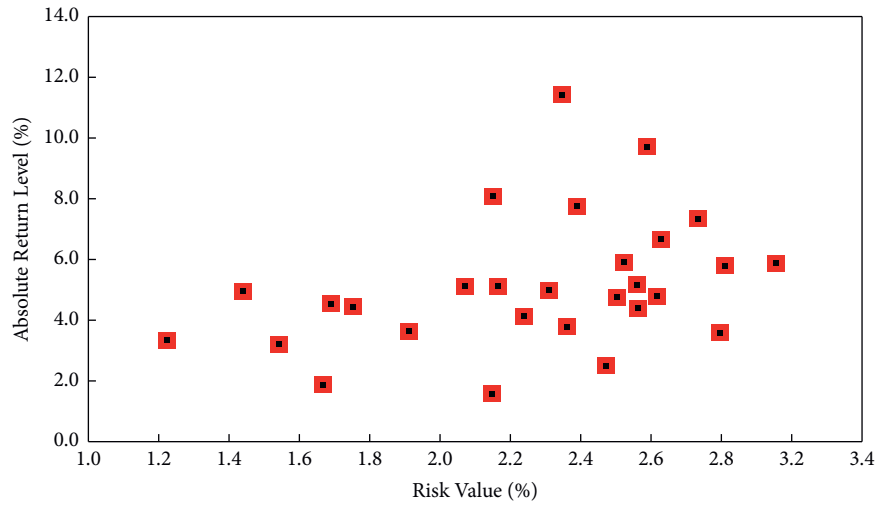

Figure 5: Scatter chart of return and VaR of fund companies.

Table 1: Performance indicators of the fund.

Indicators	Indicator value	Indicators	Indicator value
Stage yield	−11.00%	Jensen alpha	−1.11%
Volatility	1.38%	Loss ratio	45%
Average loss	−1.07%	Beta	0.624
Sharp ratio	−10.06%	Sotino ratio	−0.223
Information ratio	Approximately 0		

Table 2: Three regression models of linear regression technology.

Models	Alpha	*P* value	Beta1	*P* value (beta1)	Beta2	*P* value (beta2)
T-H models	−0.0067	0.006	0.8835	0.000	3.0512	0.018
H-M models	−0.00115	0.000	0.6121	0.000	97.2363	0.224
C-L models	−0.0117	0.000	1.7974	0.045	0.6081	0.000

more data to ensure the accuracy of performance evaluation. Here, we use Bayesian models to address data accuracy issues in machine learning to help achieve accurate performance evaluations quickly. The Bayesian models in Figures 9 and 10 provide further insight into the machine training process and the degree of performance statistics during training, as shown in Figures 9 and 10.

As can be seen from Figures 9 and 10, the degree of approximation of the machine learning results gradually increases with the number of training sessions. In Figure 9

Table 3: Multifactor attribution analysis model.

	Explosion_turn	Explosion_scale	Explosion_beta	Explosion_volatility
2016-02-22	−0.094073	−0.02039	0.087151	−0.03889
2016-02-23	−0.122745	−0.011229	0.061206	−0.237779
2016-02-24	−0.150539	−0.002904	0.027562	−0.209910
2016-02-25	−0.142255	−0.003158	0.027469	−0.244269
2016-02-26	−0.160840	0.004011	0.000641	−0.346814

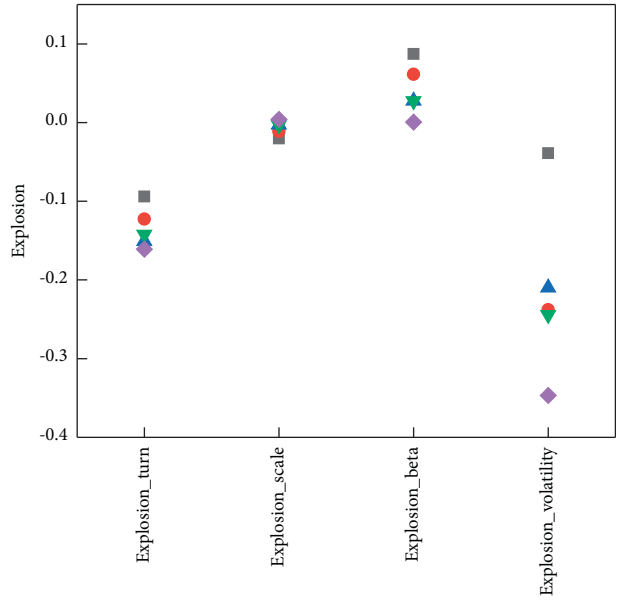

Figure 6: Multi factor fluctuations in different periods.

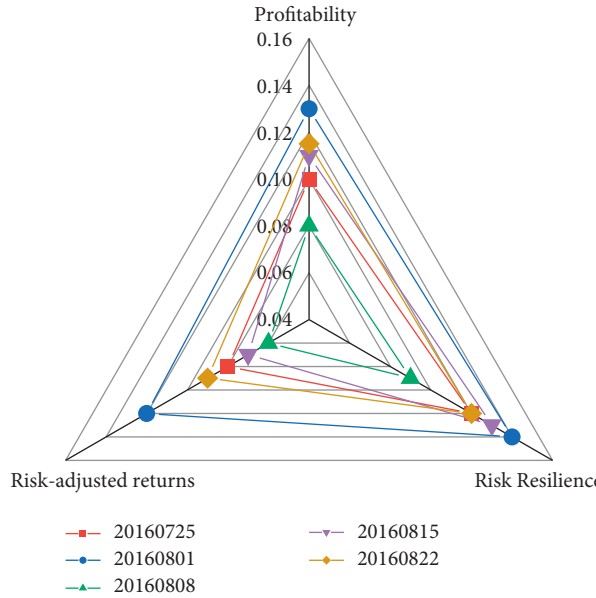

Figure 7: Evaluation of fund performance value at different times.

presents probability distributions getting closer to the true values as the training of the machine is prolonged. And the trend of change of the fund performance value the more statistical value is completed consistent through Figure 10. This proves that the learning method of Bayesian model is important in fund performance evaluation.

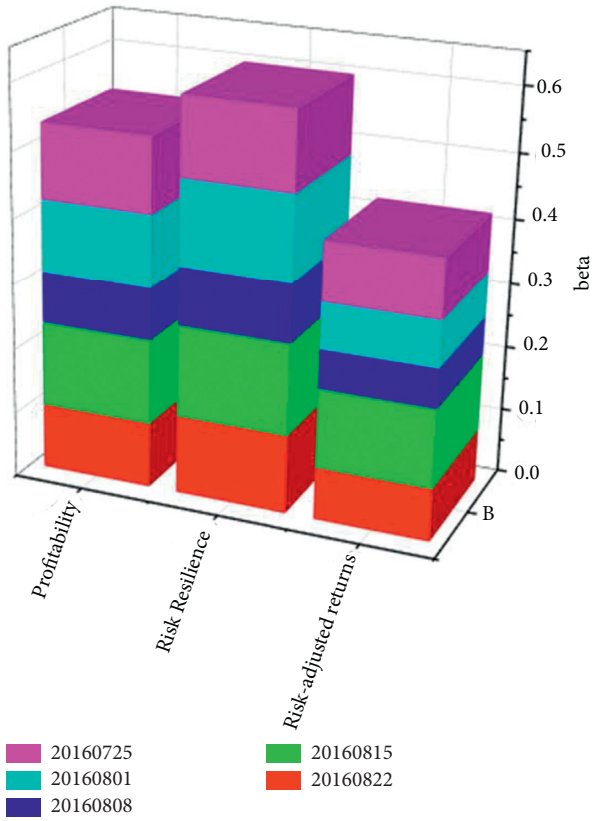

Figure 8: Size of each risk value at different times.

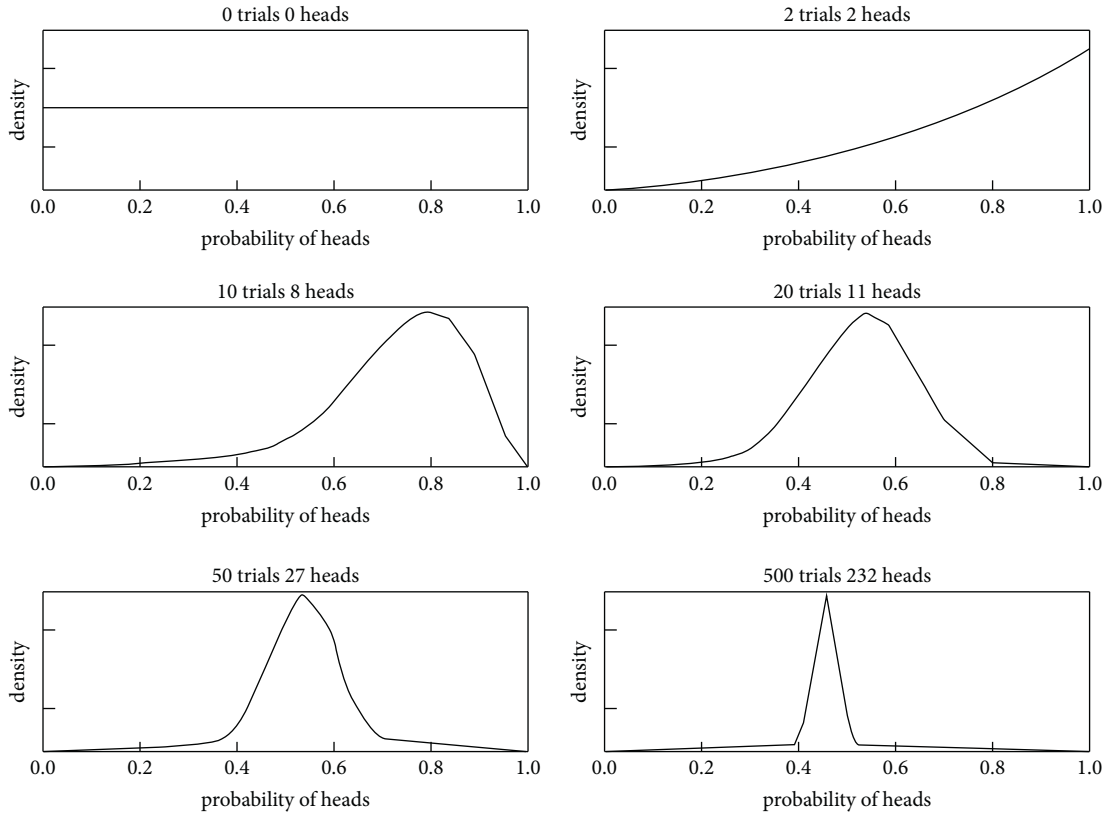

Figure 9: Training probability density of Bayesian model in machine learning.

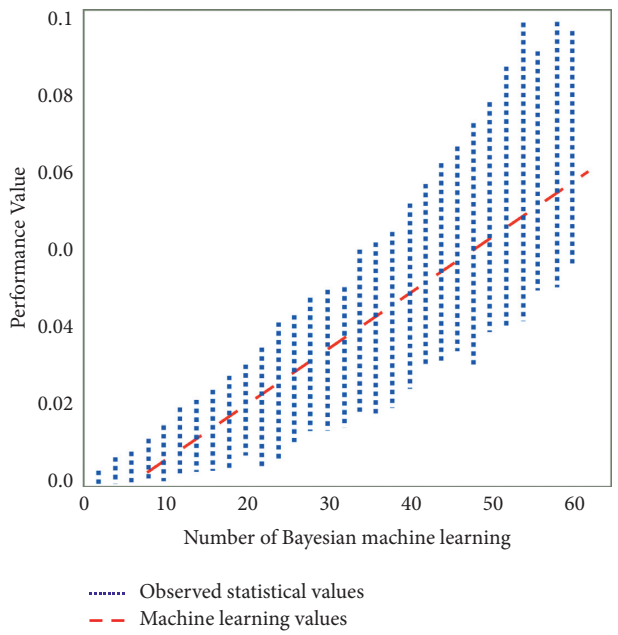

Figure 10: Training values and observation statistics of Bayesian model in machine learning.

4. Conclusions and Recommendations

(1) This paper describes the poor return of a fund in 2016, with little fluctuation, but a high proportion of losses, and the information ratio is almost 0. The stock selection ability of the fund is below the market, but the timing ability of the fund is significantly above the market.

From the multi factor point of view, the performance of the fund is mainly attributed to the volatility factor, some to the reversal factor, and other factors are not significant. The indexes that fit well with the performance of the fund are pharmaceutical, biological, mechanical equipment, computing and other industries, and the index fitting of each industry is poor.

(2) As a basic algorithm, Bayesian statistics plays an important role in machine learning. Especially in data processing, it has a good classification effect on the analysis of event probability and event reliability.

In addition to not mechanically copying the quantitative analysis indicators of fund evaluation, the following recommendations should be noted when evaluating investment funds, taking into account the actual situation of the fund market.

(1) Quantitative consideration of evaluation indicators of nonquantitative factors. In the actual evaluation process of fund performance, it should also be combined with other aspects for comprehensive evaluation. Such as, the fund company's management and management style. In addition, the economic environment and the trend of the securities industry involved in the fund can hardly be judged fairly by numerical analysis alone. It is better to consider the fund based on various factors to prevent generalization.

(2) The evaluation of investment funds should focus on performance and the sustainability of performance. Also pay attention to consider the stability of the fund, as long as to ensure a stable return is worth investing.

(3) The choice of benchmark needs a reasonable and comprehensive reference standard to compare the fund's performance with the market situation. However, there is no unified and authoritative market index in China. The method of comparing the fund with Shanghai index or Shenzhen index to reflect the fund performance is not objective enough. Because, on the one hand, neither the Shanghai index nor the Shenzhen index is a unified index of the two markets, and the fund invests in the two markets; On the other hand, the fund can only invest in the circulating shares of the two cities, and the Shanghai index and Shenzhen index take the total share capital rather than the circulating share capital as the weight. Therefore, the above index or Shenzhen index is not effective in evaluating the fund performance. Some people think that we should take the weighted average of the two indexes as the benchmark, or make appropriate adjustments to the two indexes, but there are also some difficulties in practical operation.

(4) In the evaluation of fund performance, the principle of comparative performance of similar funds must be adhered to. If it is necessary to compare the performance of different types of funds, certain transformation of indicators must be performed.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Research on the Influence of Emission Trading System on Enterprises' Green Technology Innovation

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This paper uses the data of China's A-share listed companies in Shanghai and Shenzhen stock markets from 2003 to 2014 and takes the pilot emission trading policy in 2007 for a quasinatural experiment to explore the role of the pilot emission trading policy in promoting enterprises' green technology innovation. The empirical research shows a Porter effect in the emission trading system in China. Specifically, first, the emission trading policy can significantly promote enterprises' green technology innovation in pilot areas. In addition, the incentive effect of emission trading policy on green technology innovation is significantly different due to the types of green patents. Second, the incentive effect of emission trading policy on enterprises' green technology innovation is different due to the nature and scale of enterprises. The incentive effect is greater in state-owned enterprises than in non-state-owned enterprises, and it is greater in large-scale enterprises than in small-scale enterprises. Finally, the incentive effect of emission trading policy on enterprises' green technology innovation has heterogeneity of regions. It has the greatest incentive effect in eastern region, followed by western region and then central region.

1. Introduction

After more than 30 years of development, China's economic aggregate has experienced qualitative growth. In 2021, China's total domestic GDP reached nearly 101.6 trillion yuan, successfully maintaining the second position in the world. However, the cost of rapid economic development is often the pollution of the ecological environment. If the traditional economic development model is not shifted and the ecological environment problems are neglected, it will be difficult to achieve the transformation point of ecological environment improvement. China has adopted related policies and measures against environmental pollution and achieved remarkable results. However, with the rising quality of China's economic development, the current ecological and environmental problems are still quite serious. In 2018, Yale University released the Global Environmental Performance Index ranking, in which China ranked 120th, reflecting that China's existing environmental protection still needs to be further improved. The management of environmental pollution has a strong externality. It is difficult for enterprises, the main body in the profit-seeking market, to realize lucid waters and lush mountains only by their own consciousness. Therefore, it is necessary for the government to intervene. The purpose of the government's environmental policies is to enable the harmonious development of economy and ecology and promote the transformation of economy to high quality. Government's environmental regulation policies can be divided into two categories: command-oriented environmental regulations and market-oriented environmental regulations [1]. Compared with command-oriented environmental regulations, market-oriented environmental regulations are more conducive to technological innovation of enterprises [2–4]. With the improvement of marketization in China, the market-oriented environmental regulation policy has gradually become an important tool to improve the environment [5]. Whether the market-oriented environmental policy has advantages needs to be verified. Meanwhile, whether market-oriented environmental policy tools can

speed up the construction of a green technology innovation system in China needs to be further studied.

The existing market-oriented environmental regulation tools in China mainly adopted are emission trading, carbon emission trading, and environmental tax. In July 2002, the pilot emission trading policy was implemented in Shandong Province, Shanxi Province, Jiangsu Province, Henan Province, Shanghai City, Tianjin City, Liuzhou City, and China Huaneng Group Corporation, also known as the "4 + 3+1" pilot emission trading policy. In 2007, China gradually expanded the scope of the pilot areas. Zhejiang Province, Hubei Province, Chongqing City, Hunan Province, Inner Mongolia Autonomous Region, Hebei Province, Shaanxi Province, Henan Province, and Shanxi Province were also included in the pilot areas of emission trading. With the expansion of the pilot areas, the pollution varieties included in emission trading are gradually growing, and the emission trading volume is also increasing year by year [6]. At the same time, the total amount of pollutant emissions also shows an apparent downward trend. In 2010, China's sulfur dioxide emissions were only 85.71% of those in 2005, down by 14.29%. It can be seen from the data that China's emission trading system plays a significant role in environmental governance.

In April 2019, China issued the "Guiding Opinions on Building a Market-oriented Green Technology Innovation System," which elaborated the path and time of building a green technology innovation system. Building a green technology innovation system has become an urgent problem to be solved. Due to China's slow process of marketization, imperfect market mechanism in the past, and slow construction of intellectual property protection systems, enterprises lack the motivation for technological innovation. However, the core factor for the coordinated development of ecological environment and economic society is science and technology. The progress of science and technology is conducive to the better coordinated development of the two. At this stage, most enterprises tend to adopt passive and defensive measures when facing environmental regulation policy, and they are less likely to take the initiative to manage the environment. When dealing with environmental pollution, enterprises often focus on the end treatment of pollutant discharge, without paying attention to the process and source treatment of pollutant discharge, which leads to the increase of environmental treatment cost. This is insufficient to meet the growing demand for green products. As the main body of the market, enterprises are the essential objects of building a green technology innovation system. Enterprises' green technology innovation is closely associated with market-oriented environmental policies. Because emission trading is relatively mature in China, this paper will explore the relationship between emission trading and enterprises' green technology innovation.

From the existing literature, there are few studies on the relationship between pilot emission trading policy and green technology innovation, especially those on enterprises' green technology innovation, the main body of microeconomy. This paper aims to theoretically analyze the theoretical mechanism and verify the influence mechanism between them through actual data. The theoretical significance of this paper is to elaborate the theoretical mechanism of emission trading policy on enterprises' green technology innovation and quantitatively analyze the incentive effect of pilot emission trading policy on enterprises' green technology innovation by using the measurement methods such as score matching and DID, thus supplementing the existing literature. The practical significance is to verify the incentive effect of the pilot emission trading policy on enterprises through actual data and further elaborate the influence mechanism between emission trading policy and green technology innovation in a certain period, thus providing some inspiration for building a green innovation system and further improving the emission trading policy.

The possible innovations of this paper are as follows. First, there are few studies on the relationship between emission trading system and green technology innovation. Moreover, domestic and foreign studies are primarily based on the "Porter Hypothesis." However, due to the differences in methods and indicators adopted by scholars, the conclusions drawn are not entirely consistent. Most of the existing studies are located in the whole industry, the polluting industry, or the green industry. There are few studies only taking the SO2-emitting industry as the research object. Therefore, it is innovative to take SO2-emitting enterprises as the research sample in this paper. Second, this paper details the action mechanism of emission trading system on enterprises' green technology innovation and explores the heterogeneity of the incentive effect from a multidimensional perspective.

2. Literature Review

The influence of environmental regulation policy on green technology innovation has been controversial in academic circles. According to neoclassical economics theory, namely, from a static point of view, environmental regulations increase enterprises' pollution-control cost, thus generating a crowding-out effect on their R&D innovation and inhibiting their green technology innovation. For example, Rhoades [7] thinks that the environmental regulation policy makes enterprises in the fierce market competition environment passively transform technologies and processes, change the original high-pollution production mode, and guide them to carry out innovation activities that have economic effects and protect the ecological environment. However, in reality, the complexity of green technology innovation often leads to the weakening of enterprises' green technology innovation. Gray and Leonard empirically find that environmental regulations force enterprises to shift some production resources to pollution control, thus increasing their production costs and reducing high-risk innovation activities [8, 9]. Fisher et al. [10] divide two stages when enterprises face environmental regulations, namely, the compliance stage and the active management stage. In the first stage, enterprises are generally unwilling to follow the regulations and respond passively because these regulations will increase their governance costs. In the second stage, enterprises

gradually pay attention to the active management of ecological environment, but will not rely on green technology innovation. From the heterogeneity of regions, Dong Zhiqing [11] argues that the development of highly polluting enterprises in neighboring places with high environmental regulation intensity drives the overall output value up in the long term, which in turn increases the investment in green technology innovation. In the long run, polluting enterprises in neighboring areas gradually shift to clean technology, thus eventually weakening their green technology innovation.

From a dynamic perspective, the most representative one is the "Porter Hypothesis" put forward by foreign scholar Potter in 1991. Its core view is that environmental regulations will increase the pollution-control cost of enterprises, but it will generate their innovation activities. The effect brought by innovation activities may offset the increased cost, thus reducing the overall production cost and enhancing the competitiveness of enterprises. Subsequently, Porter and Vander Linde, Xepapadeas et al., and Ambec et al. conclude that environmental regulations can promote technological innovation of enterprises, resulting in "innovation offset" [12–14]. Chinese scholars Bai Jia et al. and Chen Qiang et al. empirically verify that the Porter Hypothesis is also applicable in China, and appropriate environmental regulation can promote the technological innovation of enterprises [15, 16]. Li Wei et al. [17] find that traditional enterprises are inclined to internalize pollution costs when confronting environmental regulations, increase R&D investment in clean and green technologies, and then promote the efficiency of green technology innovation. Tao Feng et al. [18] prove that environmental regulations can drive enterprises' green technology innovation from the perspective of environmental protection target responsibility system, and this system has a positive effect on the number of green patent applications, but it will lead to the corresponding decrease in the quality of innovation. However, a number of scholars discover that the relationship between environmental regulations and technological innovation is not a simple linear relationship, but a more complicated U-shaped relationship. For example, UIECE has investigated more than 2,500 enterprises in Europe and found that environmental regulations both promote and inhibit the technological innovation of enterprises, but the promotion effect is weaker than the inhibition effect. Jiang Fuxin [19] use data on manufacturing industries in Jiangsu and empirically verify that the technological innovation of enterprises decreases first and then increases as environmental regulations intensify. Meanwhile, they state that environmental regulations can promote the technological innovation of enterprises only when the intensity of environmental regulations exceeds a certain degree. Zhang Juan et al. [20] find a positive U-shaped relationship between environmental regulations and green technology innovation by using the game model.

Because the influence of environmental regulations on technological innovation will be affected by various factors, simple linear or nonlinear relationship can not describe the relationship between them well. Zhao Xikang and Aiken et al. find that environmental regulations do not affect the technological innovation of enterprises, and environmental regulation policy does not have a significant Porter effect on enterprises [21, 22]. Jiang Ke [23] states that when the quantitative indicator of enterprise innovation is the number of patent applications, there are different effects between them due to the influence of human capital, but there is no obvious statistical relationship between them when other quantitative indicators are taken. You et al. [24] explain that the reason for this insignificant relationship between them is that environmental regulations bring both positive and negative effects to the technological innovation of enterprises, and the two kinds of effects hedge against each other, thus leading to an overall insignificant relationship.

The existing studies on the effect of emission trading policy are carried out from environmental performance, economic performance, and technological innovation. First of all, the research conclusion proves that the emission trading policy has a significant emission reduction effect. For example, Schleich and Betz [25] find that the emission trading system can effectively promote the emission reduction activities of small- and medium-sized enterprises, but the emission reduction effect largely depends on the actual reported emission levels of enterprises. Betsil and Hoffmann [26] think that the emission trading mechanism can effectively reduce greenhouse gas emissions in industry. Yan Wenjuan et al. [27] and Li Yongyou [28] conclude that the emission trading policy can effectively reduce the emissions of pollutants in the pilot areas. In other words, the emission trading policy has a significant emission reduction effect. Shi Dan and Li Shaolin [29] conclude that emission trading can significantly improve the total factor energy utilization rate of unit area, and the limited emission trading policy may even have a restraining effect. Shin [30] argues that China's environmental policy has weakened its own institutional innovation due to the excessive imitation of foreign environmental policy, thus leading to the failure of China's emission trading system. Borghesi et al. [31] conduct an empirical analysis using data from Italian manufacturing enterprises and demonstrate that European emission trading policy has a limited emission reduction effect. Chinese scholars, Li Yongyou, and Shen Kun [32] find that the pilot emission trading policy in 2002 does not play a significant role in reducing pollutant emissions, but increases the pollutant emissions in the pilot areas. From the energy perspective, Shao et al. [33] believe that the reason why the emission reduction effect of emission trading is not obvious lies in the energy rebound effect. Tu et al. [34] think that the emission trading system in 2002 does not realize the "Porter effect." Ren et al. [35] conclude from the perspective of total factor productivity that the emission trading policy adjusts enterprises' technological innovation and market resource allocation to improve total factor productivity. Qi et al. [36] explore the issues of emission trading policy and green technology innovation and discover that the emission trading policy promotes enterprises' green innovation in 2007.

After sorting out the relevant literature, it is found that there are three deficiencies in existing studies. First, there are few studies on emission trading policy and enterprises' green

technology innovation. Second, the effect of emission trading policy is controversial, and whether it has a positive or negative impact on enterprises' green technology innovation needs to be verified urgently. Third, they do not consider the effects of industry, ownership nature, and other factors in emission trading policy influencing enterprises' green technology innovation.

3. Theoretical Analysis and Research Hypotheses

Based on the "Porter Hypothesis," this paper expounds the mechanism between emission trading policy and enterprises' green technology innovation. Porter believes that appropriate environmental regulations can generate enterprise innovation activities [12]. Emission trading, as one of the core tools of market-oriented environmental regulation policy, should also generate innovation activities of enterprises in theory. The emission trading system is based on the ownership of pollutants, which quantifies the price of pollutant emissions. In this regard, enterprises can reduce their pollutant emissions through green technology innovation, sell the excess emission rights in the market, and obtain extra profits. Because the emission trading system makes the amount of pollutant emissions market-priced, enterprises can plan their costs according to their actual situation and make flexible decisions on whether to carry out green innovation and whether to buy emission credits, thus helping them achieve the goal of pollution control at the lowest cost [37, 38]. The emission trading policy simply means that the local government sets the maximum emission quotas for each region and then allocates these emission quotas to each enterprise reasonably. Then, enterprises can freely trade these quotas in the market. As the emission trading system makes the pollutant emission have a price, the cost of enterprises with higher pollutant emissions will increase, and the returns and profits will decrease. When the unit return is equal to the unit cost, enterprises will reach the point of stopping business and face three choices of stopping business, relocating to other places, or carrying out green innovation locally, so as to reduce their pollutant emissions and the related cost. The opportunity cost of stopping business or relocating is generally too high. The cost of factory building and market development will become sunk cost, and there is uncertainty about the future implementation of emission trading policy in the relocated place. Therefore, enterprises will prioritize carrying out green innovation locally [39].

In view of this, this paper puts forward H1: the emission trading policy promotes enterprises' green technology innovation.

From the nature of enterprises, state-owned enterprises are often far less sensitive to prices than non-state-owned enterprises. When the emission rights are marketized, non-state-owned enterprises will be more active in green technology innovation. Moreover, when emission trading is not implemented, green technology innovation is similar to public goods, and its yield rate is low. After the implementation of the emission trading policy, the private attributes of green technology innovation products mean that enterprises can obtain excess returns by carrying out green innovation. State-owned enterprises attach more importance to social responsibility and are far larger than non-state-owned enterprises in capital and enterprise scale. The implementation of emission trading will encourage state-owned enterprises to carry out green innovation, so that they can obtain profits while fulfilling their social responsibilities. In the meantime, because non-state-owned enterprises pay more attention to private interests, they will compare the returns from green technology innovation with those from their own main product innovation and then choose the optimal solution. Due to the large investment and long payback period of green technology innovation, it is riskier for them. Compared with its main product innovation, green technology innovation is more difficult and less profitable, so non-state-owned enterprises tend to shift their capital to main product innovation.

Based on the above analysis, this paper puts forward H2: the incentive effect of emission trading policy on enterprises' green technology innovation is heterogeneous due to the nature of enterprises, and its incentive effect on state-owned enterprises is greater than that of non-state-owned enterprises.

From the perspective of enterprise scale, large-scale enterprises are far superior to small- and medium-sized enterprises in capital and technology. After the marketization of emission rights, small- and medium-sized enterprises confront greater competitive pressure. The main reason is that green technology products become more personal and exclusive after the marketization of emission rights. Small- and medium-sized enterprises have to intensify their green technology innovation to enhance their competitiveness. In addition, after the implementation of emission trading, the pollution-control cost of small- and medium-sized enterprises correspondingly rises due to the lack of technology, thus reducing their profits and further worsening the living environment of enterprises. From the types of enterprises' green innovation products, the profits brought by invention patents are generally much higher than those brought by utility model patents. As the main body in the profit-seeking market, enterprises pursue the maximization of profits and tend to choose high-profit invention patents.

Hence, this paper puts forward the following hypotheses.

H3: emission trading has a stronger incentive effect on large-scale enterprises' green technology innovation.

H4: compared with enterprises' green utility appearance patents, emission trading has a stronger role in promoting enterprises' green invention patents.

4. Model Setting and Variable Description

4.1. Model Setting. This research expects to evaluate the pilot emission trading policy. A DID model is set up to study the influence of emission trading on enterprises' green technology innovation. The model is set as follows:

$$\text{EnvrPantent}_{ijt} = \beta_0 + \beta_1 \text{post}_t * \text{treat}_j + \beta_2 \text{post}_t + \beta_3 \text{treat}_j + \rho X_{\text{it}} + \phi t + \varphi_j + \varepsilon_{ijt}. \quad (1)$$

Among them, t, i, and j, respectively, represent the year, the individual enterprise, and its region. ϕt represents the time fixed effect. φj represents the region fixed effect. $\varepsilon i jt$ represents the random interference item.

The explained variable is EnvrPatent_{ijt}, which indicates the number of green patent applications of listed companies. In the heterogeneity analysis, this paper also discusses the results of utility model green patents. The explanatory variables of the model include the dummy variable of the policy pilot area and the dummy variable of the policy pilot time. *treat j* represents the dummy variable of the emission trading pilot area. If the enterprise is located in a pilot area, the value is 1; otherwise, the value is 0. *postt* represents the dummy variable of the time for implementing the policy. It the time is during the pilot period of emission trading (2007 and afterward), the value is 1; otherwise, the value is 0.

4.2. Variable Selection and Processing. In this paper, SO2-emitting enterprises in A-shares of Shanghai and Shenzhen stock markets are selected as research objects, and the sample period is from 2003 to 2014. The selection steps are as follows. First, the SO2-emitting industries are identified. Referring to the research of Qi et al. [36], the mining industry and manufacturing industry are selected as the research industries, and the criterion for determining the industries is the "11th Five-Year Plan for the Prevention and Control of Acid Rain and Sulfur Dioxide Pollution" issued by the State Environmental Protection Administration. Second, the scope of SO2-emitting enterprises is determined by referring to the SO2 emission information in the annual report and social responsibility report (CSR) of listed companies manually collected by Ren et al. [35]. Third, to make the results of this paper more robust and reliable, the enterprises with severe sample missing and ST enterprises are excluded by referring to the common practices in the existing literature.

In this paper, the economic characteristics at the enterprise-level are selected as the control variables of the model. It mainly includes enterprise scale (logarithm of net assets and logarithm of number of employees), enterprise maturity (logarithm of enterprise age), enterprise social wealth creativity (logarithm of Tobinq), and enterprise credit evaluation (logarithmic of enterprise liabilities). Descriptive statistics of variables in this paper are presented in Table 1.

5. Empirical Analysis

5.1. Baseline Analysis. According to the previous research hypotheses, this paper first tests the hypotheses based on model (1). In columns (1)-(3) of Table 2, the time fixed effect and region fixed effect are gradually increased. In columns (4)-(6), the control variables are further added and replaced by panel regression. To eliminate the influence of time trend term, this paper adds in columns (7) and (8) the time trend effect of provinces and the time trend effect of industries. In addition, the standard error used in the regression of this paper is the robust standard error adjusted by heteroskedasticity.

The regression results in Table 2 show that the emission trading system promotes enterprises in the pilot areas to carry out green technology innovation activities. The regression results presented in columns (1)-(3) of Table 2 reveal that the coefficients of "did" are positive, and the coefficients are all significant at the level of 10%, which preliminarily indicates that the emission trading system can significantly promote enterprises in pilot areas to carry out green technology innovation activities. In columns (4)-(6), after adding control variables and replacing with panel linear regression, the coefficients of "did" are still positive, showing that the baseline model set in this paper is reasonable. Taking column (4) as an example, the implementation of emission trading system increases the number of enterprises' green patent applications by 1.3198, which is significant at the level of 1%. After adding the time trend effect, the regression results of columns (7)-(8) demonstrate that the coefficients of "did" are still significantly positive at the level of 10%, indicating that it is still reasonable after controlling the stricter effect, and the emission trading system increases the number of enterprises' green patent applications in the pilot areas. To sum up, hypothesis 1 is verified.

5.2. Robustness Test

5.2.1. Measurement Errors. Exclude the year when the policy is launched. Since the emission trading system was introduced in the middle of 2007, the samples in 2007 are excluded in this paper to avoid possible measurement errors. Specifically, this paper reassigns the values for the policy identification items. When the year is within 2003–2006, Post is 0; when the year is within 2008–2014, Post is 1. Other variable settings are consistent with model (1). Column (1) of Table 3 lists the regression results after excluding the year when the policy is launched. It can be seen that the coefficient of "did" is 1.3368, which is still significant and positive at the level of 1%, indicating that the previous conclusion is relatively robust.

5.2.2. Missing Variables. PSM-DID estimation: because DID method is prone to "Selection Bias" and it cannot guarantee that the sample characteristics of the policy group and the control group are the same before the policy implementation, errors may occur when the sample size is large. The samples in this paper are listed enterprises all over the country, and the economic development level and technical ability vary greatly in different regions. Therefore, this paper uses the propensity score matching (PSM) to use control variables as identification objects, matches the enterprises in the policy group and the control group, and then regresses the retained samples with the DID method. Figure 1 demonstrates the 1 : 1 nearest neighbor matching result

Table 1: Descriptive statistics.

Variable	Meaning	Mean	Standard deviation	Minimum	Maximum
EnvrPatent	Number of enterprises' green patent applications	0.342	6.728	0.000	529.000
UtyEnvrPatent	Number of enterprises' green utility model patent applications	0.559	3.836	0.000	154.000
Netasset	Logarithm of enterprises' net assets	20.662	1.539	11.513	27.715
Totalliability	Logarithm of enterprises' liabilities	20.908	1.202	12.315	27.907
people_number	Number of enterprises' employees	7.595	1.289	0.000	13.223
tobin_q	Logarithm of enterprises' Tobinq	0.549	0.494	−1.875	7.461
Age	Logarithm of enterprises' age	2.430	0.471	0.000	3.664

Table 2: Baseline regression.

Variable	(1) Poisson	(2) Poisson	(3) Poisson	(4) Poisson	(5) FE	(6) FE	(7) Poisson	(8) FE
did	1.0583***	1.0456*	1.1184*	1.3198***	1.0600**	0.8018*	1.0702***	0.8028*
	(0.1745)	(0.5992)	(0.5945)	(0.4112)	(0.4802)	(0.4696)	(0.3699)	(0.4661)
Treat	−2.3330***	−2.3368***	−4.8667***	−2.7290***			−253.8961	
	(0.1695)	(0.5531)	(0.7007)	(0.6465)			(215.0887)	
Post	0.6713***	0.1675*	1.6287	0.9545*	1.9215***	2.2936***	0.5313	2.2400***
	(0.0446)	(0.9974)	(0.9917)	(0.5029)	(0.1087)	(0.6068)	(0.9280)	(0.8357)
Totalliability				0.1932**		−0.0300	0.3198***	−0.0414
				(0.0893)		(0.1203)	(0.1126)	(0.1229)
Netasset				0.3199***		0.2089	0.1659	0.2204
				(0.0969)		(0.1783)	(0.1211)	(0.1770)
people_number				0.5855***		0.3263**	0.4930***	0.3543**
				(0.0698)		(0.1610)	(0.0774)	(0.1731)
tobin_q				0.1463		−0.0141	0.0041	−0.0143
				(0.2493)		(0.1474)	(0.2584)	(0.1422)
Age				−0.3659***		−0.4484	−0.3506***	−0.4496
				(0.1274)		(0.4182)	(0.1239)	(0.5057)
Time trend effect of provinces							Controlled	Controlled
Time trend effect of industries							Controlled	Controlled
Time fixed effect		Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Region fixed effect			Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
N	14120	14120	14120	13515	3700	3635	13515	3635
R2	0.0427	0.0652	0.2688	0.6462			0.6511	

Table 3: Robustness test.

Variable	(1) Exclude the year when the policy is launched	(2) PSM estimation
did	1.3368***	1.3198***
	(0.4141)	(0.4112)
Treat	−2.7202***	−2.7290***
	(0.6495)	(0.6465)
Post	0.9821*	0.9545*
	(0.5109)	(0.5029)
Control variable	Controlled	Controlled
Time fixed effect	Controlled	Controlled
Region fixed effect	Controlled	Controlled
N	12602	13014
R2	0.6448	0.6462

of the PSM, suggesting that the matching result is good. Column (2) of Table 3 presents the results of the PSM-DID model, indicating that the emission trading system still significantly improves the green technology innovation of listed companies, and the previous conclusions are still robust.

5.3. Heterogeneity Analysis

5.3.1. Heterogeneity of Patent Natures. To expand the research on the types of enterprise green innovation, this paper uses enterprises' green utility model patents to replace the green patent applications. Furthermore, it investigates the

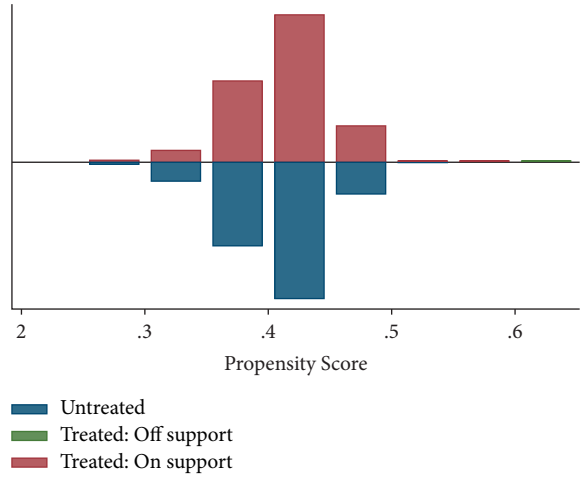

Figure 1: PSM matching results.

Table 4: Heterogeneity of patent natures and enterprise natures.

Variable	(1) Green patent	(2) Green utility model patents	(3) Non-state-owned enterprises	(4) State-owned enterprises
did	1.3198***	0.3605	−1.5346**	2.0282***
	(0.4112)	(0.2665)	(0.6648)	(0.4060)
Treat	−2.7290***	−1.3860***	−0.0218	−3.1195***
	(0.6465)	(0.4302)	(0.9073)	(0.7532)
Post	0.9545*	2.6131***	16.8917	0.5431
	(0.5029)	(0.2878)	(13.2532)	(0.5702)
Control variable	Controlled	Controlled	Controlled	Controlled
Time fixed effect	Controlled	Controlled	Controlled	Controlled
Region fixed effect	Controlled	Controlled	Controlled	Controlled
N	13515	13515	6341	7174
R^2	0.6462	0.4075	0.3682	0.7484

Table 5: Heterogeneity of enterprise scale and region.

Variable	(1) Large-scale	(2) Small-scale	(3) Eastern region	(4) Central region	(5) Western region
did	1.4500**	0.0573	1.6855***	−2.1302*	1.1579
	(0.6421)	(0.4309)	(0.4209)	(1.1566)	(0.8925)
Treat	−2.8513***	−2.0659**	−2.4403***	2.7855**	0.7730
	(0.8735)	(0.8250)	(0.4436)	(1.3797)	(0.8881)
Post	0.8186*	3.2583***	0.9163*	17.5341***	1.6934**
	(0.4803)	(0.7003)	(0.5235)	(1.2225)	(0.7598)
Control variable	Controlled	Controlled	Controlled	Controlled	Controlled
Time fixed effect	Controlled	Controlled	Controlled	Controlled	Controlled
Region fixed effect	Controlled	Controlled	Controlled	Controlled	Controlled
N	7043	6693	8312	3364	1839
R^2	0.6645	0.1299	0.6878	0.2144	0.2978

Porter effect of different natures of patent. This paper continues to use the Poisson regression. The regression results in Table 4 show that the influence of green utility model patents is not significant compared with the positive promotion of green patents at the level of 1%. It indicates that the Porter effect of emission trading policy on green innovation of enterprises mainly lies in green invention patents with "profound" innovation rather than green utility model patents.

5.3.2. Heterogeneity of Enterprise Natures. Emission trading is a policy. To explore the response of enterprises with different ownership systems to the policy, this paper divides enterprises into non-state-owned enterprises and state-owned enterprises. Column (3) of Table 4 shows that the coefficient of "did" for non-state-owned enterprises is -1.5346, significant at the level of 5%, indicating that the emission trading system reduces the level of green technology innovation of non-state-owned enterprises. Column

(4) presents that the coefficient of "did" for state-owned enterprises is 2.0282, significant at the level of 1%, indicating that state-owned enterprises are more stimulated by green innovation in the emission trading system. Although the result is contrary to hypothesis 2, it may be in line with reality. Because of the characteristics of China's political system, the state-owned enterprises have higher flexibility for the policies put forward by the state than non-state-owned enterprises, so they will react more strongly when the policies are introduced. Therefore, this result is understandable.

5.3.3. Heterogeneity of Enterprise Scale. The innovation level of enterprises is obviously closely related to the enterprise scale. Based on hypothesis 3, we divide enterprises into large-scale enterprises and small-scale enterprises according to their median net assets, and we further investigate the heterogeneity of the influence of the emission trading system. From the results in columns (1) and (2) of Table 5, it can be observed that the larger the enterprise scale, the greater and more significant the incentive effect of emission trading system. Thus, hypothesis 3 is verified.

5.3.4. Heterogeneity of Region. The eastern region has long been economically developed in China. The strategy of developing the western region is also launched in the western region in the time interval selected in this paper. To further study the heterogeneity of the influence of emission trading system, this paper divides the regions of enterprises into eastern, central, and western regions according to the regions where enterprises are registered. The results listed in columns (3)-(5) of Table 5 demonstrate that the incentive effect in the eastern region is the most significant and greatest, followed by the western region and then the central region.

6. Conclusion

This paper makes a quasinatural experiment with China's pilot emission trading policy introduced in 2007. Based on the data of enterprise-level green patent applications of A-share listed companies in Shanghai and Shenzhen stock markets from 2003 to 2014, the differences of green innovation applications, enterprise ownership, enterprise scale, and region are defined. The influence of the pilot emission trading system on enterprise-level green innovation activities is verified by DID, two-way fixed effect model, and PSM-DID.

The empirical results are as follows. First, the emission trading policy effectively promotes the enterprises in the pilot areas to carry out green technology innovation activities. Second, the emission trading policy has a stronger promoting effect on green invention patent applications than on green utility model patent applications. Third, the incentive effect of emission trading policy on green technology innovation is stronger in state-owned enterprises, enterprises with higher net assets, and enterprises in the eastern region.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Assessment of the Impact of China's Carbon Emissions Trading Pilot Policy on the Export Product Quality

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This paper carries out the quasi-natural experiment on China's carbon emissions trading pilot policy to assess the impact of China's carbon emissions trading pilot policy on the export product quality of enterprises in the pilot areas by using the data of listed companies and China Customs, and employing the DDD method. Meanwhile, it analyzes the heterogeneity of the impact under different ownership attributes and energy-intensive attributes of enterprises. The empirical results are as follows. First, due to the implementation of the carbon emissions trading pilot policy, the enterprises in the included industries bear the emission reduction cost. The export product quality of the enterprises in the included industries in the pilot areas is negatively affected compared with that of nonincluded enterprises in the nonpilot areas. Second, the impact of the carbon emissions trading pilot policy on the export product quality of enterprises may be heterogeneous due to the different ownership attributes of enterprises. The carbon emissions trading pilot policy significantly reduces the export product quality of non-state-owned enterprises, but has no significant effect on state-owned enterprises. Third, the impact of the carbon emissions trading pilot policy on the export product quality of enterprises is heterogeneous due to different energy-intensive attributes of enterprises. The carbon emissions trading pilot policy significantly reduces the export product quality of enterprises in energy-intensive industries, but it does not have a significant impact on enterprises in non-energy-intensive industries.

1. Introduction

Global warming has become a common challenge for human society in the twenty-first century. As the world's largest carbon emitter, China plays a significant role in global climate governance. In the Paris Agreement released in 2015, China proposed that its self-imposed contributions to emission reduction should be that the carbon intensity in 2030 will be 60%–65% lower than that in 2005, and carbon dioxide emissions will reach the peak by around 2030 while striving to reach the peak as soon as possible. In 2021, China increased its self-imposed contributions to emission reduction, and promised to achieve peak carbon dioxide emissions by 2030 and carbon neutrality by 2060. Under the dual pressure of international emission reduction commitments and domestic environment, the Chinese government has shifted the critical policy tool for controlling greenhouse gas emissions to a market-based tool, namely the carbon emissions trading market. Since 2005, the European Union, the United States, the United Kingdom, New Zealand, Japan, Australia, South Korea and other countries have initiated or implemented the carbon emissions trading, and achieved remarkable results in promoting emission reduction. From 2013 to 2014, China successively launched the carbon emissions trading pilot policy in Hubei, Guangdong, Beijing, Shanghai, Shenzhen, Tianjin and Chongqing (referred to as "Two Provinces and Five Cities"). In 2017, China's national carbon emissions trading market was launched, and it only included the electric power industry. In July 2021, the national carbon market was officially launched for online trading, which will gradually include petrochemical, chemical, building materials, steel, non-ferrous metals, paper-making and other industries. In the carbon emissions trading market, the government sets emission reduction targets and total quotas, and allocates initial carbon emission quotas to emission-controlling enterprises

through free or auction. Enterprises adjust the surplus and deficit of carbon emission quotas through trading in the carbon market, to achieve low-cost emission reduction and accomplish the goal of total control through the market mechanism.

The market internalizes the negative externalities of greenhouse gases such as carbon dioxide, and follows the "polluter pays" principle. Under the condition of setting the total control target, the emission-controlling enterprises obtain the initial carbon quota through free or auction. Furthermore, emission-controlling enterprises have three approaches to achieve emission control targets at the minimal cost: (1) improve energy utilization efficiency, and develop clean and low-carbon technologies to reduce emissions, so that the actual total emissions are less than the total quotas; (2) purchase the carbon quota through the carbon price signal in the carbon market if their actual emissions exceed the initial carbon quota; (3) prefer not to reduce emissions or purchase carbon quotas, and face huge administrative fines when their actual emissions exceeding the initially allocated carbon quota. In these three paths, emission-controlling enterprises choose the way to minimize the emission reduction cost of their enterprises. It is worth noting that the carbon market is the policy tool for environmental regulation, and emission-controlling enterprises belong to carbon-intensive industries. These three ways of fulfilling the target will all generate corresponding emission reduction cost, thereby increasing enterprises' production costs. According to the traditional economic viewpoint, environmental regulation will reduce the competitiveness of enterprises. However, the "Porter Hypothesis" holds that appropriate environmental regulations will not only harm the competitiveness of enterprises, but also form the effect of "innovation compensation" to enhance the competitiveness of enterprises [1]. So far, China's carbon pilot policy in "Two Provinces and Five Cities" has been in operation for 7 to 8 years, achieving remarkable emission reduction effects [2, 3]. However, there is no conclusive evidence on how it affects the competitiveness of enterprises, especially international competitiveness [4]. Therefore, this paper studies the impact of the carbon emissions trading pilot policy on the export product quality of enterprises in the industries included. This paper hopes to provide references for adjusting the total quota and allocation mechanism in the market, and balancing the benefits and emission reduction of enterprises. According to the "weak Porter hypothesis", the carbon trading market helps to form an equilibrium carbon trading price. Incentivize regulated industries or enterprises to adjust and improve their business decisions, product structure, production process, R&D innovation, etc., and gradually transition from the production of pollution-intensive products to green and clean products, thereby reducing carbon emission intensity.

2. Data and Empirical Models

2.1. Data Sources and Variable Processing. The data of Shenzhen, a pilot area for the carbon emissions trading, is included in Guangdong Province, and it is not listed separately. In addition, regarding the industries included in the carbon emissions trading market, this paper comprehensively corresponds the industries included in each pilot area to two industries and industries to which the listed companies belong, and obtains a total of 19 included industries.

To study whether China's carbon emissions trading market has an impact on the export product quality of listed companies, this paper matches the WIND database, CSMAR database and China Customs database. The economic characteristic data of the listed companies comes from this matching database. The sample time is from 2000 to 2014. The export product quality of listed companies is calculated according to the relevant data of the customs database.

The proxy variable method, price index method, and demand function method are taken to depict product quality. Proxy variables mainly include the ISO9000 dummy variable, the proportion of industry R&D and advertising investment in sales, and unit value. Although proxy variables can be directly observed, they can only reflect the product quality of enterprises to some extent [5–7]. The value index method regards the export price index as the product quality index of enterprises, or decomposes the product quality into unit value and price index. Although the product price reflects the product quality, there are various factors triggering the fluctuation of the product price, and the product quality of enterprises cannot be accurately identified [8]. Therefore, the demand function method is increasingly employed to assess the product quality [9]. In this paper, the demand function method is used to measure the product quality. The demand function set in this paper is similar to the Manova structure:

$$lnq_{ijdtm} = lnE_{ijdt} + (\sigma - 1)lnP_{dt} - \sigma lnp_{ijdtm} + (\sigma - 1)ln\lambda_{ijdtm}. \tag{1}$$

Among them, λ_{ijdtm} represents the product quality of the product j exported by the enterprise i to the country d in the period t. q_{ijdtm} represents the export volume of the enterprise. E_{ijdtm} represents the consumption level given by exogenous factors. P_{dt} represents the CES price index. p_{ijdtm} represents the price of the product. σ is elasticity of substitution. m represents the trade mode. Therefore, by estimating the following model, the export product quality of the enterprise ε_{ijdtm} can be obtained:

$$lnq_{ijdtm} = aNI_{dt} - \sigma lnp_{ijdtm} + \varepsilon_{ijdtm} + \delta_i + \delta_t. \tag{2}$$

In this Equation, NI_{it} represents the income level of the country d that the enterprise faces i in the period t. $\varepsilon_{ijdtm} = (\sigma - 1)ln\lambda_{ijdtm}$, δ_i, and δ_t represent individual effect and time effect. The specific calculation method of NI_{it} is as follows:

$$NI_{it} = \frac{\sum_{d,m,j\epsilon M_{it}} p_{ijdtm} q_{ijdtm} lnNI_{dt}}{\sum_{d,m,j\epsilon M_{it}} p_{ijdtm} q_{ijdtm}}, \tag{3}$$

NI_{it} indicates the income level of the destination country.

Combined with the customs database and related data, the product quality of the enterprise can be roughly calculated through the regression of the above measurement model:

$$\widehat{\lambda}_{ijdtm} = \frac{\widehat{\varepsilon}_{ijdtm} + \widehat{\delta}_i + \widehat{\delta}_t}{(\widehat{\sigma} - 1)}. \tag{4}$$

This paper solves two key problems. Firstly, regarding σ (product elasticity of substitution), Khandelwal et al. [10] assumed that σ ($\sigma = 4$) was the same for all products, which obviously ignored the heterogeneity of products. In this paper, the method of Fan et al. [11] is adopted to allow different industries to have different elasticity of substitution. Secondly, because $\widehat{\varepsilon_{ijdtm}}$ contains the product quality information, which means cov (q_{ijdtm}, p_{ijdtm}) ≠0, endogeneity problems arise when using OLS estimation. Thus, Piveteau and Smaghhue [12] suggested using the real exchange rate fluctuations of the importing country of intermediary products as an instrumental variable for product prices. However, for intermediaries, the correlation between the instrumental variable of product prices and p_{ijdtm} is not high, so the data of intermediaries should be excluded from the measurement. However, such methods ignore an essential feature of Chinese export enterprises that intermediaries account for a high proportion of export enterprises (60%–70%). Obviously, the methods of Piveteau and Smaghhue [12] will cause a large number of observed values missing in the customs database, resulting in measurement errors. Instead, this paper uses unobserved demand fluctuations in the export destination country as the instrumental variable for the following reasons. The unobserved demand fluctuations cannot be predicted in advance by enterprises, and enterprises' production and operation decisions will shift, so the instrumental variable is not correlated with the export product quality of enterprises, but the unobserved demand fluctuations will be reflected in the prices of enterprises' export products through the price conducting mechanism.

$$cov\left(q_{ijdtm}, D_u\right) = 0. \tag{5}$$

D_u indicates the unobserved demand fluctuations, and depicts it from enterprise demand change and product demand change. The enterprise demand change is as follows:

$$D_{it} = \frac{\sum_{d,j\epsilon M_{it}} ex_{djit} ex'_{djit} / Im_{djt}}{\sum_{d,j\epsilon M_{it}} ex_{djit}}. \tag{6}$$

Among them, Im_{djt} represents the total import amount and Im_{djt} represents the adjusted export amount of UN comtrande.

Product demand changes are as follows:

$$D_{jt} = \frac{Im_{djt}}{Im_{dt}}. \tag{7}$$

To depict the relativity of China's product quality upgrade, this paper constructs the relative quality index of export products $\widetilde{\lambda}_{ijdtm}$, and uses it to measure the quality level of China's export products:

$$\widetilde{\lambda}_{ijdtm} = \frac{\widetilde{\lambda}_{ijdtm}}{Q_{jt}^{Im}} = \frac{\left(\widehat{\delta}_i + \widehat{\delta}_t + \widehat{\varepsilon}_{ijdtm}\right)}{\left(\widehat{\delta}_d - 1\right) Q_{jt}^{Im}}. \tag{8}$$

Q_{jt}^{Im} represents the world average quality level of the product j in the year t.

In this paper, the product quality at the product level is summed up to the enterprise level by taking the proportion of the export volume of a certain product of an enterprise to the total export volume of the enterprise that year as the weight. China's import and export tariffs are partially adjusted in January 2012. After the adjustment, the total number of import and export tax items increases from 7,977 in 2011 to 8,194. Table 1.

Considering other enterprise-level factors may have the potential impact on the export product quality, this paper selects a series of important factors affecting the export product quality of enterprises as control variables, including economic growth, technological level, population. Moreover, this paper selects the panel data at the provincial level and the panel data at the industry level as control variables. ① Enterprise age ($\ln age$). The accumulation of business experience may affect the export product quality [13]. ② Enterprise size ($\ln size$). Enterprises with larger size may export products with better quality because of the obvious competitive advantages in the scale economy and overseas markets. This paper uses the total year-end assets of enterprises to measure the enterprise size. ③ Enterprise production capacity (ln capacity).Enterprises with strong production capacity have advantages in the industry competition. The intensity of competition in the industry will affect the entry of new enterprises, the distribution of the total export volume among existing enterprises, the choice of export destinations and the R&D of new products, thus affecting the export product quality. This paper uses the number of employees in enterprises to measure the ability of enterprises. ④ R&D investment ($\ln RD$). The export products produced by enterprises with higher technical level have higher quality level. ⑤ Enterprise price index (ln wage).The price factor represents the product quality of enterprises to some extent, which is expressed by the employee wage payable in this paper [14].

2.2. DDD Baseline Model. To evaluate whether China's carbon emissions trading pilot policy affects the export product quality of the enterprises in the included industries, this paper compares the differences between the pilot area (treatment group) and the nonpilot area (control group) before and after the implementation of the policy. Based on the traditional difference-in-difference (DD) method, the DDD method is adopted to introduce the attribute of whether the industry of the enterprise is included in the carbon trading market, compare the impact differences between the included enterprises (treatment group) and nonincluded enterprises (control group) in the pilot area before and after the implementation of the policy, identify the effects of the policy from various confounding factors and assess the causal effects of policy. This method can further eliminate the non-time-varying and unobservable factors except the pilot policy, and identify the net effect of carbon market implementation. Thus, the identification of policy treatment effect is relatively accurate and robust [15].

Table 1: Export product quality of listed companies.

Year	Obs	Mean	Std. dev.	Min	Max
2000	312	1.068	1.811	−2.381	3.330
2001	272	1.256	1.789	−1.909	3.419
2002	301	1.370	1.691	−1.494	3.558
2003	316	1.451	1.775	−1.465	3.728
2004	401	1.246	1.901	−1.999	3.694
2005	389	1.205	1.944	−2.157	3.792
2006	391	1.102	1.958	−2.410	3.806
2007	442	1.207	1.979	−2.114	4.017
2008	468	1.121	2.009	−2.288	3.910
2009	529	0.910	2.056	−2.760	3.707
2010	725	0.786	2.100	−2.968	3.644
2011	863	0.867	2.091	−2.734	3.754
2012	892	-0.0312	2.256	−3.624	3.301
2013	891	0.828	2.013	−2.743	3.619
2014	910	0.814	2.057	−2.824	3.708

The DDD basic model of the impact of the carbon emissions trading pilot policy on the emission reduction and economic performance of regional enterprises is as follows:

$$\begin{aligned} Y_{ijt} &= \beta_1 ETS_i \times \text{Sector}_j \times \text{Post}_t + \beta_2 ETS_i \times \text{Sector}_j \\ &\quad + \beta_3 ETS_i \times \text{Post}_t + +\beta_4 ETS_i \times \text{Post}_t + X\theta + \alpha_i \\ &\quad + \delta_j + \mu_t + \alpha_i^* \text{time} + \delta_j^* \text{time} + \varepsilon_{ijt}. \end{aligned} \tag{9}$$

In the model, i, j, and t indicate the province where the enterprise is located, the industry of the enterprise and the year, respectively. Y_{ijt} is an explained variable that represents the export product quality of enterprises. ETS_i is a dummy variable of the policy pilot. If the province i where the enterprise is located is a pilot area of carbon market policy (Beijing, Shanghai, Guangdong, Hubei, Tianjin, Chongqing), the value is 1; otherwise, it is 0. Post_t is a dummy variable before and after the year of policy implementation. If the year t is the year of policy implementation and subsequent years, the value is 1; otherwise, the value is 0. Since China's carbon emissions trading pilot has been initiated in succession since 2013, this paper uses 2013 as the starting year of policy implementation. Sector_j is a dummy variable of whether the industry of the enterprise is included in the carbon market. If the industry of the enterprise is included in the carbon trading market, the value is 1; otherwise, the value is 0. X is the control variables, including enterprise age $\ln age$, enterprise size $\ln size$, enterprise production capacity $\ln capacity$, enterprise price factor $\ln wage$ and enterprise R&D investment $\ln RD$. ε_{ijt} is the random disturbance term. α_i, δ_j and μ_t are the province fixed effect, industry fixed effect and time fixed effect, respectively. In addition, $\alpha_i^* \text{time}$ and $\delta_j^* \text{time}$ are introduced into the model, respectively, to control the time trend effect of the region and industry. Furthermore, in the regression of the model, the enterprise fixed effect and time trend effect of enterprise are also controlled. Then, the time-invariant and time-varying factors of the regional, industry and enterprise are controlled to better estimate the net effect of the carbon emissions trading market policy on the export product quality of enterprises. In this Equation, the concerned coefficient is the coefficient β_1 of the interaction term, $ETS_i \times \text{Sector}_j \times \text{Post}_t$, which measures the degree of difference in the export product quality between the enterprises in the pilot areas and those in the nonpilot areas before and after implementing the carbon market policy. If the value of β_1 is significantly negative, it indicates that the carbon emissions trading pilot policy lowers the export product quality of enterprises in the industry included in the carbon market.

3. Empirical Result Analysis

3.1. The Impact of the Carbon Emissions Trading Pilot Policy on the Export Product Quality. According to the constructed baseline model (1) and the DDD regression model, this paper first verifies whether the implementation of the carbon emissions trading pilot policy significantly affects the export product quality of enterprises in the pilot areas. The estimation results are shown in Table 2. Among them, Column (1) presents the estimation results that only industry fixed effect, enterprise fixed effect, and time fixed effect are controlled. Column (2) shows the estimation results that only the province fixed effect, industry fixed effect, enterprise fixed effect, and time fixed effect are controlled. Column (3) displays the estimation results that only the province fixed effect, industry fixed effect, and enterprise fixed effect are controlled. Column (4) demonstrates the estimation results that only province fixed effect, industry fixed effect, enterprise fixed effect, and time fixed effect are controlled. Column (5) shows the estimation results that province fixed effect, industry fixed effect, enterprise fixed effect, time fixed effect, as well as the time trends of the province and industry are controlled. Column (6) displays the estimation results that the time trends of province, industry and enterprise are controlled on the basis of Column (5).

The regression results in Table 2 show that the implementation of the carbon emissions trading pilot policy has significantly reduced the export product quality in the pilot areas. Columns (1), (2), and (3) in Table 2 show the estimation results that three kinds of province fixed effect, industry fixed effect, enterprise fixed effect, and time fixed effect are controlled, respectively. Column (4) shows the

Table 2: Impact of the carbon emissions trading pilot policy on export product quality of enterprises.

	Export product quality					
	(1)	(2)	(3)	(4)	(5)	(6)
$ETS_i \times \text{Sector}_j \times \text{Post}_t$	−0.717*** (0.177)	−0.687*** (0.177)	−0.692*** (0.175)	−0.717*** (0.177)	−0.556*** (0.177)	−0.561*** (0.178)
$ETS_i \times \text{Post}_t$	0.621*** (0.088)	0.619*** (0.088)	0.599*** (0.084)	0.621*** (0.088)	0.917*** (0.113)	0.919*** (0.113)
$ETS_i \times \text{Sector}_j$	0.435 (0.305)	0.126 (0.252)	0.425 (0.305)	0.435 (0.305)	0.504 (0.303)	0.517 (0.303)
$\text{Sector}_j \times \text{Post}_t$	0.776*** (0.087)	0.745*** (0.085)	0.752*** (0.083)	0.776*** (0.087)	0.962*** (0.110)	0.963*** (0.110)
ln age	−0.749*** (0.173)	−0.757*** (0.173)	−0.855*** (0.129)	−0.749*** (0.173)	−0.683*** (0.171)	−0.723*** (0.176)
ln size	0.344*** (0.108)	0.331*** (0.108)	0.315*** (0.103)	0.344*** (0.108)	0.369*** (0.107)	0.358*** (0.108)
ln capacity	−0.123 (0.086)	−0.121 (0.086)	−0.119(0.086)	−0.123(0.086)	−0.124 (0.085)	−0.115 (0.085)
ln *R D*	−0.039 (0.051)	−0.033 (0.051)	−0.046(0.051)	−0.039(0.051)	−0.011 (0.051)	−0.006 (0.051)
ln wage	0.083*(0.044)	0.081*(0.044)	0.080*(0.044)	0.083*(0.044)	0.074* (0.043)	0.072* (0.043)
Observed value	3590	3590	3590	3590	3590	3590
R2	0.063	0.061	0.062	0.063	0.080	0.081
Province fixed effect		Y	Y	Y	Y	Y
Industry fixed effect	Y		Y	Y	Y	Y
Enterprise fixed effect	Y	Y	Y	Y	Y	Y
Time fixed effect	Y	Y		Y	Y	Y
Province*time fixed effect					Y	Y
Industry*time fixed effect					Y	Y
Enterprise*time fixed effect						Y

Note. The standard deviation is within brackets. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

estimation results that these four kinds of fixed effects are all controlled. In these cases, the regression coefficients of the DDD interaction item, $ETS_i \times \text{Sector}_j \times \text{Post}_t$ have little difference, and remain between −0.69 and −0.72 at the significance level of 5%. However, when the time trends of the province, industry and enterprise are controlled in Column (5) and Column (6), the regression coefficients of the DDD interaction item $ETS_i \times \text{Sector}_j \times \text{Post}_t$ is about -0.56 at the significance level of 5%. This indicates that it is necessary to consider the time trends of province, industry and enterprise in the model estimation of this paper, and the time-varying factors of province, industry and enterprise will be further excluded to estimate the net effect of the implementation of the carbon trading pilot policy. The estimation results show that the establishment of the carbon trading market does have a negative impact on the export product quality of enterprises in included industries compared with enterprises in nonincluded industries in nonpilot areas. Moreover, the carbon emissions trading pilot policy reduces the export product quality index of enterprises in industries included by nearly 0.56.

The carbon emissions trading is a market-based environmental regulation policy tool. Under this policy regulation, the enterprises in the included industries will undertake additional emission reduction tasks compared to those in nonincluded industries. In other words, faced by a certain initial carbon quota, they need to reduce emissions to fulfill their obligations, or pay economic costs to buy quotas in the carbon market for emissions. Then, enterprises in the included industries will bear additional emission reduction cost whether they invest capital, equipment, manpower, improve management efficiency to reduce emissions, or purchase carbon quotas in the carbon market [16]. This leads to an increase in production costs for enterprises in the included industries, and the cost increase effect brought by the carbon emissions trading market is greater than the innovation effect, which ultimately leads to the decline in the export product quality [17]. Enterprises have to reduce the quality of products to maintain profits. In the meantime, they also reduce the quality of products to maintain the market share without raising prices. The findings of this paper are consistent with the results of Chapple et al. [18], which state that the EU carbon trading system reduces the competitiveness of emission-controlling enterprises and increases the cost of enterprises from the perspective of market share. This paper finds that China's carbon emissions trading pilot more or less reduces the export competitiveness of enterprises from the perspective of the export product quality.

3.2. Robustness Test Analysis. The empirical results of the baseline model show that the carbon emissions trading pilot policy reduces the export product quality of enterprises in the included industries. To further verify whether this effect indeed comes from the implementation of the carbon trading policy, rather than other policy that may affect the change of export product quality, this paper further sets the year without the implementation of the carbon pilot policy as the year with the implementation of the policy through the placebo test. It also conducts the robustness test by comparing the significant difference between the treatment effect after the implementation of the carbon emissions trading pilot policy and that before the implementation of the policy, as follows:

$$\begin{aligned} Y_{ijt} = {} & \lambda_0 ETS_i \times \text{Sector}_j \times \text{Post}_{2008} + \lambda_1 ETS_i \times \text{Sector}_j \times \text{Post}_{2009} + \lambda_{12} ETS_i \times \text{Sector}_j \times \text{Post}_{2010} + \beta_1 ETS_i \times \text{Sector}_j \times \text{Post}_t, \\ & + \beta_2 ETS_i \times \text{Sector}_j + \beta_3 ETS_i \times \text{Post}_t + \beta_4 ETS_i \times \text{Post}_t + X\theta + \alpha_i^* \text{time} + \delta_j^* \text{time} + \mu_t + \varepsilon_{ijt}. \end{aligned} \tag{10}$$

Among them, Post_{2008}, Post_{2009}, and Post_{2010} are time dummy variables, which, respectively, mean that the value is 1 when the year is 2008, 2009 and 2010; otherwise it is 0. It should be noted that the actual year of implementing the carbon pilot policy adopted in this paper is 2013. In 2011, China announced the launch of the carbon emissions trading pilot. The launch of the carbon emissions trading pilot policy may have a corresponding impact in 2011 and 2012. Given this, 2011 and 2012 are set as the year with the dummy implementation of the policy in the placebo test. The meanings of other variables are consistent with (9). When the coefficient β_1 of the interaction term $ETS_i \times \text{Sector}_j \times \text{Post}_t$ is significant and the coefficients of interaction term $ETS_i \times \text{Sector}_j \times \text{Post}_{2008}$, $ETS_i \times \text{Sector}_j \times \text{Post}_{2009}$, and $ETS_i \times \text{Sector}_j \times \text{Post}_{2010}$ are not significant, it indicates that the export product quality has not changed significantly before the implementation of the carbon trading policy, but it varies significantly after the implementation of carbon trading policy. Therefore, the trend variation of the export product quality of enterprises indeed comes from the carbon emissions trading pilot policy implemented in 2013 and later, rather than other policy factors.

According to (10), the dummy years of the carbon market policy implementation in 2008, 2009, and 2010 are constructed. Furthermore, whether the emission reduction effect of the carbon market is really due to the establishment of the carbon market in 2013 is analyzed. If the export product quality of enterprises in the pilot areas in 2008, 2009 and 2010 is significantly different from that of enterprises in the nonpilot areas, the variation of export product quality is not caused by the carbon pilot policy. On the contrary, if the export product quality of the enterprises in the pilot areas in 2008, 2009 and 2010 is significantly different from

enterprises in the nonpilot areas, but it changes significantly compared with the enterprises in the nonpilot areas however after the implementation of the pilot policy in 2013, it suggests that the carbon emissions trading pilot policy indeed causes the change in the export product quality of enterprises.

The results of the robustness test are shown in Table 3. The results reveal that in the placebo test, the export product quality of enterprises in the included industries in the pilot areas has not changed significantly compared with enterprises in the nonincluded industries in the nonpilot areas whether considering the dummy carbon market policy in 2008, 2009, and 2010, or the dummy carbon market policy in 2009 and 2010. However, after the implementation of the carbon trading pilot in 2013, the export product quality of enterprises in the pilot areas is significantly lower than that of enterprises in the nonpilot areas at a significant level of 5%. The coefficients of interaction terms are not significant before 2013, but are significant after 2013, indicating that the decrease of export product quality is indeed due to the establishment of the carbon market in 2013. Hence, this further proves the credibility of the previous regression results of the baseline model.

4. Heterogeneity Analysis

4.1. Enterprise Ownership. The impact of the carbon emissions trading pilot policy on the export product quality of enterprises may be heterogeneous due to the different ownership attributes of enterprises. Based on the baseline model, this paper divides the whole sample into two subsamples of state-owned enterprises and non-state-owned enterprises according to the attributes of enterprise ownership. Furthermore, it investigates the different effects of the carbon emissions trading policy implementation on the export product quality of state-owned enterprises and non-state-owned enterprises in pilot areas compared with those of non-state-owned enterprises and non-state-owned enterprises in nonpilot areas. This paper aims to explore whether the carbon emissions trading policy generates heterogeneous effects on the export product quality of enterprises with different ownership attributes.

The estimation results are shown in Table 4. Whether controlling the province fixed effect, industry fixed effect, time fixed effect, province time trend, industry time trend or enterprise time trend, the DDD coefficients are not significant in the subsamples of state-owned enterprises, but significantly negative in the subsamples of non-state-owned enterprises. This shows that the impact of the carbon emission trading pilot policy on the export quality product of enterprises does have heterogeneity differences in the ownership attributes of enterprises. The carbon trading pilot policy does not significantly affect the export quality product of state-owned enterprises, but significantly reduces that of non-state-owned enterprises. The possible reasons mainly come from two aspects. First, most state-owned enterprises are traditional industries, and they often need to follow the development path of high pollution and high emissions; However, the state-owned enterprises are generally large in scale and volume, and often bear a greater responsibility for the local economy, and also have a relatively underlying relationship with the government. Then, the environmental regulation policies, such as the carbon emission trading, may have a weak regulatory effect on the state-owned enterprises, and its impact on their export quality product may be small [19]. Secondly, compared with non-state-owned enterprises, state-owned enterprises enjoy abundant capital investment, financial subsidies, tax relief and financing facilities, etc. Compared with non-state-owned enterprises, they have enough ability and strength to deal with environmental regulation policies, such as carbon emission trading, without affecting their export quality product. On the contrary, non-state-owned enterprises have to confront the environmental regulation of the carbon emission trading. Moreover, under the carbon emissions trading, they will face more intense market competition, so it is difficult to consider improving the productivity of enterprises and their export quality product.

4.2. Energy-Intensive Attribute. The impact of the carbon emissions trading pilot policy on the export product quality of enterprises may also be heterogeneous due to the different energy-intensive attributes of enterprises. The carbon emissions trading policy is to regulate the total carbon emissions of energy-intensive industries, and achieve the goal of promoting emission reduction of enterprises with heavy emissions through marketization. For enterprises in energy-intensive and non-energy-intensive industries, the carbon market makes them face different pressures and emission reduction cost, so the impact on their product quality is different. To study the heterogeneity of the impact of the carbon emissions trading pilot policy on the export product quality in included energy-intensive enterprises and non-energy-intensive enterprises, industries with energy intensity higher than the average energy intensity of all included industries are set as energy-intensive industries, while industries with energy intensity lower than the average energy intensity of all included industries are set as non-energy-intensive industries. Furthermore, based on the baseline model, the samples in the included industries are divided into sub-samples of energy-intensive industries and non-energy-intensive industries according to the energy-intensive attributes of industries to study whether the carbon emissions trading policy has different effects on the export product quality of enterprises in energy-intensive and non-energy-intensive industries.

The estimation results are shown in Table 5. Whether controlling the province fixed effect, industry fixed effect, time fixed effect, province time trend, industry time trend or enterprise time trend, the DDD coefficients are significant in the subsamples of energy-intensive industries, but not significant in the subsamples of non-energy-intensive industries. The result shows that the impact of the carbon emissions trading pilot policy on the export product quality of enterprises does have heterogeneity differences in the energy-intensive attributes of industries. Compared with the nonincluded industries in nonpilot areas, the carbon

Table 3: Placebo test.

	Export product quality			
	(1)	(2)	(3)	(4)
$ETS_i \times \text{Sector}_j \times \text{Post}_t$	−0.561*** (0.181)	−0.565*** (0.181)	−0.569*** (0.183)	−0.571*** (0.183)
$ETS_i \times \text{Sector}_j \times \text{Post}_{2010}$	0.183 (0.222)	0.185 (0.222)	0.165 (0.232)	0.172 (0.232)
$ETS_i \times Sector_j \times Post_{2009}$	−0.483 (0.302)	−0.471 (0.302)	−0.500 (0.305)	−0.491 (0.303)
$ETS_i \times \text{Sector}_j \times \text{Post}_{2008}$			−0.101 (0.378)	−0.076 (0.380)
Observed value	3590	3590	3590	3590
R2	0.083	0.083	0.083	0.083
Province fixed effect	Y	Y	Y	Y
Industry fixed effect	Y	Y	Y	Y
Enterprise fixed effect	Y	Y	Y	Y
Time fixed effect	Y	Y	Y	Y
Province*time fixed effect	Y	Y	Y	Y
Industry*time fixed effect	Y	Y	Y	Y
Enterprise*time fixed effect		Y		Y

Note. The standard deviation is within brackets. *, **, and *** represent significance levels of 10%, 5% and 1%, respectively. The economic characteristic variables of enterprises, including total assets, number of employees, age of enterprises, R&D investment, as well as wage, and the interaction items are all controlled, and no report will not be presented here due to the limited space.

Table 4: Heterogeneity analysis of considering enterprise ownership attribute.

	State-owned enterprise		Non-state-owned enterprises	
	(1)	(2)	(3)	(4)
$ETS_i \times Sector_j \times Post_t$	0.008 (0.083)	0.005 (0.083)	−0.488*** (0.131)	−0.488*** (0.131)
$ETS_i \times \text{Post}_t$	0.221*** (0.052)	0.223 (0.052)	0.560*** (0.084)	0.560*** (0.084)
$ETS_i \times \text{Sector}_j$	0.247 (0.144)	0.255 (0.144)	0.168 (0.228)	0.168 (0.228)
$\text{Sector}_j \times \text{Post}_t$	0.253*** (0.052)	0.254 (0.052)	0.563*** (0.081)	0.563*** (0.081)
Observed value	Y	Y	Y	Y
R^2	Y	Y	Y	Y
Province fixed effect	Y	Y	Y	Y
Industry fixed effect	Y	Y	Y	Y
Enterprise fixed effect	Y	Y	Y	Y
Time fixed effect	Y	Y	Y	Y
Province*time fixed effect		Y		Y

Note. The standard deviation is within brackets. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively. The economic characteristic variables of enterprises, including total assets, number of employees, age of enterprises, R&D investment, as well as wage, and the interaction items are all controlled, and no report will not be presented here due to the limited space.

Table 5: Heterogeneity analysis of considering energy-intensive attribute.

	Energy-intensive industry		Non-energy-intensive industry	
	(1)	(2)	(3)	(4)
$ETS_i \times Sector_j \times Post_t$	−0.057* (0.032)	−0.056* (0.032)	0.008 (0.087)	0.008 (0.087)
$ETS_i \times Post_t$	−0.009 (0.019)	−0.010 (0.019)	0.072 (0.051)	0.072 (0.051)
$ETS_i \times Sector_j$	0.046 (0.054)	0.043 (0.054)	−0.565*** (0.154)	−0.566 (0.154)
$Sector_j \times Post_t$	0.130*** (0.020)	0.131*** (0.020)	0.778*** (0.055)	0.778 (0.0550)
Observed value	Y	Y	Y	Y
R^2	Y	Y	Y	Y
Province fixed effect	Y	Y	Y	Y
Industry fixed effect	Y	Y	Y	Y
Enterprise fixed effect	Y	Y	Y	Y
Time fixed effect	Y	Y	Y	Y
Province*time fixed effect		Y		Y

Note. The standard deviation is within brackets. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively. The economic characteristic variables of enterprises, including total assets, number of employees, age of enterprises, R&D investment, as well as wage, and the interaction items are all controlled, and no report will not be presented here due to the limited space.

emissions trading pilot policy significantly reduces the export product quality of enterprises in the included energy-intensive industries, but does not have a significant impact on the export product quality of enterprises in the non-energy-intensive industries. This result is also in line with expectations. For the energy-intensive enterprises included

in the carbon market pilot policy, they bear great pressure to reduce emissions. They need to upgrade equipment or develop new technologies to improve energy efficiency or energy consumption structure to reduce emissions, or they need to buy a certain amount of carbon quotas in the carbon market to meet their own emission needs, and this extra emission reduction cost is likely to force enterprises to lower their product quality for the sake of ensuring sufficient income. For enterprises in non-energy-intensive industries, the pressure of emission reduction is smaller than that in energy-intensive industries, and the export product quality is not affected by the cost of emission reduction.

5. Conclusions and Policy Implications

This paper carries out the quasinatural experiment on China's carbon emissions trading pilot policy to assess the impact of China's carbon emissions trading pilot policy on the export product quality of enterprises in the pilot areas by using the data of listed companies, and the DDD method, and analyze the heterogeneity of the impact under different ownership attributes and the energy-intensive attributes of enterprises. The empirical results are as follows. First, due to the cost of emission reduction, the implementation of China's carbon emissions trading pilot policy has a negative impact on the export product quality of the enterprises in the pilot areas, compared with the nonincluded enterprises in the nonpilot areas. Second, the impact of the carbon emissions trading pilot policy on the export product quality of enterprises may be heterogeneous due to the different ownership attributes of enterprises. The carbon emissions trading pilot policy significantly reduces the export product quality of non-state-owned enterprises, but has no significant impact on the export product quality of state-owned enterprises. Third, the impact of the carbon emissions trading pilot policy on the export product quality of enterprises is heterogeneous due to different energy-intensive attributes of enterprises. The carbon emissions trading pilot policy significantly reduces the export product quality of enterprises in energy-intensive industries, but it does not have a significant impact on enterprises in non-energy-intensive industries.

To help the enterprises in the included industries to complete the task of emission reduction while maintaining sustained international competitiveness, the research findings of this paper have the following implications:

For emission-controlling enterprises, the scarcity of carbon emission rights leads to the extra carbon emission cost for included enterprises when the total carbon emission of the industry is restricted. This increases the production cost of enterprises in the short term, resulting in the decline of product quality. In the long run, enterprises, especially those in non-state-owned enterprises and energy-intensive industries, should shift to a clean, low-carbon and efficient development model to maintain competitiveness in the international market. First of all, enterprises should carry out the reform, abandon the extensive development mode, improve the productivity and energy efficiency of enterprises, eliminate or update backward equipment and technology, promote energy saving and efficiency improvement of key equipment, effectively save energy and reduce carbon emission intensity. Secondly, enterprises in energy-intensive industries should optimize the energy consumption structure. To further control the production costs increased by emission reduction cost, enterprises, especially energy-intensive enterprises, should actively carry out the transformation of energy consumption structure, promote the substitution, transformation and upgrading of coal consumption, increase renewable energy electricity consumption, and promote the transformation of energy consumption patterns. Finally, enterprises in the included industry should develop or introduce energy-saving and low-carbon technologies, and transform to the low-carbon development strategy. The current quota allocation method of the carbon emission rights pilot trading is mainly allocated free of charge. In the future, the carbon market will reduce the total amount of quotas and increase the proportion of auction allocation. Therefore, enterprises included in the pilot carbon market should lay out their measures of transformation and emission reduction in advance, and cope with the further increase in emission reduction cost in the future with a higher potential for emission reduction, especially for non-state-owned energy-intensive enterprises.

For the government, the implementation of the carbon market under the total carbon emission limit relies on the price signal reflected by the carbon price to encourage or constrain the emission-controlling enterprises to make decisions in emission reduction. Enterprises with different emission levels obtain different carbon emission quotas, leading to differences in emission reduction costs and production costs. Different quota allocation methods will have a more significant impact on the quotas obtained by enterprises. If the quota allocation is too tight, it will cause tremendous economic losses to the production and operation of enterprises. If the quota allocation is too loose, enterprises will not be motivated enough to reduce emissions. Therefore, the government authorities should take into account the fairness and efficiency of quota allocation and further improve the quota allocation mechanism. Secondly, the carbon price reflects the carbon emission reduction of the included enterprises to some extent. Excessive carbon price makes the enterprise unable to bear the excessive emission reduction cost, resulting in the carbon leakage risk of relocation. Low carbon price cannot effectively motivate enterprises to reduce emissions, so stable and reasonable carbon price is the fundamental guarantee for enterprises to achieve emission control. Government authorities should design a systematic price stability mechanism and take reasonable price management measures to ensure the sound and stable operation of the carbon market.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Performance Evaluation of China's Basic Pension Insurance Based on a Three-Stage Superefficient SBM-DEA Model

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This study looks at the efficiency and effectiveness of the pension insurance system, thus establishing a pension insurance performance evaluation index system. Based on the SBM-DEA model with non-radial and non-angular outputs, the performance evaluation model of basic endowment insurance system was constructed using this index system. By studying the basic pension insurance for employees, this study analyses the basic pension insurance data of 31 provinces in China from 2016 to 2020 and conducts experiments. The results show that the overall performance of the basic endowment insurance system for urban workers in all provinces of China shows a downward trend. The development level of each province is obviously not balanced. The results also show clear regional characteristics and exhibit an east-high-high-low pattern with uncoordinated levels of development with each other. In view of this phenomenon, the Dagum is used to measure the spatial difference in the performance of the basic endowment insurance system. Finally, kernel is used to predict its dynamic evolution trend from the time dimension.

1. Introduction

With the strengthening of the old-age insurance system, the social security function and importance of the old-age insurance are increasing day by day. Because of the increasingly serious population aging, the system is facing the severe challenge of sustainable development, and how to objectively and scientifically evaluate the operation process and effect of the current old-age insurance system has become the further improvement and development of the system. These problems with the pension system need to be solved urgently. So, constructing a systematic and scientific evaluation index system of the endowment insurance system is important, and the operational efficiency of the endowment insurance system is quantitatively evaluated, its operation status is timely grasped, the existing problems are found out, and effective measures are taken to improve the operational capacity of the endowment insurance system and promote the sustainable development of the endowment insurance system. At present, the academic research on the performance of the old-age insurance system is limited to the research on the performance evaluation of social security, and there are few research results only on the evaluation of the performance of the old-age insurance system. In 2012, Shang Jinyun and Lee *J* [1] constructed a new-type rural social endowment insurance operation quality evaluation index system in five aspects and used the analytic hierarchy process to screen the indicators and determine the indicator weights. In 2012, Know [2] started from the international pension system evaluation system, analyzed China's pension system from four aspects, and gave specific suggestions. In 2013, Zhang [3, 4] qualitatively analyzed the efficiency of China's social system from macro-, meso-, and micro-levels and put forward ideas to improve the efficiency of the system. Li and Zhang [5], Zhong [6], and others used AHP to evaluate the effectiveness of China's system and the performance of town basic pension expenditures, respectively. In 2017, Wang [7] established a "3E" index system for the performance expenditures and conducted a study on the expenditure performance of China's basic pension by designing evaluation criteria for various scoring indicators.

The abovementioned research results mainly focus on the qualitative analysis level, and the constructed index system mainly focuses on comprehensive evaluation. The characteristics of performance are not obvious, the methods adopted are highly subjective, and the evaluation methods are relatively weak. The SBM-DEA model was created by Fried [8] in 2002. Its main idea is as follows: in the first stage, the input-output indicators are substituted into the traditional DEA model (BBC model or CCR model), and the slack variables of each decision-making unit are calculated [9–11]. Therefore, the SBM-DEA model of undesired outputs and the stochastic frontier analysis (SFA) method are used in the paper to construct a SBM-DEA model with nonradial, non-angular, and undesired outputs. This study establishes the performance evaluation index system from three aspects, economy, efficiency, and effectiveness of the system, and uses the index system combined with the generalized SBM-DEA method of panel data to construct the performance evaluation of the system. The model, excluding external objective environmental variables, conducts an empirical analysis on the performance of workers in 31 provinces in China from 2016 to 2020.

2. Construction of Performance Evaluation Index System of BPI System

From the perspectives of economy, efficiency, and effectiveness of BPI system [12–14], this study selects indicators such as AGD P ratio of pension insurance fund expenditure, pension insurance fund balance rate, and pension insurance coverage rate. The ratio of GDP of expenditure (Exs./G DP) [15]: this indicator reflects the strength of pension insurance participation in national income distribution.

Balance ratio (BR) of pension insurance fund [16]: this indicator reflects the sustainable development of the system, i.e., the accumulated balance of insurance fund/total expenditure of pension insurance fund.

Coverage rate (CR) of pension insurance [17]: this indicator reflects the coverage and development level of the system, i.e., the number of insured persons/the number of urban employed persons.

Pension replacement rate (RR) [18]: this indicator reflects the level of pension insurance payment, i.e., per capita pension/average wage of employees in employment.

Pension support rate (DR) [19]: this indicator measures the extent of the support burden and reflects the ability to pay, i.e., the number of retirees/insured employees.

3. Construction of Performance Evaluation Model of Basic Endowment Insurance System

As a way to analyze the relative of similar organizations, the DEA method is mainly used for the efficiency evaluation among decision-making units in a long period of time [20]. In this study, the SBM-DEA method is applied to the method with multiple inputs and multiple factors. The specific calculation steps of the three-stage SBM-DEA model are as follows [21].

Stage 1: the SBM model of undesired output proposed by Tone is used to measure the efficiency of system in each province in the first stage. Each province is a production (*DMU*). A DMU has m inputs $X = (x_1, x_2, \ldots, x_m) \in R_m^+$ and S outputs, in which S_1 has an expected output $Y = (y_1, y_2, \ldots, y_{S_1}) \in R_{S_1}^+$ and S_2 has an undesired output $Z = (z_1, z_2, \ldots, z_{S_2}) \in R_{S_2}^+$. We assume that the nondesired output Z is weakly disposable, and the desired output Y with input X is strongly disposable; then, the desired output Y and the nondesired output Z are the convex and closed sets. The possible set P is as follows:

$$P = \{(x, y, z) | x \geqslant X\lambda,\ y \leqslant Y\lambda,\ z = Z\lambda;\ \lambda \geqslant 0\}. \tag{1}$$

Equation (1) represents the weight vector of cross-sectional observations. The specific SBM model for a specific production decision unit DMU is constructed as follows:

$$\min p = 1 - 1/m \sum_{m}^{i=1} \frac{S_i^-}{x_{io}} / 1 + \frac{1}{S_1 + S_2} \left(\sum_{S_1}^{r=1} \frac{S_r^g}{y_{no}^g} + \sum_{S_2}^{r=1} \frac{S_r^b}{y_{no}^b} \right) x_0 = X\lambda + S^-,\ y_0^g = Y\lambda - S^g,\ y_0^b = Y\lambda + S^b,\ S^- \geq 0, S^g \geq 0, S^b \geq 0, \lambda \geq 0. \tag{2}$$

In equation (2), $p\,(0 \leq p \leq 1)$ denotes the efficiency value of enterprise green technology innovation, which is a strictly monotonic decreasing function of slack variables about input elements, desired output, and non-desired output; S^- and S^b denote excess of input and non-desired output, respectively, and S^g denotes the deficiency of desired output. To avoid the problem of linear programming without feasible solutions, this study uses global covariance efficiency indicators for efficiency evaluation with reference to Li Zhanfeng et al. [22]. However, even if the slack is considered, the environmental factors still have an impact on the efficiency, and then, the second stage of measurement is needed to obtain more accurate results.

Stage 2: the above calculation results consider the role of input-output slack variables, but they are also influenced by the combination of internal factors. Traditional DEA models do not distinguish between the effects of internal and external environments and random errors on efficiency values but are uniformly classified as internal effects, which is undoubtedly not an accurate analysis of the results. As the data for each DUM input and output slack are truncated at zero, this paper uses the stochastic frontier SFA model to fit the input slack and environmental variables in the first stage [23].

The amount of slack S_{ij} in the *jth* decision unit on the *ith* input is assumed to be influenced by the K observable environmental variables $Z_{ij}' = [z_{1j}', z_{2j}', \ldots, z_{Kj}']$, $j = 1, 2,$

$\ldots, n$. The regression model for the amount of slack S_{ij} and the environmental $Z_{ij}^{'}$ variable is as follows:

$$S_{ij} = f\left(Z_{ij}^{'}; \beta_i\right) + \nu_{ij} + \mu_{ij}, \tag{3}$$

where β_i is the vector of parameters to be estimated when the corresponding dependent variable is the *ith* input slack, $\nu_{ij} + \mu_{ij}$ is the mixed error term, and the statistical noise is $\nu_{ij} \sim N(0, \sigma_\nu^2)$, μ_{ij} is the effect of factors that the firm itself can control on the input slack variables, and a larger μ_{ij} means the greater the level of inefficiency of the firm, assuming that $\mu_{ij} \sim N(\mu^i, \sigma_\mu^2)$, ν_{ij}, and μ_{ij} are independent of each other. After estimating the unknown parameters with great likelihood, the initial input data are adjusted according to the following equation:

$$x_{ij}^A = x_{ij} + \left[\max\left\{z_j\widehat{\beta}_i^-\right\} - z_j\widehat{\beta}_i^-\right] + \left[\max\left\{\widehat{\nu}_{ij}^-\right\} - \widehat{\nu}_{ij}^-\right], \tag{4}$$

where x_{ij}^A is input variable and x_{ij} is the original input variable. After the above processing, all DMU will be at the same environmental level, which helps to truly reflect the DMU and facilitate the subsequent comparison of the differences among the decision-making units themselves after removing external pressure.

Stage 3: using the adjusted data instead of the original data, the efficiency is estimated using the non-expected output SBM model from stage 1. Here, the effects of environmental factors and random errors on the results are removed, and the new efficiency values reflect more accurately than the actual innovation efficiency level of the decision unit.

3.1. Indicator Selection and Processing. Referring to the practice of Yang Shuwang et al., this study selects input indicators from three aspects of labor force, innovative capital, and energy consumption [24–26]. Among them, the internal expenditure stock is accounted. The specific calculation method is as follows:

$$K_{i,t} = I_{i,t} + (1 - \vartheta)K_{i,t-1}, \tag{5}$$

where $K_{i,t}$ and $K_{i,t-1}$ denote the stock of R&D funds in province i in period t and period t-1, respectively; ϑ is the depreciation rate, which takes the value of 15% in the paper [27, 28]. $I_{i,t}$ is the actual R&D funds in province i in period t. Referring to the treatment of Zhu Pingfang et al., the *R&D* deflator = 0.45 × fixed asset investment price index +0.55 × consumer price index.

4. Empirical Analysis of the Performance of the Basic Pension Insurance System for Urban Employees

Considering that urban basic pension insurance is the most important component of the current social pension insurance system in China, this study selects the performance of the basic pension insurance system for urban workers in 31 provinces in China from 2016 to 2020 for empirical analysis.

4.1. Data Sources. According to the system, raw data are obtained from the China Statistical Yearbook and the China Labor Yearbook in 2016 and 2020, respectively, and the index values are calculated for each region in each year to construct the corresponding panel data set. The performance evaluation model of the system is used to reflect the differences and trends of basic pension insurance in each region [29].

4.2. Performance Evaluation of the Basic Pension Insurance System for Urban Workers. The performance evaluation model of the system is applied to measure the performance of the system in each province from 2016 to 2020, and the performance evaluation values of the system for workers in each province are shown in Tables 1–4.

A comparison of the performance value evaluations for the national average, the eastern, the central, and the western regions is shown in Figure 1.

4.3. Analysis of the Performance Level of the Basic System for Urban Workers in Each Province. From the performance evaluation values in Figure 2, we can see that only the performance values of Guangdong in 2016–2020, Fujian in 2016, and Xizang in 2019 are greater than or equal to 1, and the performance levels of the above regions are effective in the corresponding years relative to the performance levels of urban workers' basic pension insurance in 2016. Except for the specified regions in the above years, the performance values of the remaining regions in other years are less than 1. The performance levels are ineffective in the long term. The remaining regions all have performance levels less than 1, with Fujian, Henan, Yunnan, and Tibet having near long-term valid performance, and the remaining regions will have lower validity [30]. The results indicate that the overall performance of these provinces is poor and also suggest that the indicators still need further improvement.

4.4. Analysis of Changes and Fluctuations in the Performance of the Basic System for Urban Workers in Various Provinces. The longitudinal analysis of provinces shows that only Beijing and Guangdong show an increase in performance, while the rest of the regions basically show a year-on-year decrease. According to the average performance of each province from 2016 to 2020 in Table 1, the average performance of Guangdong, Tibet, Fujian, and other three regions is relatively high, followed by Shandong, Henan, and Yunnan, and the average performance of the rest of the regions is relatively low at 0.2–0.56.

From the horizontal comparison among provinces, it can be seen from Figure 3 that the difference between the performance values of the highest and lowest regions of the system in China in each year from 2016 to 2020 is between 0.76 and 0.97, reflecting the uneven development of the system for workers in each province in China. The gap between the relative advantages and disadvantages is more obvious.

Table 1: Performance evaluation values of the national average workers' basic pension insurance system.

	Beijing	Tianjin	Hebei	Shanxi	Neimenggu	Liaoning	Jilin	Heilongjiang
2016	0.3882	0.3904	0.6605	0.5085	0.6855	0.3420	0.3935	0.2765
2017	0.4006	0.3896	0.5871	0.4662	0.5933	0.3650	0.3620	0.2462
2018	0.4415	0.3642	0.5498	0.4425	0.5106	0.3254	0.3244	0.2336
2019	0.4324	0.3599	0.5117	0.4109	0.4527	0.3006	0.3006	0.2195
2020	0.4328	0.3351	0.4590	0.3782	0.3913	0.2604	0.2604	0.1910
Average	0.4155	0.3678	0.5536	0.4413	0.5267	0.3282	0.3282	0.2334

Table 2: Performance evaluation values of the system for workers in the eastern region.

	Shanghai	Jiangsu	Zhejiang	Anhui	Fujian	Jiangxi	Shandong	Henan
2016	0.2382	0.6373	0.8503	0.5842	1.0000	0.5753	0.8999	0.7366
2017	0.2047	0.5595	0.6085	0.5028	0.9414	0.3569	0.5069	0.6850
2018	0.1777	0.4893	0.5137	0.4976	0.8568	0.5421	0.8652	0.6874
2019	0.1757	0.4702	0.4418	0.4810	0.6894	0.4586	0.6528	0.6617
2020	0.2115	0.4328	0.3482	0.4395	0.8798	0.3586	0.5862	0.6359
Average	0.2016	0.5178	0.5525	0.4935	0.9226	0.4613	0.7339	0.6813

Table 3: Performance evaluation values of the system for workers in the central region.

	Hubei	Hunan	Guangdong	Guangxi	Henan	Chongqing	Sichuan	Guizhou
2016	0.4304	0.5534	1.0000	0.6302	0.4471	0.3156	0.3357	0.5961
2017	0.3562	0.5862	0.9562	0.5620	0.4239	0.2652	0.3071	0.5826
2018	0.3698	0.4689	0.8563	0.5892	0.3736	0.2689	0.2650	0.5613
2019	0.4520	0.5420	0.7852	0.4366	0.3589	0.2374	0.3562	0.5535
2020	0.3025	0.3958	1.4523	0.4968	0.3224	0.2456	0.1568	0.5070
Average	0.3800	0.4710	1.0844	0.6341	0.3852	0.2624	0.2718	0.5601

Table 4: Performance evaluation values of the system for urban workers in the western region.

	Yunnan	Xizang	Shanxi	Gansu	Qinghai	Ningxia	Xinjiang	Average
2016	0.6875	0.8659	0.5651	0.4909	0.4262	0.3766	0.3787	0.5571
2017	0.6952	0.9523	0.5865	0.3256	0.4563	0.3511	0.3544	0.5172
2018	0.6523	0.9976	0.5985	0.3154	0.4862	0.3466	0.3490	0.4876
2019	0.6412	1.0405	0.6521	0.3568	0.4136	0.3300	0.3453	0.4691
2020	0.5698	0.7181	0.4401	0.3252	0.3931	0.3078	0.3056	0.4271
Average	0.6408	0.9232	0.4915	0.3985	0.4142	0.3402	0.3466	

4.5. Analysis of the Regional Characteristics of the Performance of the Basic Pension Insurance System for Urban Workers. It can be seen that the regional characteristics of the performance of the worker system in China are clear: the eastern region shows a higher level than the western region. The average performance in the western region is higher than that in the central region, showing an overall pattern of high and low levels in the east. The average performance level of Yong, central, and western regions all shows a clear downward trend from 2016 to 2020, in which the average performance of boiling region is higher than the average performance level. The average performance of the system in central China has a large gap compared with that in eastern China. This also reflects that the way of economic development in the central region does not necessarily govern the level of performance of the system.

Figure 4 shows that the performance in China shows an unbalanced spatial distribution pattern. However, the above analysis does not provide enough valuable information on the spatial and temporal variation of the performance of the system for workers and its dynamic evolution. Therefore, we use the Dagum to measure the spatial variation of the performance system for urban workers and then use the kernel density estimation method to predict its dynamic evolution from the time dimension.

Compared with the traditional Gini coefficient, the Dagum and its subgroup method not only add the consideration of the subsample distribution state but also effectively solve the problem of crossover phenomenon between samples and the source of regional disparity, making the analysis conclusion more accurate [15]. The Dagum Gini coefficient is defined by the following equation:

$$G = \frac{\sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{n_j}\sum_{r=1}^{n_h}\left|y_{ji} - y_{hr}\right|}{2n^2\overline{y}}, \tag{6}$$

where G is the Gini coefficient; the larger the coefficient, the larger the gap. k is the total number of regions, j and h are two different regions within k regions, i and r are provinces

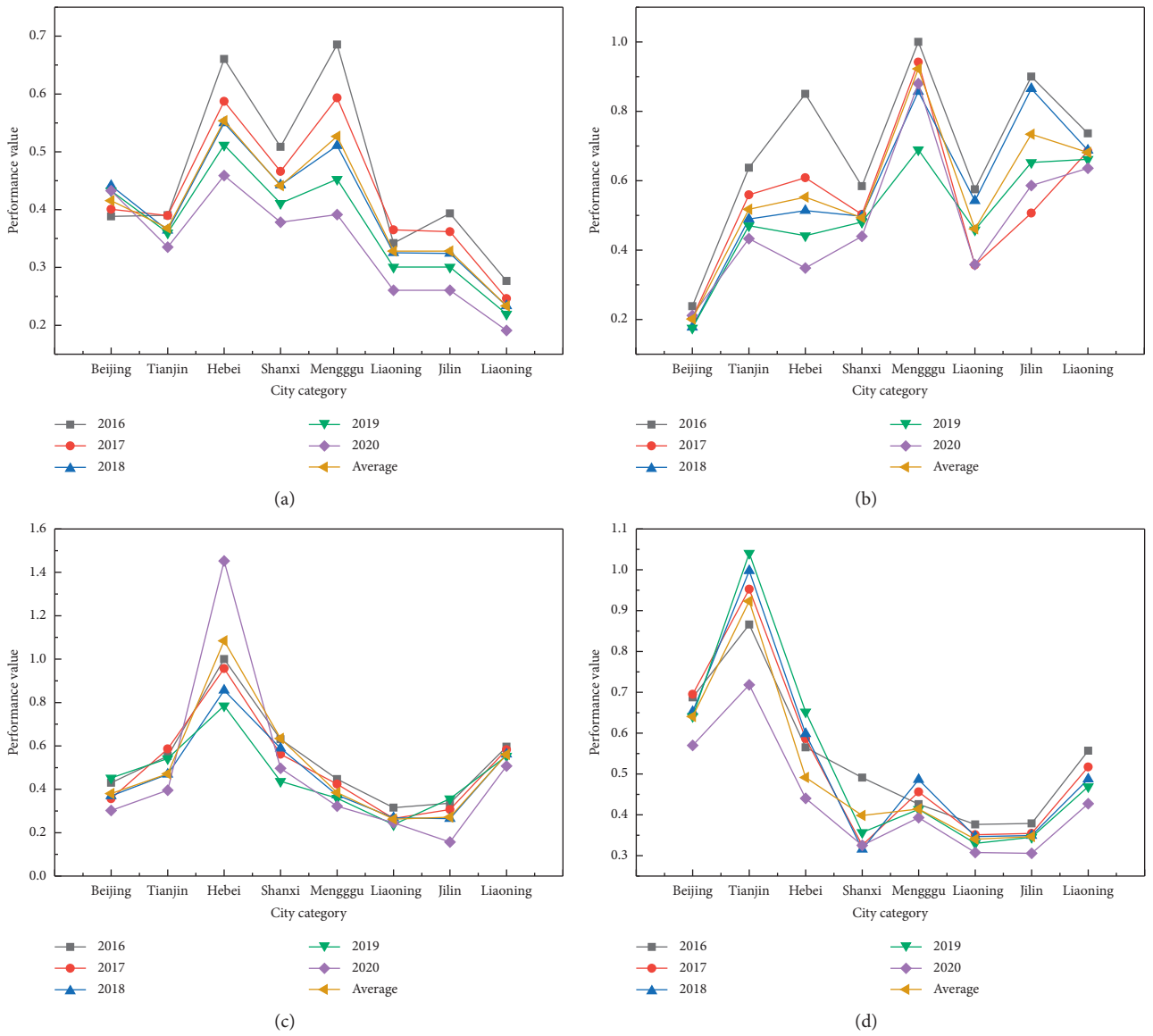

Figure 1: Comparison of performance value evaluation in different regions. (a) National average. (b) Eastern region. (c) Central region. (d) Western region.

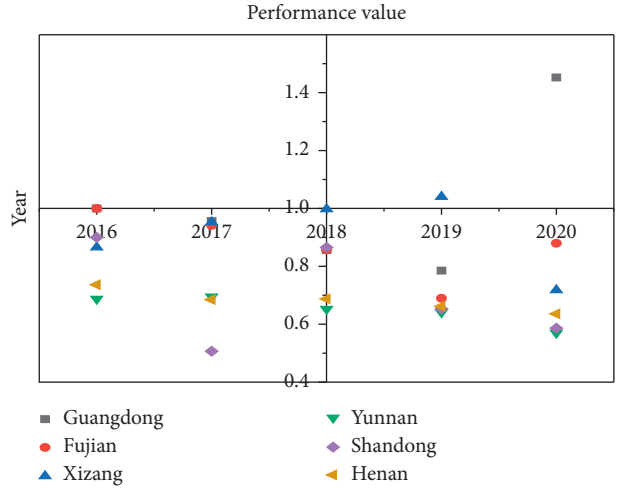

Figure 2: Comparison of performance evaluation values of employee pension insurance in multiple provinces.

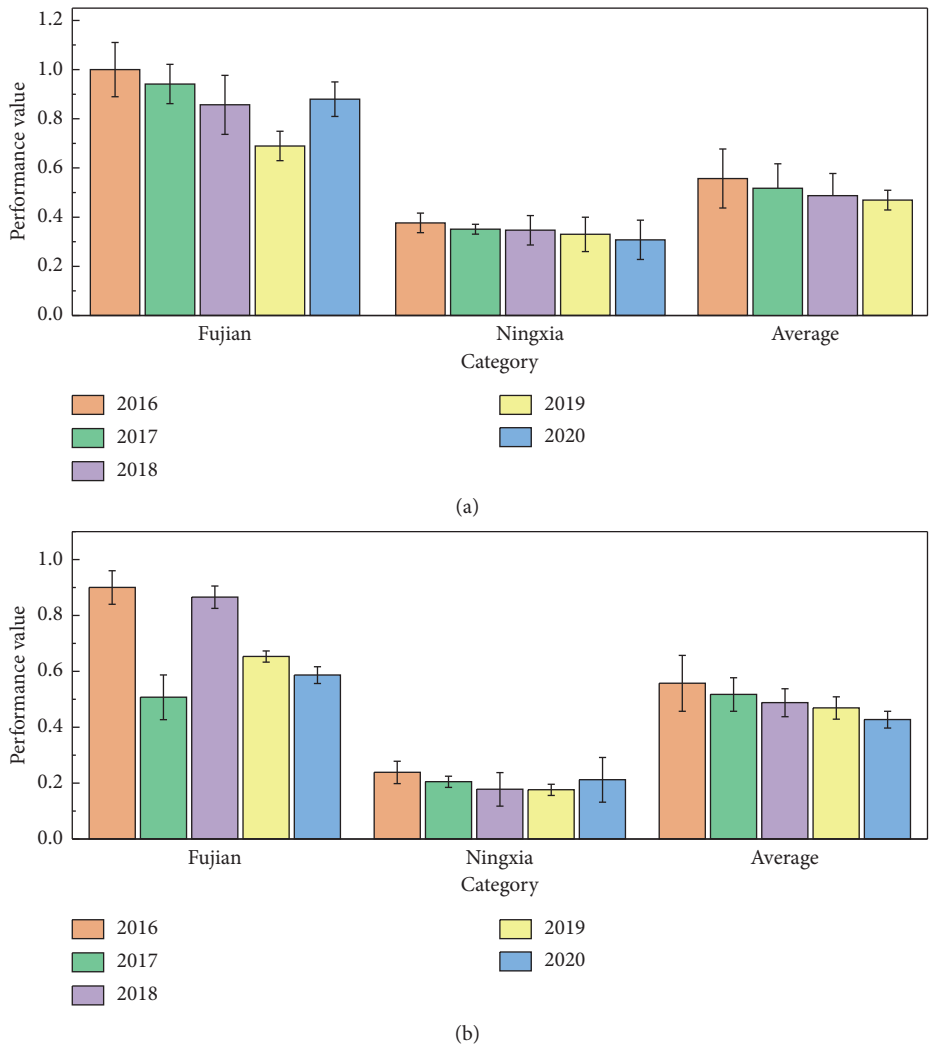

Figure 3: Comparison of performance differences in pension insurance systems among different provinces.

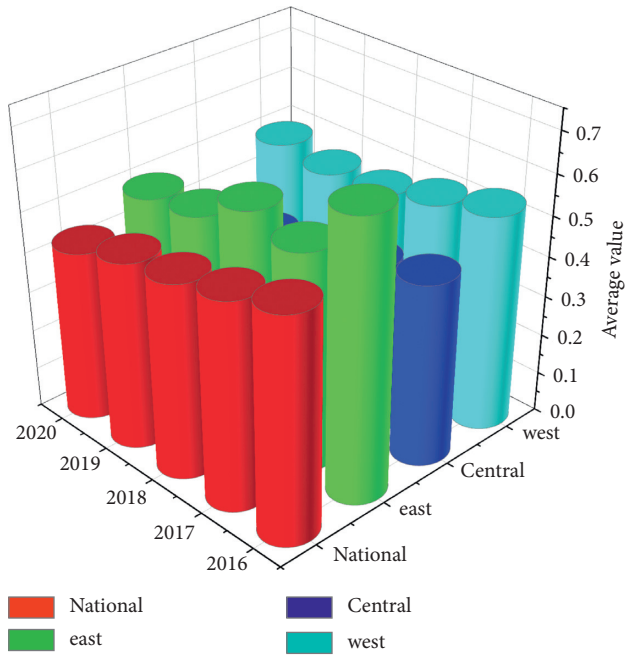

Figure 4: Comparison of the three major economic regions with the national average performance level in 2016–2020.

Table 5: Dagum Gini coefficient and its decomposition results.

Years	Interregional Gini coefficient G_{nb}			Regional Gini coefficient G_{ω}			Contribution rate (%)		
	East	Central	West	East	Central	West	G_{ω}	G_{nb}	G_t
2016	0.299	0.327	0.179	0.225	0.136	0.207	27.17	58.62	14.22
2017	0.350	0.361	0.213	0.229	0.209	0.200	26.08	57.80	16.12
2018	0.338	0.308	0.261	0.257	0.295	0.203	29.76	40.15	30.09
2019	0.236	0.237	0.234	0.144	0.227	0.235	29.19	37.52	33.29
2020	0.208	0.229	0.202	0.156	0.189	0.201	29.72	37.84	32.44

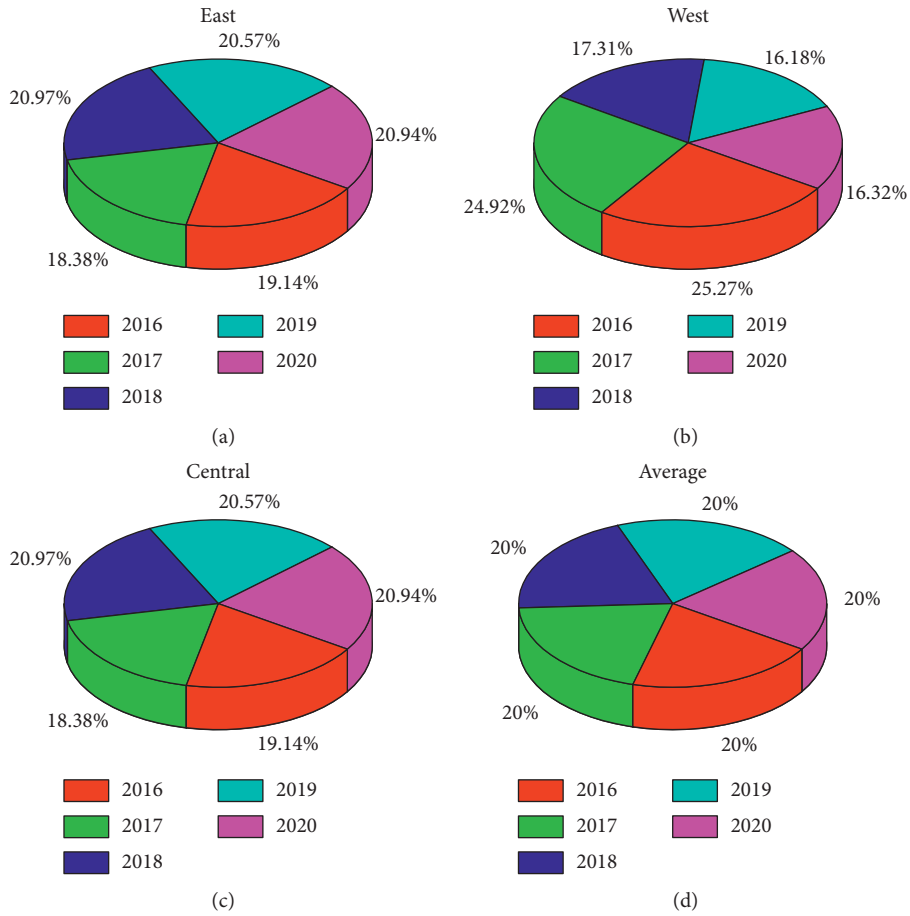

Figure 5: Comparison of Dagum's Gini coefficient and its decomposition results in pie charts. (a) East. (b) West. (c) Central. (d) Average.

within different regions, respectively. $n_j(n_h)$ indicates the number of provinces within $j(h)$ regions, $y_{ji}(y_{hr})$ indicates the efficiency of the system for urban workers in $i(r)$ provinces in $j(h)$ regions, $\overline{y}$ indicates the arithmetic efficiency of the system for workers in each province mean value. The spatial differences in the efficiency of the system for urban workers in 2016–2020 were measured and decomposed using the coefficient and method proposed by Dagum, and the calculation results are shown in Table 5.

As can be seen from Table 5, the contribution rates of the east, west, central, and national average are shown in Figure 5.

As can be seen from Figure 5: in terms of the magnitude of contribution, the contribution of interregional variation is the largest, and the contribution of super-variable density is the lowest. Among them, the contribution rate is the largest at 69.29%, the lowest at 35.45%, and the majority of years are above 50%, which indicates that interregional differences are the main source of spatial differences in the efficiency of urban workers' basic pension insurance system.

In the following, to describe the development pattern of institutional efficiency in the time dimension, the kernel density curve of its distribution pattern is estimated here using the kernel function, and the results show the dynamic evolution characteristics of institutional efficiency. The period 2016–2020 is selected as the sample observation time point, and Figures 6(a) and 6(b) represent the three-dimensional plots of kernel density for the whole country and the eastern, central, and western regions, respectively.

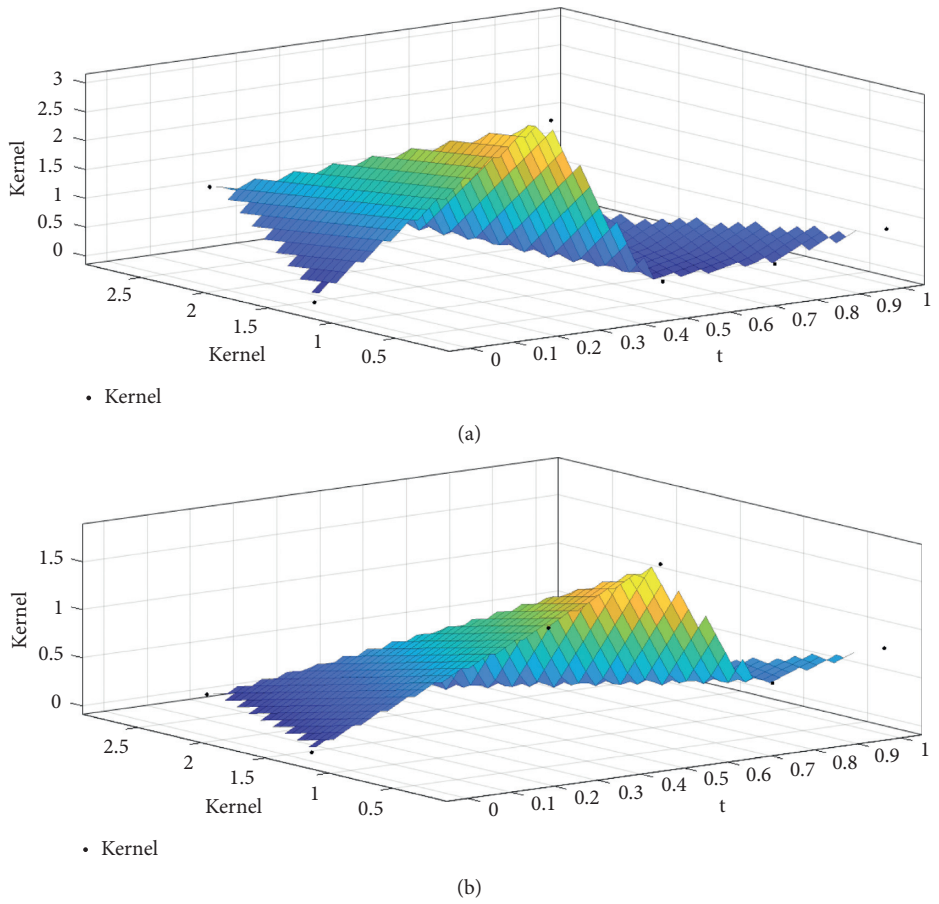

Figure 6: Three-dimensional map of nuclear density in the east-west region. (a) East. (b) West.

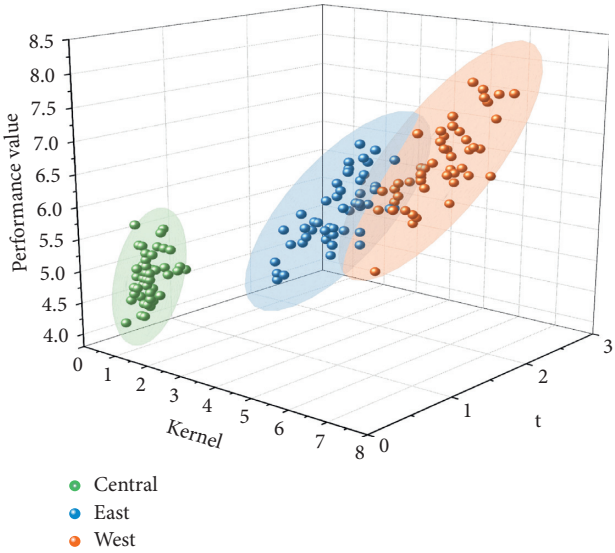

Figure 7: East, west, and central future development efficiency forecast.

The spatiotemporal divergence in the efficiency of the system for workers is very obvious as shown in Figure 6. Among them, the differences between east-central and east-west show a significant trend of narrowing in general, and the differences between central and western regions also show a small trend of narrowing. In the time dimension, the polarization of efficiency tends to slow down although it is obvious. The future development efficiency projections for the east, west, and central regions are shown in Figure 7.

5. Conclusion

This study constructs a performance evaluation model of the basic pension insurance system based on a three-stage SBM-DEA method with panel data and empirically analyses the performance of the system for workers in China. Based on the performance of the basic pension insurance system in China from 2016 to 2020, the following conclusions are obtained.

(1) The overall performance of the basic pension insurance system for urban workers in China is decreasing, and the performance is on the low side, and there is still room for further improvement of the indicators.

(2) The development of the system for workers has a large gap between the relative merits and demerits of each province, and there is an obvious unevenness.

(3) The performance of system for workers has obvious K-domain characteristics; it basically shows a pattern of high, middle, and low in the east.

(4) The performance level of each province in China is not coordinated with its economic development, and the level of economic development of the local K region does not necessarily restrict the performance development level of the basic pension insurance system.

The problems are found in the performance evaluation process, and this study puts forward the following relevant policy recommendations.

(1) Relevant departments should formulate and implement the policy of gradual delayed retirement as soon as possible to cope with the negative impact of population aging on the basic pension insurance fund, reduce the burden of basic pension insurance support, and improve the basic pension insurance performance level.

(2) We will strengthen the operation and management of the old-age insurance system, increase the collection of old-age insurance funds, expand the coverage of the old-age insurance system, adjust the replacement rate of old-age insurance, improve the security of the old-age insurance system, and further improve the basic old-age insurance system.

(3) The economy of region K should be integrated in order to promote the coordinated development of region K, bearing in mind that the pursuit of individual indicators and effects should not be pursued in isolation and that the degree of variation in absolute terms among the indicators should be rationalised.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest or personal relationships that could have appeared to influence the work reported in this study.

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Research Article

Comprehensive Evaluation Method of Teaching Effect Based on Particle Swarm Optimization Neural Network Model

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The important role of teaching evaluation system is embodied in: starting from the teaching goal and the vocational education teaching activities. This paper studies the optimization algorithm and optimization system, it not only makes the algorithm involve basic mathematical operations, and the computer support required for the data processing process is not high, but it also improves the evaluation of the degree of optimization. In view of these characteristics, this paper has conducted in-depth research to fully prove the feasibility and superiority of the content of this article. The specific summary is as follows: (1) Introduced the design concept of particle swarm optimization teaching evaluation system. (2) The use of object-oriented programming algorithms makes it easier for the algorithm to find an entry point, solve practical problems, and optimize the reusability of the algorithm method. (3) Particle swarm optimization based on quantum behavior, adjusting parameter values, the highest and the lowest, greatly reduces the difficulty of program parameter adjustment. (4) In terms of operation, it can quickly and efficiently complete the maintenance of teacher teaching information, evaluation relationship management of teacher teaching quality evaluation, evaluation content management, student evaluation, supervision evaluation, college leadership evaluation, evaluation performance management, and other operations. The interface is extremely humane. It adopts a web-style tour method. There are many types of functions, and the system includes common functions required for general teacher teaching information management and quality evaluation, and while providing various functions, it closely integrates the various actual needs of the college. The security performance is good. The system provides user name and password verification, which improves the security of the system. Database management is convenient and fast, providing a database-friendly management interface, and timely and accurate query. (5) This system adopts an object-oriented development method. During the development process, full consideration of the user's needs enabled the system to have powerful functions and streamlined procedures. In the end, this application software basically completed the goals required by the requirements analysis.

1. Introduction

At present, my country's higher vocational and technical education is developing rapidly and its scale is constantly growing. Higher vocational and technical education has become an inseparable and important part of my country's education system. The relationship between vocational and technical education and economy is the most direct and close. It has cultivated the "technical", "practical," and "applied" compound talents required by the production line. In recent years, China's vocational and technical education has made faster growth in terms of school scale, professional orientation, enrollment, and geography. How to ensure the teaching quality of vocational and technical education and train "composite" high-quality to adapt to the development of my country's social and economic construction has now been an important problem. The evaluation of teaching quality has become one of the main concerns. Although China's higher vocational education started late, the scale of development is staggering [1–5].

As in 2010, there have been more than 1500 vocational colleges of various types across the country, including those

established by some undergraduate colleges. The total number of vocational colleges exceeds 1700, where the number of enrollment and the number of students at school accounted for 60% of ordinary colleges and universities. School teaching quality is the lifeline of school survival and development. The teaching quality evaluation system is an objective, fair, and comprehensive monitoring system that can help improve the quality of vocational schools [6–8].

Classroom teaching quality is the fundamental way to the school's educational goals. Implementing teacher's classroom teaching quality on one hand helps the education department and school administrators understand the teaching progress. The capability of teachers to work directly affects the level of talent training. However, it is always a complicated and difficult process to evaluate the teaching ability level of a school. The establishment of classroom teaching quality evaluation systems for teachers in various vocational colleges has established many evaluation methods, but usually after collecting a large amount of evaluation data, data mining decision rules are adopted. Often in data processing, many problems will be faced [9–11].

Evaluation of predictive models: If it is based on different indicators, after comparing and evaluating different prediction models, the comparison results may also be different, which just shows the inconsistency of different evaluation indicators. Therefore, the evaluation of the prediction performance of the prediction model must be based on certain evaluation indicators. Under normal circumstances, people often choose a more valuable evaluation system based on actual conditions. Modern financial econometrics is mainly based on mathematical statistical models and studies and describes the characteristics and laws of financial markets. Financial markets are more complex and nonlinear, so new methods and tools need to be introduced. The financial market is ever-changing, and the evaluation of forecasting methods or systems is also varied, and a certain forecasting method can only be better than other methods for a certain period of time or under certain conditions. Therefore, how to evaluate the quality of various forecasting methods is an important issue in financial forecasting analysis. It is necessary to optimize the time and control parameters too much, and it is always difficult to control during the optimization process. Therefore, it is necessary to seek a simpler and more efficient global optimization algorithm, which is a research hotspot in the field of evaluation systems [12–15].

The particle swarm optimization (PSO) algorithm (as shown in Figure 1) is a simple and effective random search swarm intelligent algorithm. It has the advantages of easy implementation and fewer control parameters. Therefore, it has become an intelligent optimization, evolutionary calculation, and new hotspot. Now, the algorithm has been applied to medical images, stocks, videos, and so on. This research is still in its infancy, but the existing research results show that it has great feasibility in optimization processing. It can be seen that the degree of combination of swarm intelligence algorithm and evaluation optimization is an inevitable trend in the field of theoretical research and applied research.

The advantage of Hepner's fetish group: Since the particle swarm algorithm has been proposed, due to the fast algorithm calculation and easy implementation, it has attracted the attention of the international community and many scholars in the research field. Their research can be divided into: algorithm, algorithm analysis, improvement, and algorithm application [16–18].

First, Kennedy and Eberhart first proposed an improved binary PSO algorithm in 1997, which provides a structural optimization method for neural networks for the performance comparison of PSO algorithm and genetic algorithm, as shown in Figure 2. Second, in order to improve the convergence performance of the algorithm, Shi and Eberhart introduced the inertia weight to the speed term of the PSO algorithm in 1998 and proposed to dynamically adjust the inertia weight during the evolution process to balance the globality of convergence and the speed of convergence. Related scholars call it the standard PSO algorithm (StandardPSO, SPSO). Relevant scholars have carried out a detailed algorithm analysis on this through algebraic methods and have given guiding suggestions for parameter selection [19–21].

Angeline borrowed computational evolutionary algorithms in 1998 and 1999, chose the concept of hybrid power, and introduced the PSO algorithm. Eliminate the difference between particles, there will be a higher amount of particles copied by the particles, and by comparing the value of each particle, the convergence of the algorithm is improved. Lovbjerg uses the further evolution of the computer system in the PSO algorithm, such as replication, the concrete form of the crossover algorithm, and the effectiveness of the simulation algorithm through the typical test function [22, 23].

To ensure the diversity of the group, Kennedy introduces the concept of neighborhood topology to adjust the dynamic selection of neighborhoods and at the same time, introduces social beliefs to combine the spatial neighborhood with the ring topology in the neighborhood topology to increase the information exchange between neighborhoods and improve the group diversity. Lovbjerg et al. introduced the concept of subpopulation in genetic algorithm into PSO algorithm in 2001 and at the same time, introduced a propagation operator to exchange information among subpopulations. From the perspective of probability and statistics in 2004, J. Kennedy adopted a normal distribution of random perturbations in the movement of particles and adopted a neighborhood ring topology to improve the performance of the PSO algorithm. In the same year, R. A. Krohling changed the acceleration factor changes in the evolution equation from the original uniform distribution to the normal distribution and achieved certain results [24–29].

Teaching evaluation is an ancient and young subject. Countries such as the United States, Britain, and Germany started earlier. They began to use it as an independent branch subject at the end of the 19th century and gradually developed in a scientific direction. Teaching evaluation is produced with the emergence of education and develops with the development of education. The development of teaching assessment can be divided into three stages. The first stage was from the

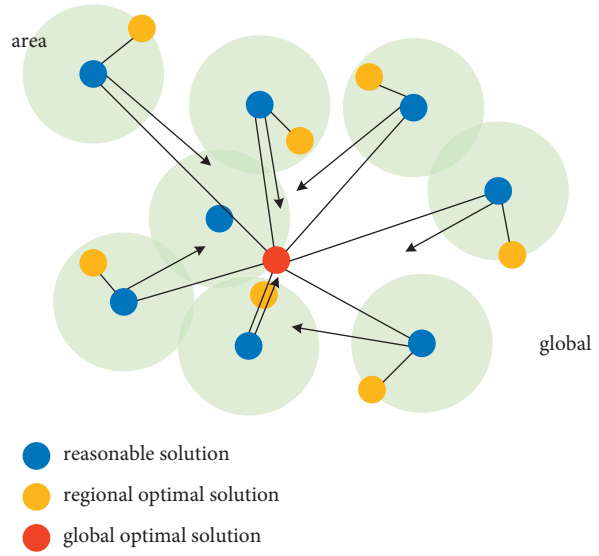

Figure 1: Particle swarm algorithm.

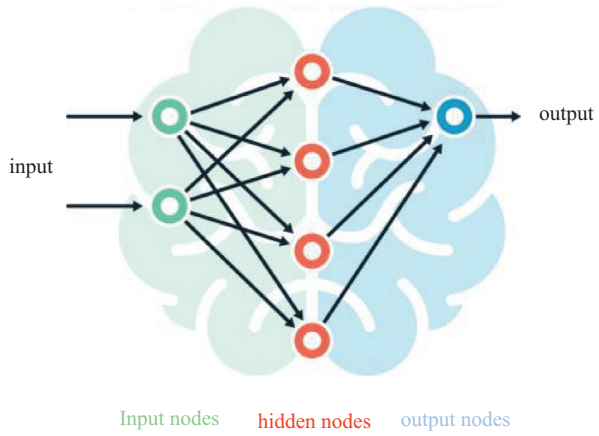

Figure 2: Neural network.

1930s to the 1950s. The characteristics of this stage are as follows: teaching evaluation theories and methods have been further enriched and developed, but teaching evaluation activities have not yet been popularized. The second stage was from the 1950s to the 1980s. During this period, teaching evaluation changed from a topic of concern to educators to a topic of concern to governments and the general public. The third stage is from the 1980s to the present. It is characterized by the evaluation methods and the introduction of new scientific methods. In the process of evaluation, people gradually began to use systematic scientific methodology to carry out educational evaluation, coupled with the use of fuzzy mathematics, data mining technology, neural network, and other technologies. There are many methods of teaching quality evaluation, among which the most common evaluation method consists of comprehensive judgment method, rating method, comment method, realistic method, and comprehensive scoring method.

In order to improve the global convergence of the PSO algorithm, ensuring the diversity of particles is the key. In order to ensure the diversity of the particles in the population during the evolution process, Suganthan introduced the concept of the space domain in the standard PSO algorithm. The particles in the same space domain were formed into a subparticle group for evolution, and the selection threshold was dynamically changed with the evolution.

2. Particle Swarm Optimization Model

Genetic algorithm, as shown in Figure 3, is an evolutionary algorithm used to solve the optimal search. The evolutionary algorithm was originally developed by borrowing gene mutation, elimination selection and hybrid evolution. PSO is an evolutionary computing technology, Eberhart and Kennedy invented from the predation behavior of birds. The PSO algorithm is similar to the genetic algorithm and is also an iterative optimization tool. A set of random solutions are generated when the system is initialized, and the optimal value is searched through iteration, but there is no mutation

of genetic algorithm crossover and mutation, and only the particles in the solution space are searched according to the optimal particles.

Using evolutionary calculation to optimize the evaluation degree of the teaching evaluation system, compared with the existing methods such as fuzzy comprehensive processing, neural network processing, weighted average processing, analytic hierarchy process, and grey relational evaluation theory evaluation, the accuracy and speed are greatly improved.

In 1995, Kennedy and Eberhart published an article regarding to particle swarm algorithm. The difference is that particle swarm algorithm, unlike other evolutionary algorithms for personal use, but the search space of each particle can be expressed by the size and weight of a certain speed. The flight speed can be adjusted according to the flight experience and flight dynamics of individuals and groups. The algorithm regards each individual as a particle in an N-dimensional search space, and adopts a velocity-position search model (N is the number of independent variables in the actual problem solving). The position of each particle is

$$x_i = (x_{i1}, x_{i2}, \Lambda, v_{iN}). \tag{1}$$

In the formula: $i = 1, 2, \Lambda, m$ is the population size.

Formula (1) is a latent solution. Its speed is

$$v_i = (vx_{i1}, v_{i2}, \Lambda, v_{iN}). \tag{2}$$

The aforementioned formula determines the displacement of the particle in the unit iteration number of the search space. PSO randomly initializes the position and velocity of m particles (m is the population size). In each iteration, the particle updates its velocity and position by dynamically tracking the two extreme values. The first is the optimal solution generated by the particle search from the initial to the current iteration number: individual extreme value:

$$P_i = (P_{i1}, P_{i2}, \Lambda, P_{iN}), \tag{3}$$

where P is the power.

The second is the current optimal solution of the particle population: the global extremum:

$$P_g = \left(P_{g1}, P_{g2}, \Lambda, P_{gN}\right). \tag{4}$$

The corresponding formula is as follows:

$$\begin{aligned} v_{id}^{k+1} &= wv_{id}^{k} + \rho_1 r_1\left(P_{id} - x_{id}^{k}\right) + \rho_2 r_2\left(P_{gd} - x_{id}^{k}\right), \\ x_{id}^{k+1} &= x_{id}^{k} + v_{id}^{k+1}, \end{aligned} \tag{5}$$

where $d = 1, 2, \Lambda, N$ is the dimensionality; $v_{i\,d}^{k}$ is the d-dimensional component of the flight velocity in the kth iteration of the ith particle, and the particle velocity νi is limited by a maximum velocity; ρ_1, ρ_2 are learning factors, which are nonnegative constants. This parameter is used to adjust the role of the particle's own experience and social experience in the movement, which means that each particle is pushed toward Pi. P_g is the weight of the statistical acceleration term at the position; w is the weighting coefficient, with a value between 0.4 and 0.9. w is determined by the following formula:

$$w = w_{\max} - \frac{w_{\max} - w_{\min}}{\mathrm{Num}_{\max}} \times \mathrm{Num}, \tag{6}$$

where $w_{\max}$ and $w_{\min}$ are the maximum and minimum values of w, respectively, and $\mathrm{Num}_{\max}$ and Num are the maximum number of iterations and the current number of iterations, respectively.

It represents the process of particles learning the experience of other particles and represents the sharing of information and social collaboration between particles. The model without the second part is called the model with only the social part. The model converges fast, but it is easy to fall into the local optimum for complex problems. Without the third part, there is no connection between individuals, and the probability of finding the optimum is low. The error is shown in Figure 4.

For convenience, this article expresses the form of the classic particle swarm algorithm as follows:

$$\begin{aligned} V_i(t+1) &= V_i(t) + c_1 r_1 \left(P_i(t) - x_i(t)\right) + c_2 r_2\left(P_g(t) - x_i(t)\right), \\ x_i(t+1) &= x_i(t) + V_i(t+1). \end{aligned} \tag{7}$$

Particle swarm optimization based on quantum behavior (QPSO algorithm) is a classic PSO algorithm, which is formed on the basis of improvement. It mainly combines the ideas of quantum physics to modify the "evolution" method (that is, update the particles in the PSO position method), the main consideration is to update the position of the particles, the specific calculation process is as follows:

The QPSO particle has the following three formulas:

$$\begin{aligned} m\mathrm{best}(t+1) &= \frac{1}{M}\sum_{i=1}^{M} P_i(t), \\ PP_{ij}(t+1) &= f_{ij}(t+1)P_{ij}(t) + \left(1 - f_{ij}(t+1)\right)P_{gj}(t), \\ x_{ij}(t+1) &= PP_{ij}(t+1) + \mathrm{Rand}(t+1)a(t+1)\left|m\mathrm{best}_j(t+1) - x_{ij}(t)\right|\ln\left(\frac{1}{u_{ij}(t+1)}\right). \end{aligned} \tag{8}$$

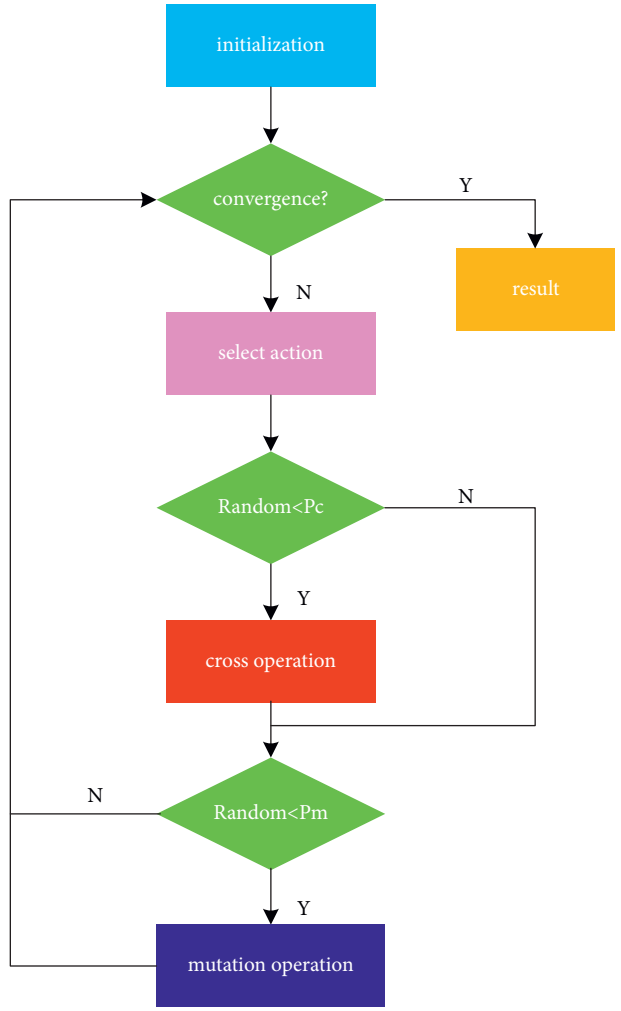

Figure 3: Block diagram of the genetic algorithm optimization program.

At the same time, this method also has some shortcomings. However, as a kind of bionic random algorithm, evolutionary calculation itself has many shortcomings. For example, the most adequate genetic algorithm in research. Although it can be used to solve complex problems, it has been difficult to overcome the shortcomings of premature convergence; genetic manipulation and evolution at the same time.

3. Detailed Design of Teaching Evaluation System

Comprehensively considering the rapid development of education and the various situations that occurred in the development of school informatization, combined with the reality of Wuxi Transportation Higher Vocational and Technical School, after the implementation of the teacher teaching information management and quality evaluation system, the following goals should be achieved:

(1) Teachers' teaching information management is informatized, and teachers' teaching information can be grasped at any time

(2) The evaluation of teachers' teaching quality is standardized and institutionalized, and all teachers are evaluated using uniform standards

(3) Teachers' teaching quality evaluation factors are targeted and detailed, and the content of the evaluation is different according to the identity of the evaluator (student, supervisor, and college leader)

(4) Provide fast, accurate, and detailed latest information on teacher evaluation results

(5) The interface is friendly and beautiful, the operation is simple and easy, and the query is flexible and convenient

(6) Through the implementation of the system, the management level of teacher information can be improved

(7) The system is easy to maintain, reliable, and safe to meet the requirements of practicability and advancement

Feasibility analysis is essential to carry out a major compression to simplify the system analysis and design process. Its purpose is to determine whether the problem can

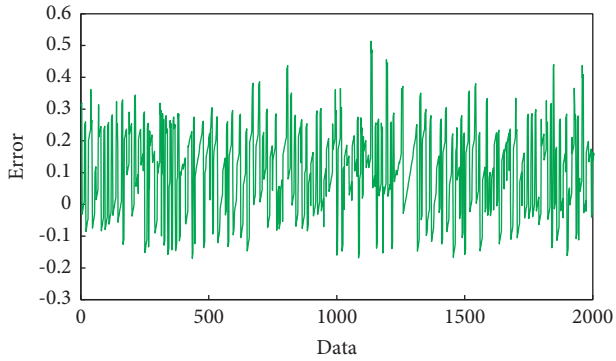

Figure 4: Error.

be solved in the shortest possible time with the least cost. Generally speaking, the feasibility of the system can be analyzed in terms of economic feasibility, technical feasibility, and operational feasibility.

Evaluate the consequences of the operation of the new system. At the same time, considering the existing personnel management issues, it is analyzed whether the development of the new system can be completed within a given time. The economic feasibility study report carried out a cost-benefit analysis, estimated the operation and maintenance cost of the new system and the future system, and the development cost. It is estimated that the new system can greatly improve management efficiency and benefits.

Measure whether the required technology is available according to the goals of the system and consider or analyze it from the performance requirements of hardware and software, environmental conditions, and operational levels. Considering the feasibility of system implementation, the software design adopts ASP.NET 2.0 and uses SQL Server 2000 database as the storage data management platform. In terms of hardware, there is a lot of room for choice, as long as it is a Pentium III series, computer memory is 128 MB or more, and the hard disk is about 300 MB, it can meet the development requirements of the system! Obviously, the higher the hardware configuration, the smoother the system will run. Considering the current overall configuration level of computer hardware, this system is feasible. In terms of software, as ASP.NET 2.0 and SQL SERVER 2000 are two very mature development tools, there is no doubt in terms of security, availability, and reliability, so the software is feasible.

In today's society, with highly developed information technology and computer technology, more and more schools realize that informatization is an indispensable step to improve management efficiency. The teachers in the school are all people who have received higher management education, and they know the importance of modern management methods to the college. For the teachers' teaching information management and quality evaluation system that will replace the manual management of teachers' information and teaching evaluation, it is even more indispensable to be equipped with modern management ideas. Therefore, on the basis of giving sufficient development funds to the system, the leaders of the college integrated modern management ideas into it, making it a management system with modern management methods.

The hardware system is a computer with Windows XP operating system. This application system is established on the basis of network system and database system, and the background of development and operation is B/S network computing mode.

Evaluate the consequences of the operation of the new system. At the same time, considering the existing personnel management issues, it is analyzed whether the development of the new system can be completed within a given time. ASP.NET2.0 is currently one of the most popular Web development tools. It provides users with a complete visual development environment and can use numerous server controls to quickly develop Web applications. In other words, ASP.NET is a server-side dynamic Web development technology. At present, there are many dynamic Web development technologies. ASP.NET's predecessor, ASP (Active Server Pages), has achieved success in the field of dynamic Web technologies with its simple syntax and embedded html method. Based on ASP, Microsoft released ASP.NET in November 2000 and officially released ASP.NET 2.0, which is more powerful and easier to use in 2005. In ASP.NET 2.0, many classes have been redesigned and implemented. In order to achieve higher development efficiency, some new controls have been added. For Web application designers and developers, ASP.NET 2.0 is an important milestone in the history of Web development.

By default, three languages can be used as scripting languages in ASP.NET applications, namely, VB.NET, JScript.NET, and C#. Among them, VB.NET is an upgrade to the VB language, JScript.Net is an upgrade to the JScript language, and C# is the native language of .NET, a brand new object-oriented programming language released with the release of .NET. Therefore, C# is the best language for programming using .NET.

SQL server is the best partner of ASP.NET. It is simple to use, powerful, and meets the performance requirements of enterprise-level data management. SQL Server 2000 uses T-SQL language and is a relational database management system according to C/S mode. The teacher's teaching quality evaluation of this system uses the quantized method. The deviation comparison is shown in Figure 5.

A university widely adopts a student online evaluation system, a teaching quality management committee expert listening system and a teacher mutual listening scoring system. How to evaluate teachers in a fair and reasonable manner. Promoting teachers is a problem that the college has been committed to solving. Using neural network to process and analyze the data can better solve this problem. The system uses the data obtained by students scoring 16 indicators of the instructor as input values. The 16 indicators are: work enthusiasm and full of energy; classroom organization; degree of seriousness of lectures; timely and patient after-class tutoring and answering questions; teaching content is correct‘ appropriate capacity and speed; the teaching content focuses on science, logic, and system; able to clarify the key points and difficulties and handle properly; integrate theory with actual conditions; inspire innovative thinking; assignments and corrections; use different methods according to teaching

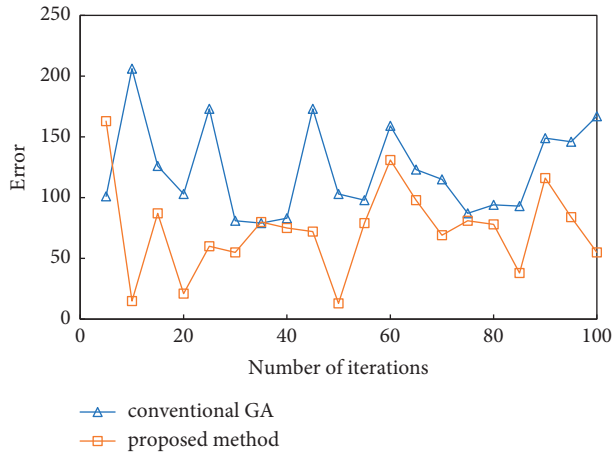

Figure 5: Error comparison.

needs; use of multimedia teaching methods; standard and vivid teaching language; clear and reasonable writing on the blackboard; able to combine teaching content and classroom discipline to educate students; teachers' compliance with discipline; and overall impression of the instructor. The output index, that is, the evaluation of classroom teaching quality uses the evaluation value of multiple experts from the teaching quality management committee after the teacher has listened to the class. The significance of using such sample data to train the neural network is that although the various indicators evaluated by the teacher are typed out by the students, the final evaluation results can reflect the evaluation ideas of the experts. According to the neural network model optimized by the aforementioned design PSO, 16 input neurons, representing 16 indicators, 8 hidden layer neurons, and 1 output layer neuron are determined. After the development of requirements analysis, design, and coding stages, the source code begins to enter the software testing stage. However, there may be some errors and defects in the software product at different stages before the test. These errors and defects need to be found and corrected in time to recover huge economic losses. Prove the correctness of the program.

4. Testing of Teaching Evaluation System

Evaluation of predictive models: if it is based on different indicators, after comparing and evaluating different prediction models, the comparison results may also be different, which just shows the inconsistency of different evaluation indicators. Therefore, the evaluation of the prediction performance of the prediction model must be based on certain evaluation indicators. Under normal circumstances, people often choose a more valuable evaluation system based on actual conditions. Modern financial econometrics is mainly based on mathematical statistical models and studies and describes the characteristics and laws of financial markets. Financial markets are more complex and nonlinear, so new methods and tools need to be introduced. The financial market is ever-changing, and the evaluation of forecasting methods or systems is also varied, and a certain forecasting method can only be better than other methods for a certain period of time or under certain conditions. Therefore, how to evaluate the quality of various forecasting methods is an important issue in financial forecasting analysis.

Low-quality software products will inevitably lead to an increase in maintenance costs and may also lead to other liability risks and loss of user credibility. At present, the correctness of the program has not been fundamentally resolved. Software testing is still the main means to find errors and defects, as shown in Figure 6 based on MATLAB.

The key to testing is the design of test cases. The white box is installed in a transparent white box, and the test fully understands the structure and process of the scheme. It designs and tests to check whether the logic path of the program works normally according to the predetermined requirements. The black box is installed in an opaque black box, and the test does not understand the structure and process of the solution. It designs and tests to check whether the logic path of the program works normally according to the predetermined requirements. The predicted results are shown in Figures 7 and 8. The rapid development of information technology has led to more and more extensive applications of software products, and the quality of software products has attracted more and more attention from people. Software developers, in order to avoid being eliminated in the fierce competition and occupying the market, must always regard product quality as an important goal of the enterprise.

As can be summarized from analyzes, the specific summary is as follows:

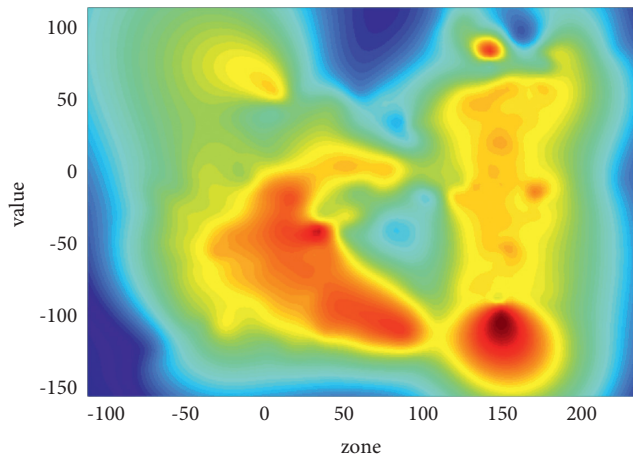

Figure 6: Value in different zones.

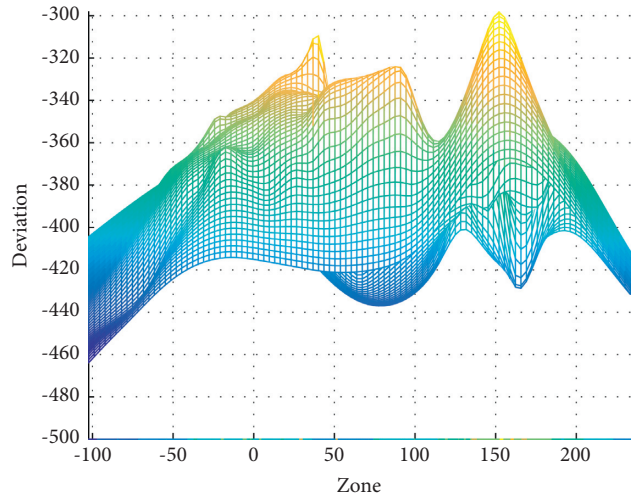

Figure 7: Deviation.

(1) Introduced the design concept of particle swarm optimization teaching evaluation system.

(2) The use of object-oriented programming algorithms makes it easier for the algorithm to find an entry point, solve practical problems, and optimize the reusability of the algorithm method.

(3) Particle swarm optimization based on quantum behavior, adjusting parameter values, the highest and the lowest, greatly reduces the difficulty of program parameter adjustment.

(4) In terms of operation, it can quickly and efficiently complete the maintenance of teacher teaching information, evaluation relationship management of teacher teaching quality evaluation, evaluation content management, student evaluation, supervision evaluation, college leadership evaluation, evaluation performance management, and other operations. The interface is extremely humane. It adopts a Web-style tour method. There are many types of functions, and the system includes common functions required for general teacher teaching information management and quality evaluation, and while providing various functions, it closely integrates the various actual needs of the college. The security performance is good. The system provides user name and password verification, which improves the security of the system. Database management is convenient and fast, providing a database-friendly management interface, and timely and accurate query.

(5) This system adopts an object-oriented development method. During the development process, full consideration of the user's needs enabled the system to have powerful functions and streamlined procedures. In the end, this application software basically completed the goals required by the requirements analysis.

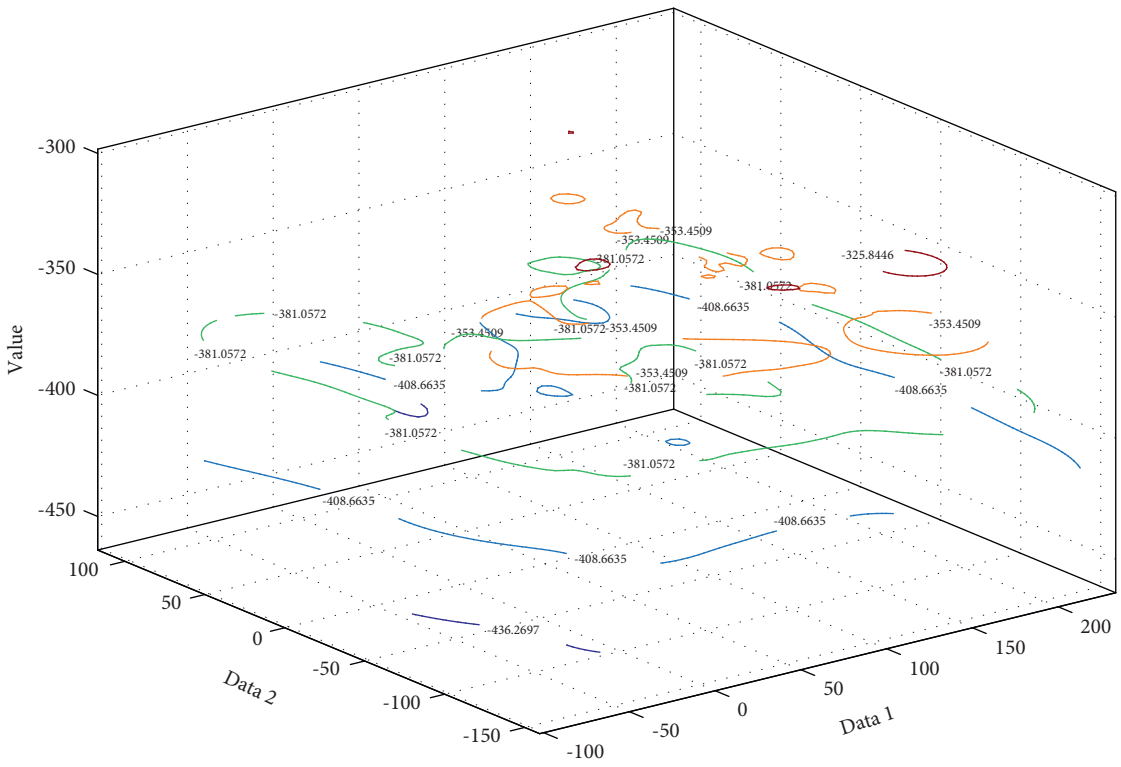

Figure 8: Value versus data.

5. Conclusion

The paper swarm optimization algorithm and optimization system not only make the algorithm only involve basic mathematical operations, and the computer support required for the data processing process is not high, but it also improves the evaluation of the degree of optimization. The specific summary is as follows:

(1) Introduced the design concept of particle swarm optimization teaching evaluation system.

(2) The use of object-oriented programming algorithms makes it easier for the algorithm to find an entry point, solve practical problems, and optimize the reusability of the algorithm method.

(3) Particle swarm optimization based on quantum behavior, adjusting parameter values, the highest and the lowest, greatly reduces the difficulty of program parameter adjustment.

(4) In terms of operation, it can quickly and efficiently complete the maintenance of teacher teaching information, evaluation relationship management of teacher teaching quality evaluation, evaluation content management, student evaluation, supervision evaluation, college leadership evaluation, evaluation performance management, and other operations.

(5) This system adopts an object-oriented development method. During the development process, full consideration of the user's needs enabled the system to have powerful functions and streamlined procedures. In the end, this application software basically completed the goals required by the requirements analysis.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Research on Efficiency in Financing of Small and Medium Companies Based on DEA Method

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At this stage, SMEs cannot survive and grow without the support of large amounts of capital, and the issue of financing efficiency has always been a bottleneck for different types of SMEs. This paper studies the financial data of relevant enterprises by constructing variable index evaluation systems such as anti-risk ability, internal management, financial system, market competitiveness, short-term debt, long-term debt, paid-in capital to property right ratio, comprehensive efficiency, pure technical efficiency, and scale efficiency and takes manufacturing, service, high-tech, and community-based small-sized and medium-sized enterprises as the research points. The DEA model is used to analyze the financing efficiency of enterprises. The results show that small-sized and medium-sized enterprises in high-tech and manufacturing industries are in the stage of increasing returns to scale. In a homogeneous environment, internal financing environment variables, total assets, asset liability ratio, debt service ratio, current ratio, and other variables have an impact on liquidity efficiency. External financing environment variables, science and technology investment, and economic level have a good and significant impact on enterprise financing.

1. Introduction

Small-sized and medium-sized enterprises are an important part of the national economy. At the same time, they play an important role in raising the level of national economic development, easing employment pressure, optimising the economic structure, and promoting social stability. As the main force of high-tech industry, Smaller and small enterprises have made some development in recent years, but they still face some difficulties and problems. The current situation of financing is not optimistic, and the low efficiency in financing has become the shackle of the development of small and medium companies. It is urgent to solve the problem of efficiency in financing of high-tech small and medium companies. Based on this, this paper will discuss the efficiency in financing of small and medium companies from the perspective of financing cost and capital use. Reviewing the relevant theoretical research on efficiency in financing, we find that the efficiency described in western economics mainly has three meanings: First, it refers to the utility expressed by the ratio of input and output and refers to the comparative relationship between cost and income. Second, it refers to whether the economic subject has brought about the rational utilization of resources in the whole society while pursuing microeconomic efficiency, and whether the allocation of resources has reached Pareto efficiency. Third, it refers to the impact of the existing institutional arrangements on the micro efficiency and allocation efficiency, as well as the efficiency evaluation of the economic system itself on this basis. The literature on efficiency in financing mainly focused on theoretical research in the early stage. There are many definitions of efficiency in financing in domestic theoretical circles. Feldman first used the concept of "efficiency in financing" when analyzing the two financing methods of direct financing and indirect financing and analyzed seven factors affecting efficiency in financing and cost [1]. Shi pointed out that enterprise financing is a

system and is closely related to transaction efficiency and allocation efficiency. Financing costs are actually composed of a variety of costs. First of all, we need to clarify what financial costs include. In short, the financial cost of the real economy mainly includes the interest and handling charges paid when receiving financial services such as credit. At the same time, these interests and service charges are the income of financial enterprises, which is used to cover various expenses for the provision of financial services—mainly including operating costs, capital costs, regulatory costs, write-down costs of nonperforming assets, and reasonable returns of shareholders [2]. If we only focus on reducing the short-term financial costs of the real economy without considering the changes in the costs related to the provision of financial services, this may lead to the contraction of the supply of financial services (such as credit), resulting in the sharp fluctuation of the financial costs of the real economy. In addition, although the income of financial enterprises is relatively explicit, many costs related to credit services are implicit and have the characteristics of unpredictable and serious postposition, which is equivalent to the functional efficiency proposed by Tobin [3, 4]. Jiny pointed out that the calculation index of efficiency in financing should at least reflect the comparative relationship between financing cost and capital use efficiency, take the comprehensive capital cost of the enterprise in the financing process as the investor, take the return on investment of the enterprise as the output, and fully consider the risk degree of financing structure and the tax credit effect of debt capital to calculate the efficiency in financing of the enterprise. Many domestic scholars tend to evaluate and analyze the efficiency in financing of listed companies by using different empirical methods. Among them, data envelopment analysis (DEA) method is relatively easy to use [5–12]. It is mainly used to analyze the relative effectiveness of multiple inputs and multiple outputs. By testing effectiveness, suggestions are put forward for invalid units. DEA method is mainly realized by DEAP 2.1 software, which is highly operable and simple.

The most common application of the DEA method is to analyse regional data (e.g., all provinces in China, districts, and towns in X province), in addition to other applications. Secondly, DEA method has a variety of models, such as BBC model, CCR model, and three-stage method. It is suitable for papers on different research topics. It is enough to find a suitable model according to the problems to be solved [13–18].

The most important thing in DEA method is to find the appropriate output index and input index. The input indicators are generally considered from the aspects of parameters such as human, financial, and resource resources. The output indicators are determined according to the research topics. Try to find existing recognized data as the output indicators. For example, to study the efficiency of e-government in each province, select the public performance evaluation results of provincial government websites as the output indicators of e-government, and select the popularity of Internet users and information infrastructure as the input indicators.

The weight in model is generated by method programming. It can meet the principle of foothold equality and has been recognized by more and more people. Zhao, Yan, Yang, and Bing used DEA method to comprehensively analyze the equity efficiency in financing of 90 listed companies initially issuing shares in the world in 2018. The research results show that the equity efficiency in financing of listed companies is generally inefficient. Ranas and Sainis make an exploratory study on the efficiency in financing of technological innovation of high-tech enterprises by using DEA model. The research shows that the efficiency in financing of technological innovation of high-tech enterprises is improved year by year, and the use efficiency of equity financing is the best. DEA is a research method of multi-index input and output evaluation. It uses mathematical programming model to calculate and compare the relative efficiency between decision-making units (DMUs) and evaluate the evaluation object. For example, there are 10 schools (i.e. 10 DMUs). Each school has input indicators (such as the per capita investment of students) and output indicators (such as the average score of students, the proportion of students' Mathematical Olympiad competition). Some schools have more investment, and some schools have less investment, but more or less investment will have corresponding output, so which school's input/output is better? The advantages and disadvantages of such input/output can be analyzed by DEA model. To put it simply, there are three people. A uses one *a* to produce one B, B uses two *a*'s to produce one B, and C uses three *a*'s to produce one B. obviously, A has the highest efficiency. We define A as the technological frontier, and A's efficiency is 1. Then, the efficiency of B is 1/2, and that of C is 1/3. Thus, we can calculate everyone's efficiency level [19–24].

2. Evaluation and Analysis Methods of Efficiency in Financing of Small and Medium Companies

(1) Analyzing multiple inputs and outputs is the most obvious advantage of data envelopment analysis. Of course, data envelopment analysis has many other advantages. There are two important links in using data envelopment analysis to construct an article. The first is the construction of decision-making unit. First, it needs to be clear that the decision-making unit is not only an entity, but also a conceptual level, such as agricultural finance, land use, and urban development. As long as you have reason and data, you can build the decision-making unit you need. For the detailed construction principles of the decision-making unit, please refer to data envelopment analysis—let the data speak for themselves by Joe Zhu. However, this does not mean that you can build the decision-making unit at will, because finally you must explain the benefits of the decision-making unit you build. If you are not familiar with the decision-making unit you build, you will have no way to start the final result analysis. Your empirical part will be disconnected from the result analysis part. The

second is the selection of input and output indicators. For the decision-making unit of the entity, the input and output indicators are actually very good to select, but for the decision-making unit at the conceptual level, the input and output indicators are more difficult to select. For example, there are many kinds of input and output indicators in the decision-making unit of "agricultural development." In this case, according to personal experience, all options are usually listed, and then data are collected to determine the final input and output indicators in combination with the availability of data. In addition, another important thing is that the number of decision-making units should be at least three times or more than the number of input and output indicators, with five times or more being the most appropriate. Joe Zhu explained this in detail in his book.

If you want to make innovations in the article by using data envelopment analysis, I think you need to make breakthroughs in two aspects. The first is the analysis dimension, which is actually the construction of decision-making unit at the conceptual level. Taking agriculture as an example, the novelty of entity decision-making units such as agricultural materials enterprises and large farms is not obvious, and the novelty of conceptual decision-making units such as agricultural finance is not obvious. Too many people have studied them, but the research on poverty alleviation, agricultural water use, and transportation construction is very popular. The second is about the application of the combination model. Those who have done data envelopment analysis will understand that with the help of DEAP 2.1 and other measurement tools, the benefit status of the decision-making unit can be calculated quickly, so its workload is not large, which is a relatively simple thing. In this case, if the research and analysis can be combined with other data models, such as Tobit, Cobb–Douglas, gray prediction, and other models, their highlights will be very prominent. At present, there are many people studying data envelopment analysis + Tobit analysis, so I think the follow-up is of little significance.

When using data envelopment analysis to write articles, I think one of the most difficult points that can reflect personal academic skills and discipline cultivation is the analysis of results and policy suggestions. The result of data envelopment analysis is a pile of cold data. How to interpret the data is particularly important. For example, the following is the result of data envelopment analysis of urban development. There were problems in pure technical efficiency and scale efficiency in 2010. Among them, pure technical efficiency is more famous. What does this mean? This requires a detailed discussion on the decision-making unit of urban development and what the technical aspects of urban development are, followed by making the corresponding result judgment in combination with the actual situation [25–28].

(2) Selection of decision-making unit (sample data) in VRS model in order to make the analysis results better reflects the overall situation of efficiency in financing of small and medium companies. This paper selects 80 listed multitype small and medium companies as the reference set, of which 41 are from Shenzhen smaller enterprise board and 24 are mainland enterprises from Hong Kong GEM. Due to the short establishment time of the SME board and the small proportion of companies listed before 2016, this paper only selects the data of listed companies in 2017 and 2018 to analyze the efficiency in financing of science- and technology-based SMEs with direct financing ability in mainland China. The 41 companies in the SME board are mainly concentrated in electronics, medicine and biology, catering services, and information technology industries. The 24 mainland companies in the Hong Kong GEM are from the "List of H-Share Companies of Chinese Enterprises (GEM)" published by the Hong Kong GEM on June 30, 2019, and are distributed in high-tech industries such as electronic and electrical appliances, medicine and pharmacy, medical and health services, Internet consulting suppliers/multimedia, computer products, and application services/software suppliers.

(3) Selection of evaluation indexes in VRS model

Investment and financing issues mainly reflect the profitability of the project, so that investors can see the return and profitability. Equity financing cost (Re) is calculated as follows:

$$\mathrm{Re} = Rf + \beta(Rm - Rf) = \text{risk} - \text{free rate of return} + \beta \times \text{rate of market portfolio}. \quad (1)$$

(4) Construction and evaluation of VRS model

According to the rule of thumb, the number of samples required to build the model is at least twice the sum of input and output items. The number of samples is more than twice the sum of input and output items, which is in line with the rule of thumb. The DEA method requires that the input and output indicators cannot be negative, and the net profit of some enterprises in the current year is negative, resulting in a negative number in the output.

Therefore, this paper determines that the efficiency in financing of enterprises with negative ROA in the current year is not effective, and its efficiency in financing value is 0. Excluding the decision-making units with negative ROA, there were 58 in 2017 and 56 in 2018.

In this paper, DEA model method is mainly used to conduct multifactor sample research to understand the impact of internal and external factors on efficiency in financing.

The basic principle of DEA model is as follows:

$$\begin{array}{l} 123 \ldots j \ldots n\, N \text{ decision} - \text{making units (DMUs)} \\ v1 x_{11} x_{12} x_{13} \ldots x_{1j} x_{1n} \\ v2 x_{21} x_{22} x_{23} \ldots x_{2j} x_{2n} \\ . \\ vi. \\ . \\ vmm x_{m1} x_{m2} x_{m3} \ldots x_{mj} x_{mm} m \text{ inputs} \\ \text{weight coefficient.} \end{array} \tag{2}$$

For each decision-making unit, DMU_j has a corresponding efficiency evaluation index:

$$\begin{aligned} h_j &= \frac{u^T y_i}{v^T x_j} \\ &= \frac{\sum_{i=1}^{n} u_i y_i}{\sum_{i=1}^{n} v_i x_i}, \quad j = 1, 2 \ldots, n. \end{aligned} \tag{3}$$

We can always take appropriate coefficients V and u so that

$$h_j < 1, \quad j = 1, \ldots, n. \tag{4}$$

For the efficiency evaluation of the J_0 decision-making unit, generally speaking, the larger HJ0 indicates that dumj0 can obtain relatively more outputs with relatively less inputs.

In this way, if we evaluate dumj0 to see whether dumj0 is relatively optimal in these n DMUs, we can investigate the maximum value of HJ0 when the weight is changed as much as possible. For example, taking the efficiency index of the J0 decision-making unit as the constraint, the following CCR (C2R) model is constructed:

$$\left\{ \begin{array}{c} \max h_{j_0} = \dfrac{\sum_{r=1}^{s} u_r y_{rj_o}}{\sum_{i=1}^{m} v_i x_{ij_o}} \\ \text{s.t.} \dfrac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x i_j} \le 1, \quad j = 1, 2 \ldots n \\ u \ge 0, v \ge 0 \end{array} \right\}. \tag{5}$$

The above planning model is a fractional planning, which uses Charnes–Cooper change to make

$$\begin{aligned} t &= \frac{1}{v^T x_0}, \\ w &= tv, \\ \mu &= tu, \\ t &= \frac{1}{v^t x_0} \Rightarrow w^t x_0 = 1. \end{aligned} \tag{6}$$

The linear programming model p can be changed into the following formula:

$$(p) \left\{ \begin{array}{c} \max h_{j_0} = \mu^T y_0 \\ \text{s.t.} w^T x_j - \mu^T y_j \ge 0, j = 1, 2, \ldots n \\ w^T x_0 = 1 \\ w \ge 0, \mu \ge 0 \end{array} \right\}. \tag{7}$$

The dual programming of programming p is programming D:

$$\left\{ \begin{array}{c} \min \theta \\ \text{s.t} \sum_{j=1}^{n} \lambda_j x_j \le \theta x_0 \\ \sum_{j=1}^{n} \lambda j y j \ge y_0 \\ \lambda j \ge 0, j = 1, 2, \ldots n \\ \theta \text{ Unbound} \end{array} \right\}. \tag{8}$$

For the convenience of discussion, calculation, and application, the relaxation factor S^+ and residual variable s^- are further introduced to change the above inequality constraints into equality constraints, as follows:

$$\left\{ \begin{array}{ll} \min & \theta \\ \text{s.t.} & \sum_{j=1}^{n} \lambda j x j + s+ = \theta x_0 \\ & \lambda j \ge 0, \ j = 1, 2, \ldots n \\ & \theta \text{ Unbound } s^+ \ge 0, s^- \le 0. \end{array} \right\}. \tag{9}$$

The above programming (d) is directly defined as the dual programming of programming (P).

The above is the calculation principle of DEA method. The following can be further understood through the whole calculation flow field, as shown in Figure 1.

3. Efficiency in Financing Theory

3.1. Meaning of Efficiency in Financing. Efficiency, in short, is the input or output in unit time and unit space. Different scholars have different definitions of efficiency in financing. Some scholars believe that efficiency in financing refers to the convenience of enterprise financing, financing cost, financing risk, and other indicators. Some scholars also believe that efficiency in financing refers to

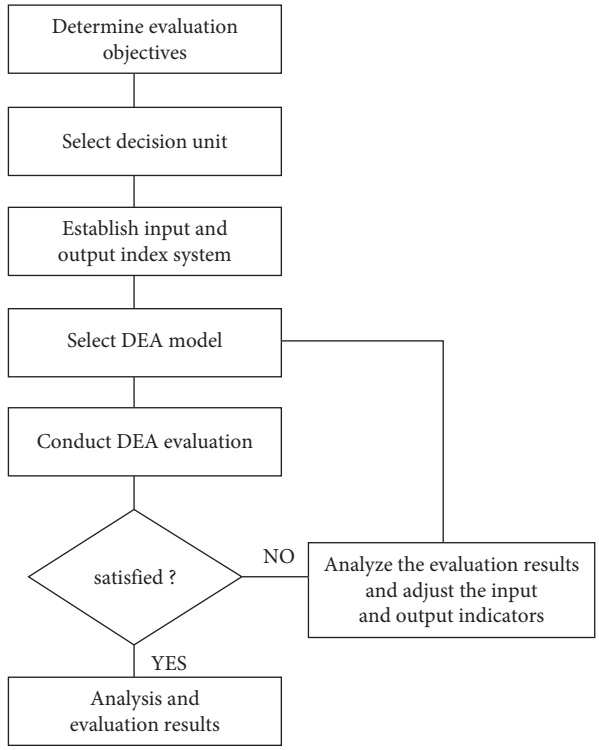

Figure 1: Calculation flow of the DEA model.

the change of enterprise capital structure in the financing process; pay attention to the utilization efficiency of funds and the improvement of operating efficiency; and mainly investigate the relevant costs, benefits, and risks of financing; the core of the analysis is capital cost and leverage efficiency. This paper holds that the efficiency in financing of small and medium companies is the evaluation of financing input and output of small and medium companies in a certain time and space. The evaluation of efficiency in financing of small and medium companies mainly includes financing cost, financing mechanism, financing freedom, and financing profit.

3.2. Evaluation Indicators of Efficiency in Financing. The evaluation indicators of efficiency in financing mainly include the following five aspects.

3.2.1. Financing Cost. The cost of financing is the cost that a business has to pay when it raises capital. This cost represents the rate of return of capital. When choosing financing mode, enterprises give priority to the level of financing cost.

3.2.2. Standardization of Financing Mechanism. The standardization of the financing mechanism can also be said to be the maturity of the capital market. The capital market with standardized mechanism often has more financing channels, less risk, and relatively high efficiency. It is difficult to quantitatively describe the financing standardization. Generally speaking, the financing mechanism can be investigated from several aspects, including policy, bank enterprise relationship, information openness, and whether there is ownership discrimination.

3.2.3. Capital Utilization. The evaluation of enterprise fund utilization rate is mainly carried out from two aspects: fund availability rate and fund utilization rate. The capital in place rate refers to the ratio between the amount of funds already raised and the expected amount of financing funds. The higher the capital in place rate, the more successful the financing of the enterprise. Among the different ways of financing a business, endogenous financing is the most efficient. The financing methods in the stock and bond markets will be undersubscribed, and the financing through bank loans will also be unable to obtain full loans. Fund utilization refers to the ability of financing enterprises to effectively digest funds. Capital utilisation is positively correlated with financing efficiency. Therefore, the higher the fund utilization rate, the higher the efficiency in financing.

3.2.4. Freedom of Financing Subject. Generally speaking, the greater the constraint, the lower the degree of freedom and the lower the final efficiency in financing. From the current financing subject in China, internal financing is less constrained by the outside world, and stock financing is mainly affected by shareholders. Therefore, it has a greater degree of control over funds, while creditor's rights financing is more constrained by creditors. If the bank loans financing now, there are very many constraints, so in general the freedom of debt financing is relatively low.

3.2.5. Financing Risk. Avoid filling out loan contracts roughly. If the purpose and use of the loan in the loan contract are not filled in correctly, the enterprise will be required to repay the loan at any time. In addition, the legal representative and operator of the enterprise still have the legal risk of committing the crime of defrauding loans. It is suggested that enterprises should strictly review the loan contract and treat the non-format part of the contract carefully.

Avoid the invalidity of the bill due to the defects of the recorded items. When the bill lacks or does not comply with the provisions, this may lead to the invalidity of the bill and affect the normal financing of the enterprise. It is recommended that enterprises fully understand the items that must be recorded when issuing bank acceptance bills, such as the words "bank acceptance bill," the entrustment of unconditional payment, the determined amount, the name of the payer, the name of the payee, the date of issuance, and the signature and seal of the drawer. In the absence of any of the above particulars, the bill of exchange shall be null and void. The bank acceptance bill shall be issued by the depositor who opens a deposit account with the acceptance bank.

Loan guarantee refers to the legal act that the bank requires the borrower to provide guarantee to ensure the realization of loan creditor's rights when issuing loans. Loan guarantee, like contract guarantee, includes guarantee, mortgage, and pledge.

Mutual guarantee loan means that two enterprises guarantee each other to obtain loans, bear the guarantee responsibility equally, and apply for loans from financial institutions. This kind of loan method is a financing tool that can obtain large loans without mutual credit guarantee of real collateral.

Joint guarantee loan refers to the loan granted by the bank to any member of the joint guarantee group after multiple natural persons or small enterprises without direct relatives voluntarily form a joint guarantee group.

Avoid the risk of borrowing new and returning old. Both parties of the loan contract agree to repay the old loan with the new loan. As the guarantor of mutual insurance and joint insurance, the guarantor may still bear the guarantee responsibility for the new loan by issuing the consent letter or receiving the notice of borrowing and repaying the old loan. It is suggested that when providing guarantee for others, enterprises should fully consider whether they are willing to bear the guarantee liability for new loans.

Avoid illegal external guarantee. An enterprise's investment in other enterprises or providing guarantee for others shall be decided by the board of directors or the shareholders' meeting (general meeting) in accordance with the provisions of the articles of association. However, the current law does not stipulate that the external guarantee provided by an enterprise in violation of internal procedures shall be deemed invalid; that is, the enterprise still needs to bear the guarantee responsibility.

Avoid providing guarantee for loan contracts suspected of violating laws and regulations. In reality, borrowers often provide false materials or forge materials to defraud bank loans, which constitutes a crime. Enterprises as guarantors still have the risk of bearing guarantee liability. It is recommended that guarantee is provided for others, especially for enterprises in mutual insurance and joint insurance. When negotiating loans with bank staff, they should try to follow the operating specifications and workflow to avoid participating in the production or submission of false materials. In mutual insurance and joint insurance, if bank staff or other enterprises require or imply that they can make loans only by making fraud and are unwilling to bear risks, they will explicitly refuse and retain relevant evidence.

Avoid senior executives taking responsibility for loans in the name of the enterprise. The person in charge directly responsible for the enterprise pledges the loan in the name of the unit and takes the loan as his own, and the enterprise cannot avoid bearing the repayment responsibility. For enterprises, the most effective preventive measure is to improve the corporate governance structure to ensure its effective operation. Ensure that the business license, organization code certificate, other licenses, property registration form, account opening license, production related qualifications, business status of the main body, and financial statements of the enterprise must indicate its purpose. If it is necessary to affix the official seal, the official seal management personnel shall verify it.

Private financing is a channel and means to obtain monetary funds by paying relatively high interest, which is different from financing from legal financial institutions. Some private small and medium companies have limited funds from formal financial institutions due to their small scale and credit problems. Therefore, they have to choose financing channels other than formal financial funds, and private financing came into being in small and medium companies. After the emergence of private financing, it has played an important role in alleviating the financing difficulties of small and micro enterprises, but there are also problems such as uneven financing institutions and easiness of causing financial risks.

Avoid listing failure. For example, due to obvious doubts about the authenticity of income, significant financial irregularities, or inability of industries or companies requiring special qualifications to obtain qualifications, the enterprise may fall into a financial crisis due to excessive financing expenses in the early stage.

The preventive method is that enterprises should understand the local policy guidance before determining to carry out the financing of the new third board. If the local government promotes the listing of enterprises on the new third board, they should understand the conditions and amount of subsidies issued by the local government. In addition, before considering the listing and financing of the new third board, enterprises should compare various intermediaries to avoid affecting their listing due to the rectification of intermediaries.

Avoid the financing effect falling short of expectations. Although the enterprises are listed on the new third board, the transactions are cold. For example, some enterprises have been listed for more than a year, but there are few transactions. The consequence is that the enterprises cannot

achieve the purpose of financing; not only can they not obtain capital support, but they also spend unnecessary costs. It is recommended that enterprises determine their positioning before determining the financing of the new third board, reasonably evaluate the quotation in the financing roadshow promotion, and carry out necessary promotion after listing.

The whole financing and influencing factors can be as shown in Figure 2.

How do the evaluation indicators reflect the efficiency in financing? For the enterprise itself, they are anti-risk ability, internal management, financial system, and market competitiveness. Specifically, what are the impacts of these four factors on different enterprises. By analyzing the relevant data, we get the results shown in Figure 2.

It can be seen from Figure 3 that the management of high-tech is relatively strict, but the anti-risk ability is relatively weak, and the market competitiveness is very high. The manufacturing industry as a whole is relatively stable, but it also has market competitiveness. For service industry and community enterprises, it is very stable and has high resistance to risks.

Further analysis and research on anti-risk ability are mainly reflected in asset liability ratio, debt service ratio, and current ratio.

$$\text{Asset liability ratio} = \frac{\text{liabilities}}{\text{assets}} \times 100\%. \tag{10}$$

It can reflect the proportion of liabilities. If an enterprise's debt level is already high, you can also compare it with its historical data to see if there is any change and what its profit was when it was in high debt in the past.

$$\text{Cash flow ratio} = \frac{\text{net cash flow from operating activities}}{\text{current liabilities}}. \tag{11}$$

The debt service ratio is to divide the relatively stable corporate profits by the debt level that must be paid. It has a greater reference value than the asset liability ratio. The mystery lies in the word "must." As a natural person, you should always consider repaying the principal and interest on loans, but as an enterprise, if your premise is to operate forever, you do not have to consider paying off the debt at all. You can borrow new debt and repay the old debt. Therefore, to identify a company's good or bad, you only need to look at how much debt it must pay.

$$\text{Current ratio} = \frac{\text{current assets}}{\text{current liabilities}} \times 100\%. \tag{12}$$

Current ratio measures the ratio between current assets and current liabilities. Current assets are assets that can quickly realize, that is, to see whether the money that can be taken out immediately is enough to pay off the debt that needs to be paid immediately. For companies with good market performance, you do not need to pay much attention to this indicator, because even if you cannot afford to pay back the money at the moment, some banks will be willing to provide loans. However, for those enterprises with difficult days and great competitive pressure, we should pay attention to the change of this ratio at any time. After processing the data, we can get the impact of different types of small and medium companies on asset liability ratio, debt service ratio, and current ratio, as shown in Figure 4.

Figure 4 clearly shows that the assets of high-tech enterprises are in a high operation state, which helps to accelerate the efficiency in financing. The manufacturing industry can accelerate the asset flow due to the ability of rapid manufacturing and sales, which can also realize the capital flow, which is conducive to financing. The other two enterprises have too slow financing due to too slow asset flow.

On this basis, this paper studies and compares the asset liability ratio, debt service ratio, and current ratio of different enterprises in different levels of cities, as shown in Figures 5–7.

Through Figures 5–7, it can be seen that high-tech, manufacturing, service, community, and other enterprises at different urban levels show a high trend in first-tier cities, and high-tech and manufacturing enterprises show a high value. This also has a very important impact on the financing time and efficiency of enterprises. Previous scholars' research on the influencing factors of enterprise efficiency in financing is mostly limited to the impact of a single external environment or enterprise internal environment on efficiency in financing, with less empirical research on enterprise internal and external financing environment at the same time. Enterprise efficiency in financing should be affected by both external financing environment and internal financing environment. The external financing environment indirectly creates opportunities for enterprise financing, while the internal financing environment directly affects the efficiency in financing of enterprises. To sum up, we can understand that external factors and internal factors are jointly composed. We introduce the financing time and efficiency of different enterprises to further understand the financing situation of each enterprise, as shown in Figure 8.

In order to fully understand the financing situation of various enterprises under the condition of multiple factors, here we take the multifactor research parameters of different types of enterprises as an example, use DEAP software to solve the linear programming problem of DEA model, sort out the evaluation results under the influence of the parameters of small and medium companies, and get Table 1.

It can be seen from Table 1 that high-tech enterprises are obviously higher in debt than other enterprises, but their financing efficiency in technology is much higher than that of other enterprises. The scale efficiency is also relatively large, but the overall paid-in capital to property right ratio is relatively high and stable. The debt is also relatively small and relatively stable as a whole. We can get the comparison of efficiency in financing under the influence of multiple factors shown in Figure 9.

Through Figure 9, we can see the peak changes of enterprises under different factors. This change shows the actual impact on efficiency in financing. In view of these situations, we can achieve more efficiency improvement through special schemes. Recommendations will be made in the next section.

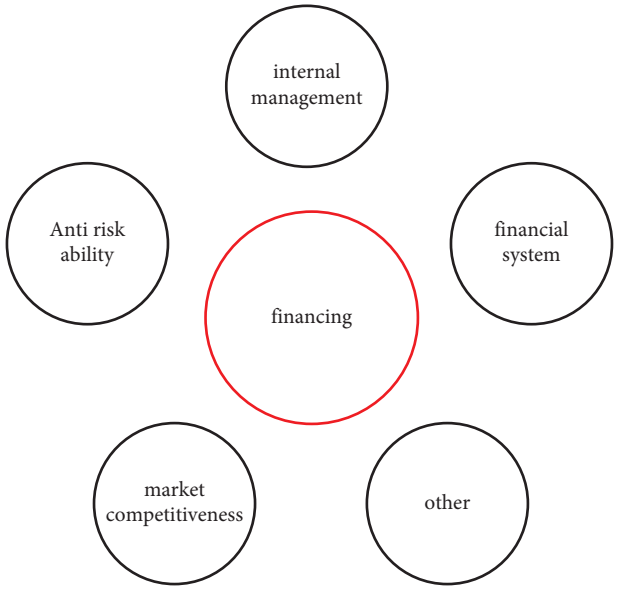

Figure 2: Financing and influencing factors.

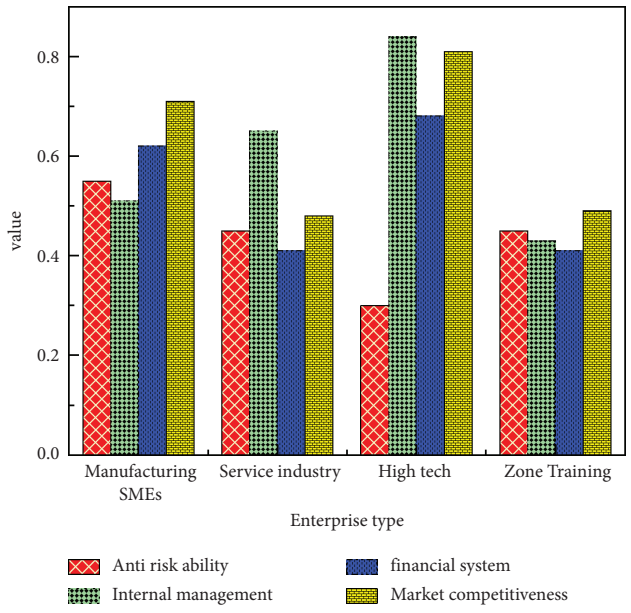

Figure 3: Financing factor values of different enterprises.

3.3. Suggestions on Efficiency in Financing of Small and Medium Companies

(1) Improve strength of high-tech small and medium companies. Medium and small high-tech companies should optimize the financing structure, reduce the debt level, broaden financing channels, and optimize the corporate governance structure, so the efficiency in financing will be improved. Increasing the main business income of the enterprise will contribute to the sustained and stable growth of the enterprise profit. The growth of the enterprise profit will certainly enable the enterprise to have more idle funds for reinvestment and other capital investment in the main business such as expanding the enterprise scale, so as to continuously expand the enterprise profit and form a virtuous circle conducive to the development of the enterprise. At the same time, it can also improve the core competitiveness of enterprises, enhance the growth of enterprises, and directly contribute to the improvement of enterprise efficiency in financing. As a high-tech smaller enterprise, we must also strengthen technological innovation and improve the high-tech content of products. Under the condition of market economy, technological innovation with the development of new products and the application of new

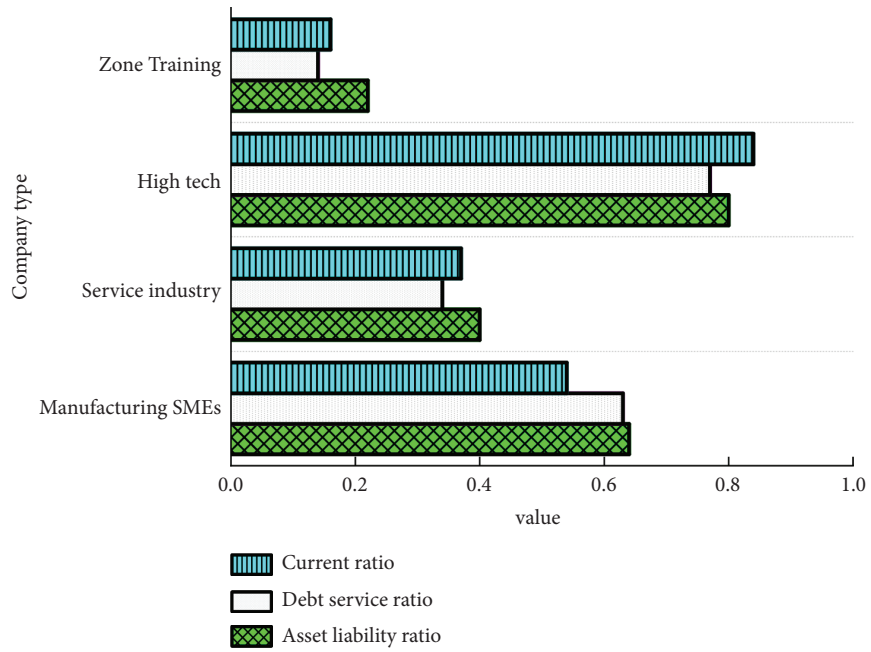

Figure 4: Asset liability ratio, debt service ratio, and current ratio of different enterprises.

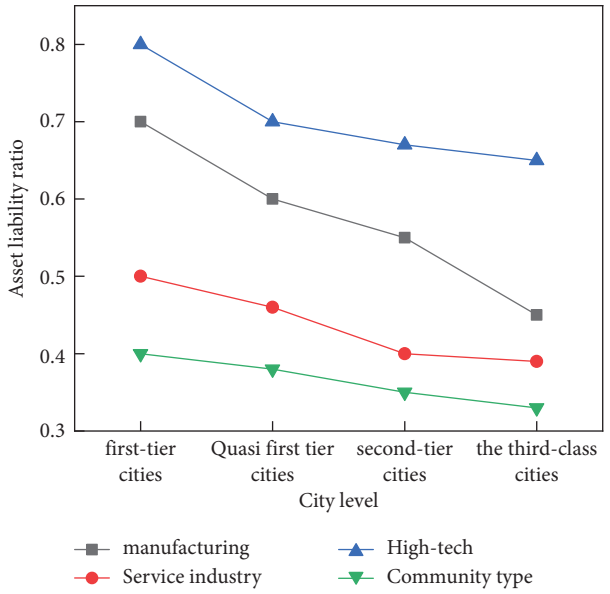

Figure 5: Asset liability ratio of various industries in different cities.

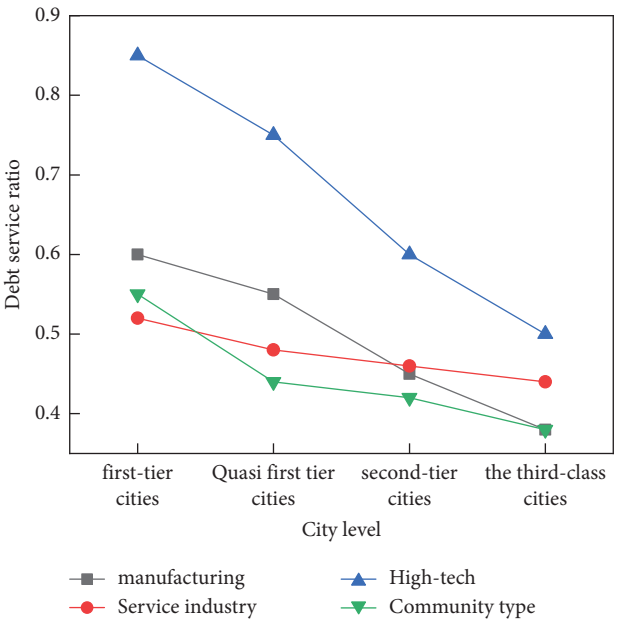

Figure 6: Debt service ratio of various industries in different cities.

technologies as the main content is the key to the accelerated development of small and medium companies. Small and medium companies should constantly increase investment in technological innovation and accelerate the renewal of technical equipment, the transformation of process, and the improvement of personnel quality, so as to improve the high-tech content of products, occupy a larger market share, and ensure the growth of main business income.

(2) To create a good external financing environment, the state should introduce policies to further encourage and support the development of smaller financial institutions, improve the indirect financing market for small and medium companies, and provide more financial support for small and medium companies. At present, the development of small and medium companies urgently requires more smaller financial institutions to meet their increasing capital needs and make up for the lack of financing support from

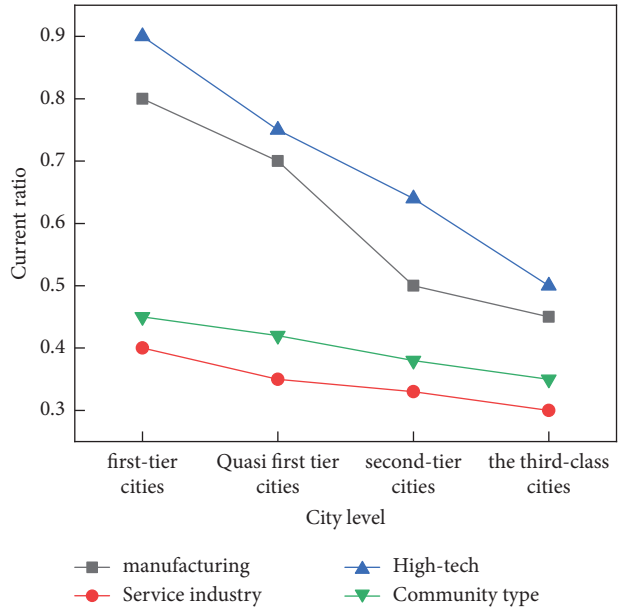

Figure 7: Current ratio of industries in different cities.

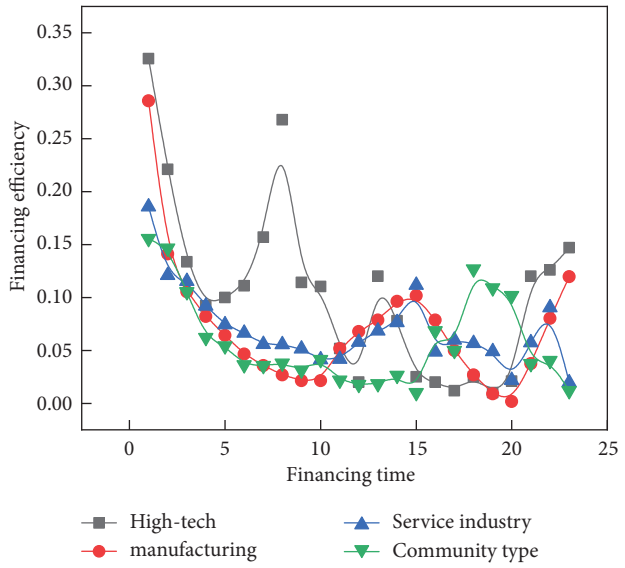

Figure 8: Time curve of efficiency in financing of each enterprise.

Table 1: Changes in different enterprises under multiple factors.

Enterprise type	Short-term liabilities	Long-term liabilities	Paid-in capital to equity ratio	Comprehensive efficiency	Pure technical efficiency	Scale efficiency
Manufacturing SMEs	0.2	0.1	0.5	0.2	0.3	0.5
Service industry	0.1	0.2	0.4	0.2	0.05	0.1
High-tech	0.3	0.3	0.3	0.5	0.6	0.4
Community type	0.1	0.2	0.2	0.1	0.1	0.1

large financial institutions. Smaller financial institutions have low transaction costs and strong risk control ability. Most smaller financial institutions and small and medium companies have regional direct dependence. The problem of serious information asymmetry of science- and technology-based small and medium companies can be solved. The state should consider developing a multi-level capital

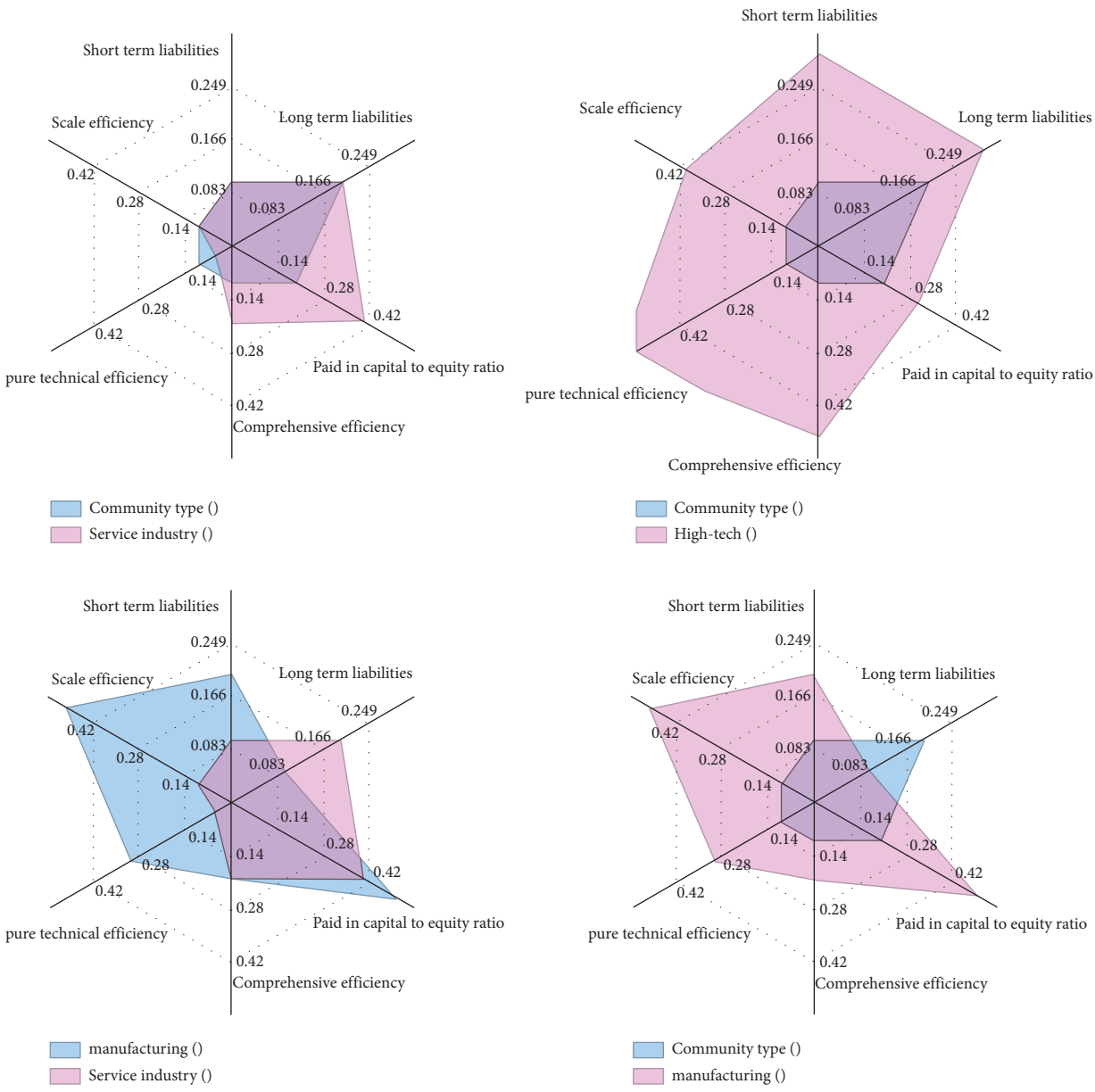

Figure 9: Impact of enterprises under multiple factors.

market, provide direct financing space, and encourage small and medium companies to go public and issue bonds for financing. There is room for direct financing as opposed to indirect financing, and this reduces the risk to society as a whole. Establishing a perfect credit guarantee system can establish a good relationship between small and medium companies and banks, improve the credit degree of small and medium companies, and promote the reform and development of China's credit system. The economic leverage effect of credit guarantee system in the allocation of social resources can reduce the cost of loans for small and medium companies and help to solve the problem of difficult loans for small and medium companies.

4. Conclusion

By using DEA model to calculate the financing efficiency of small-sized and medium-sized enterprises under multiple factors, this paper studies the impact of internal and external financing environment and related factors on enterprise financing efficiency and draws the following conclusions: The factors affecting the efficiency of SME financing are influenced by, among other things, the relationship between financing efficiency and the economy. External financing environment and random factors have a significant impact on the financing efficiency of science- and technology-based small-sized and medium-sized enterprises. The high level of economic development can accelerate the financing efficiency of enterprises, and the investment of government scientific research funds also

has a significant impact on the financing efficiency of enterprises. Enterprise internal financing environment plays an important role in enterprise financing efficiency. Relevant factors will promote the improvement of enterprise financing efficiency, and the increase of the proportion of current liabilities in the debt structure will have a negative impact on enterprise financing efficiency.

At the same time, enterprises should also pay attention to the following:

(1) For the integration of funds and sales collection, corresponding supporting arrangements should be made to make the capital flow efficiency better. However, in terms of investment, we should reasonably deal with some mortgage or project installment relations in order to really achieve better financing management and bring higher and higher capital efficiency.

(2) In the process of realizing cash flow sharing, we should reasonably grasp and manage the financing cost and form a reasonable scale. Remember, financing is for the operation of the company, not for financing. The primary and secondary relationship between the two should be clarified. Therefore, in the management process of regional companies, some people believe that it is necessary to grasp all aspects of management measures.

(3) In terms of financing management, it is necessary to formulate corresponding financing planning, and its enterprise credit management should be more professional and reliable. Standing at the strategic height of the enterprise and analyzing it as a whole, we find that it plays an irreplaceable role in the development of the enterprise. In terms of financing standards, we should continue to establish them to truly form financing evaluation rules.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Retraction

Retracted: Analysis of Performance Evaluation Model for Higher Education Informatization by Means of PLS-BP Model

Discrete Dynamics in Nature and Society

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope

(2) Discrepancies in the description of the research reported

(3) Discrepancies between the availability of data and the research described

(4) Inappropriate citations

(5) Incoherent, meaningless and/or irrelevant content included in the article

(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] K. Dong, D. Zhang, X. Liu, and D. Guo, "Analysis of Performance Evaluation Model for Higher Education Informatization by Means of PLS-BP Model," *Discrete Dynamics in Nature and Society*, vol. 2022, Article ID 9239812, 12 pages, 2022.

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Research Article

Analysis of Performance Evaluation Model for Higher Education Informatization by Means of PLS-BP Model

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In order to improve the intelligent level of higher education informatization, a novel performance evaluation model of higher education informatization by means of PLS-BP model is proposed. The principles of partial least squares (PLS) method and back propagation (BP) neural network are introduced firstly. The main components of the data are extracted by PLS method, and then combined with BP neural network, the PLS-BP model is constructed. At the end of the article, the PLS-BP evaluation model is simulated and analyzed. From the comparison results, the error between the PLS-BP evaluation model and traditional performance evaluation is relatively small, and the maximum relative error is 2.32%. The comparison results verify the accuracy of the PLS-BP model. This model presented in this paper provides a new way for the performance evaluation of higher education informatization.

1. Introduction

Higher education can serve science and technology and promote the rapid development of economy and society. At the same time, it can provide human resources for social development. In addition, higher education can provide an educational resource platform, which is conducive to the improvement of comprehensive national strength [1]. The informatization of higher education is the only way for all countries in the world to meet the challenges of the knowledge economy and realize the modernization of education [2, 3]. Meanwhile, the informatization of higher education is also a significant index to measure the comprehensive strength of education [4, 5]. Education informatization is the basis and conditions for establishing a learning society [6].

The focuses of the future development of education informatization are how to achieve the further integration and coordinated development of education [7]. For this goal, the evaluation of education informatization level must be gradually changed from "investment-based" to "performance-based," and the application and development of education informatization must be promoted through the performance evaluation of education informatization [8–10].

The research on performance evaluation is earlier, and the results are relatively significant. Benson et al. [11] evaluated the operation capacity of the education financial system based on the distribution of education resources, the efficiency of education resource distribution, and whether the provision of education services is sufficient. Ho et al. [12] selected data from 48 states in the USA as a sample, conducted regression analysis, and conducted a research and analysis on the economies of scale of college education. Zhang [13] evaluated the traditional ERP performance evaluation theory and expounded the defects of the method. Based on ERP method, combined with ERP implementation objectives, ERP performance evaluation objects and principles, an ERP performance evaluation model based on balanced scorecard is proposed. Rumualdus [14] proposed

the use of balanced scorecards to study the enterprise performance evaluation. The four factors of finance, customers, internal business, and learning and growth are used as evaluation indicators to give a detailed overview of the performance evaluation system. Dantas et al. [15] introduced the balanced scorecard method to educational institutions. The applicability of the National Business Learning Service (SENAC/RN) in educational institutions was studied. Lu et al. [16] conducted related research based on the DEA method, combined with the analysis of input and output. Wu et al. [17] studied the evaluation model and system of education informatization by using the grey fuzzy method and designed a set of evaluation system for the problem of information loss in education informatization.

Rao et al. [18] combined particle swarm optimization (PSO), Hopfield neural network, and BP neural network for equipment fault diagnosis. Cheng et al. [19] used BP neural network for damp heat detection. Based on variable input genetic algorithm (GA) and BP neural network, a temperature and humidity monitoring and prediction model is proposed. Bai et al. [20, 21] *l* combined BP neural network with robot kinematics and proposed a new robot inverse kinematics model algorithm combining FOA optimization and BP neural network. Wang et al. [22] applied BP neural network model to college students' sports performance prediction. By comparing the results of the established sports performance prediction model with the experimental data, the accuracy of the BP neural network model is verified. In the process of studying the knowledge fusion risk of innovation ecosystem, Wang et al. [23] found that integrating risk assessment with BP network model can achieve more accurate prediction of risk assessment.

The above literature has verified the wide applicability of BP neural network. With the deepening of research, BP neural network has gradually attracted people's attention in the research process of performance evaluation-related fields. In order to identify the dynamic short-term performance behavior of enterprise employees, Li et al. [24] proposed a BP neural network fuzzy system combined performance evaluation model. It overcomes the influence of factors such as potential value and performance changes on the results of performance evaluation. Yang et al. [25] introduced BP neural network model in the research process of higher education teaching management evaluation. By comparing the evaluation results of five universities, the wide applicability of BP neural network is further verified. Zhang et al.[13] researched knowledge management theory and performance evaluation method based on BP neural network, which further proves the feasibility of BP neural network in the field of performance evaluation. Traditional BP neural network has only been introduced into the field of comprehensive performance evaluation in recent years. In the process of performance evaluation, there may be a nonlinear relationship between the evaluation object and the comprehensive index, which will lead to the difference between the evaluation results and the actual results. In addition, the evaluation objects with weak correlation will also cause differences in results.

In view of the above problems, this paper proposes a performance evaluation model for higher education informatization by means of PLS-BP model. The principles of partial least squares (PLS) method and back propagation (BP) neural network are introduced firstly. The main components of the data are extracted by PLS method, and then combined with BP neural network, the PLS-BP model is constructed. At the end of the article, the PLS-BP evaluation model is simulated and analyzed.

2. Principle and Data Processing of PLS-BP Method

2.1. Principle of PLS. In the multivariate statistical data analysis methods, there are mainly the following two methods: the model method represented by multivariate linearity and the cognitive method represented by principal component analysis. Performing regression modeling before the independent variable and the dependent variable and expecting to get the relationship between the two variables is the main working idea of ordinary multiple regression analysis, but this method has received more restrictions in practical applications, of which the most important the problem is the multiple correlations between independent variables. PLS [26] can effectively overcome this problem. Unlike the traditional method, it no longer directly considers the regression modeling between two sets of variables, but extracts several pairs of systems with the best from the variable system. Explain the new comprehensive variables (also known as components) of the ability, and then use them for modeling. In terms of component extraction, the principal component analysis method is mostly used for the extraction of components in a single data table, and the canonical correlation analysis considers the extraction of components between two data tables and analyzes the correlation between the two tables. In fact, after PLS regression formally integrates the extraction methods of these two components, a new component extraction method is given, and it is used in the regression modeling analysis between the two data tables.

In general, the PLS provided a new method of multi-dependent variable to multi-independent regression modeling; at the same time, in the data in terms of simplification or dimensionality reduction, the advantages of principal component analysis methods and canonical correlation analysis methods have been absorbed, and a new component extraction method has been provided, which brings great convenience to the analysis of multivariate statistical data. The principle and detection method of PLS method are introduced as follows.

The first is the basic principle of PLS. Suppose there are P variables $y_1, y_2, \ldots, y_p$ and m variables $x_1, x_2, \ldots, x_m$. When PLS performs regression operation, the first value t_1 in the independent variable is selected firstly. That is, $t_1 = k_1x_1 + k_2x_2 + \ldots + k_mx_m$, where k_i ($i = 1, 2, \ldots, m$). At the same time, the same processing method needs to be used to extract the first component u_1 from the dependent variable data. The Lagrangian multiplier method is used to maximize the correlation between t_1 and u_1 [27]. Secondly, construct the

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regression equation of dependent variables $y_1, y_2, \ldots, y_p$ and t_1. If the current regression equation can achieve satisfactory accuracy, the algorithm can be aborted. Otherwise, continue to extract the second pair of components from the remaining information until satisfactory accuracy can be obtained. If finally extracting r components $t_1, t_2, \ldots, t_r$ from the set of independent variables, the PLS regression method first builds the regression equation of $y_1, y_2, \ldots, y_p$ and $t_1, t_2, \ldots, t_r$. Then, it is transformed into the regression equation of $y_1, y_2, \ldots, y_p$ and $x_1, x_2, \ldots, x_m$, which is called the PLS regression equation.

The next step is to perform a crossvalidation test [27]. Similar to the principal component analysis method, the PLS method generally does not need to extract the r components $t_1, t_2, \ldots, t_r$ to construct the regression equation and only needs to select the first component $(1 \le r)$ to obtain the prediction for a regression model with a good level, and we can use the crossvalidity test to determine the number of principal components required.

The i-th observation ($i = 1, 2, ..., n$) is removed each time, and the PLS regression method is used to build the model for the remaining n-1 observations. The regression equation fitted after selecting h components is studied, and the i-th observation point removed before is substituted into the regression equation established by us to obtain the predicted value of Y_j ($j = 1, 2, ..., p$) at the i-th observation point $\overline{y_{(i)j}}(h)$.

Repeat the above calculations for $i = 1, 2, ..., n$, and the sum of squared prediction errors of the j-th dependent variable Y_j ($j = 1, 2, ..., p$) can be obtained. When h components are extracted, (1) is shown in [28].

$$\mathrm{PRESS}_j(h) = \sum_{i=1}^{n} \left(\mathrm{yij} - \overline{y_{(i)j}}(h)\right)^2, \tag{1}$$

where $j = 1, 2, ..., p$.

At this time, the sum of squares of prediction errors of $Y=(y_1, y_2, \ldots, y_p)^{\mathrm{T}}$ is shown in (2).

$$\mathrm{PRESS}(h) = \sum_{j=1}^{p} \mathrm{PRESS}_j(h). \tag{2}$$

Moreover, all the sample points are used to establish a regression equation containing h components. If the value of the i-th sample point is recorded as $\overline{y_{\mathrm{ij}}}(h)$, the sum of squared errors for Y_j can be given as:

$$SS_j(h) = \sum_{i=1}^{n} \left(y_{\mathrm{ij}} - \overline{y_{\mathrm{ij}}}(h)\right)^2. \tag{3}$$

Thus, the sum of squared errors of Y can be obtained by (4).

$$\mathrm{SS}(h) = \sum_{j=1}^{n} \mathrm{SS}_j(h). \tag{4}$$

When the $PRESS(h)$ is the minimum value, h at this time is the number of components we need to extract for modeling. Generally speaking, the value of $PRESS(h)$ is usually larger than that of $SS(h)$, and the value of $SS(h)$ is smaller than that of $SS(h\text{-}1)$ [29]. Therefore, the smaller the ratio of $PRESS(h)/SS(h\text{-}1)$, the better to obtain the ideal expected value. Generally, we set the threshold as 0.05, as shown in (5).

$$\frac{\mathrm{PRESS}(h)}{\mathrm{SS}(h-1)} \le (1 - 0.05)^2 = 0.95^2. \tag{5}$$

Based on (5), adding a new component t_h is helpful to improve the model and improve its accuracy. To this end, we define the crossvalidity expression as shown in the following equation.

$$Q_h^2 = 1 - \frac{\mathrm{PRESS}(h)}{\mathrm{SS}(h-1)}. \tag{6}$$

Based on the above equation, before the end of each round of calculation of modeling, crossvalidation is performed on it. If $Q_h^2 < 1 - 0.95^2 = 0.0975$ is calculated in the h-th step, we can consider that the modeling meets the accuracy requirements; that is, the algorithm is suspended.

2.2. Principle of BP Neural Network. BP neural network [30] is a multilayer feedforward neural network, and its error propagation direction is back propagation. The principle of BP neural network is to imitate the working mode of human brain neurons and simplify the work of human brain neurons. In the process of learning and research using neural network system, we do not need to directly understand the corresponding relationship between independent variables and dependent variables, which highlights the absolute advantage of neural network system. Neural network has a three-layer information transmission structure, including input layer, middle layer, and output layer. For the three-tier structure, the connection form of the two interconnected structures is arbitrary, and the three-tier structure cannot be connected across layers.

Figure 1 shows the structure of three-layer BP neural network. As can be seen from Figure 1, the whole network system is composed of three layers. It corresponds to the information transmission process in nerve cells. In the neural network model, there are two kinds of signals: working signal and error signal. The working signal is composed of the value input by the user, and the error signal is the difference between the expected result and the real value.

Among the learning principles and methods of BP neural network, the steepest descent method should be used most. After the user sets the initial weight, the data previously entered by the user will be transmitted to the middle layer. The middle layer uses the selected learning function to learn and transmit the learning results to the output layer. If the error is smaller than the allowable range, the result will be output directly. Otherwise, the error exceeds the specified error range, and the error result will be back propagated from the output layer to the middle layer and then back propagated to the input layer. At this time, the input layer adjusts the initial weight and continues to transmit the result to the middle layer. The middle layer will adjust the corresponding weight and threshold and then transmit the result to the output layer. At this time, continue to compare

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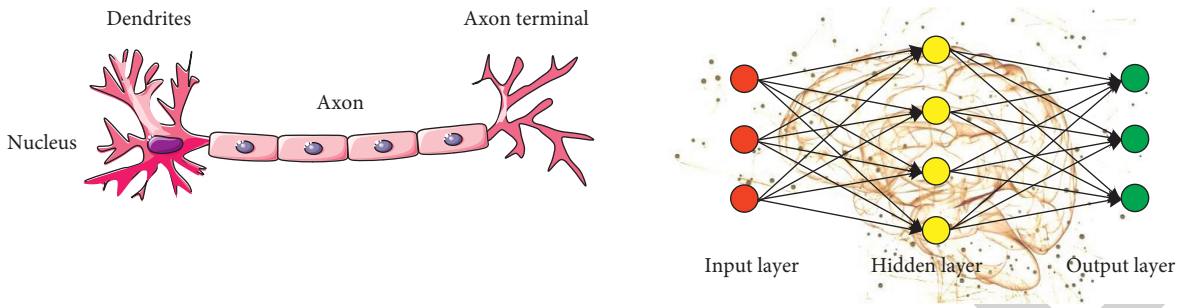

Figure 1: Structure diagram of three-layer BP neural network: (a) neural cell structure; (b) BP neural network.

the error with the expected value and repeat the above steps, until the output result. This process is to minimize the sum of squares of errors of the network.

Figure 2 shows the structure and algorithm flowchart of BP neural network. This working process is divided into two parts—Part 1: the calculation and learning process of forward propagation and Part 2: the error back propagation process when the error between the real value and the predicted value exceeds the error set by the user.

As mentioned earlier, the forward propagation process includes the sequential propagation of three layers. Similar to human nerve cells, each layer in the network is connected to each other. At the end of the forward propagation process, if the error is too large, the error will enter the back propagation process of three layers. In this process, the network will automatically adjust the initial weight and threshold set by the user. This step is to ensure that the output error is within the error range set by the user. When this purpose is achieved, the learning process ends.

3. Construction of Evaluation Model

3.1. Evaluation Indicator. The performance evaluation of education informatization can be simplified to the evaluation of the six constituent elements of the model of education informatization performance evaluation. Therefore, these six elements constitute the primary indexes of the system. Considering the operability of the index system, these six elements need to be further decomposed, and the decomposition result is the secondary indicators of the index system. In order to implement the evaluation, we also need to analyze the connotation and extension of education informatization performance evaluation, that is, from which angles to evaluate education informatization performance. The decomposition of evaluation angles constitutes three-level and four-level indicators. For each indicator item, observation points need to be set and explain the data items that each index needs to collect. The four-level indicators and observation points together constitute a complete education informatization performance evaluation index system. Because of the length, this paper only discusses the general index system of education informatization performance evaluation. On this basis, we can get the evaluation index system of each specific education category.

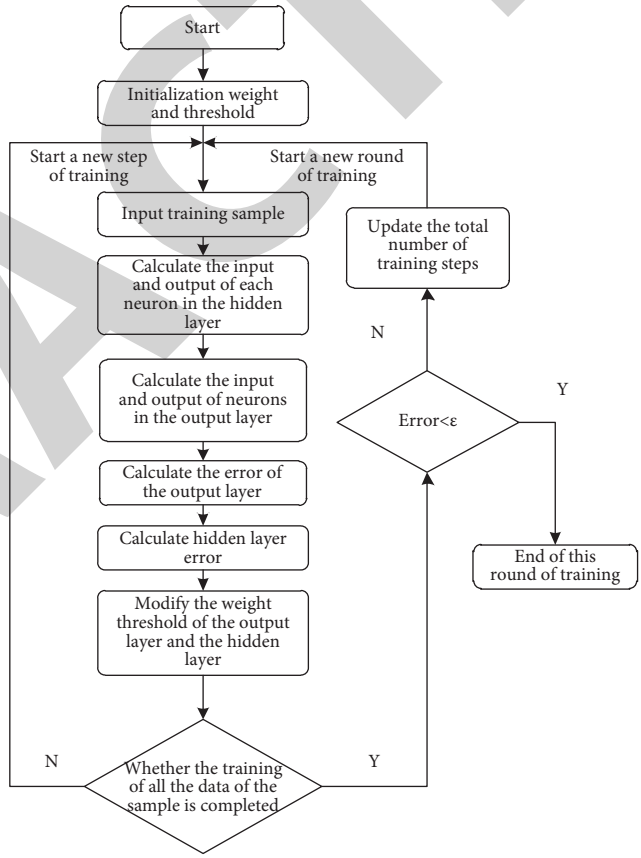

Figure 2: Calculation flowchart of BP neural network.

To sum up, the primary indicators of the performance evaluation system of higher education informatization include career development, user effect, business activities and processes, infrastructure, information system and data, and informatization team. According to the literature [18], the composition and proportion of college education information system are introduced. Figure 3 shows the performance evaluation indicators of education informatization. The decomposition of the first-level indicators constitutes the second-level indicators. Because this paper studies the general performance evaluation index system of education informatization, different education categories such as colleges and universities, vocational education, basic

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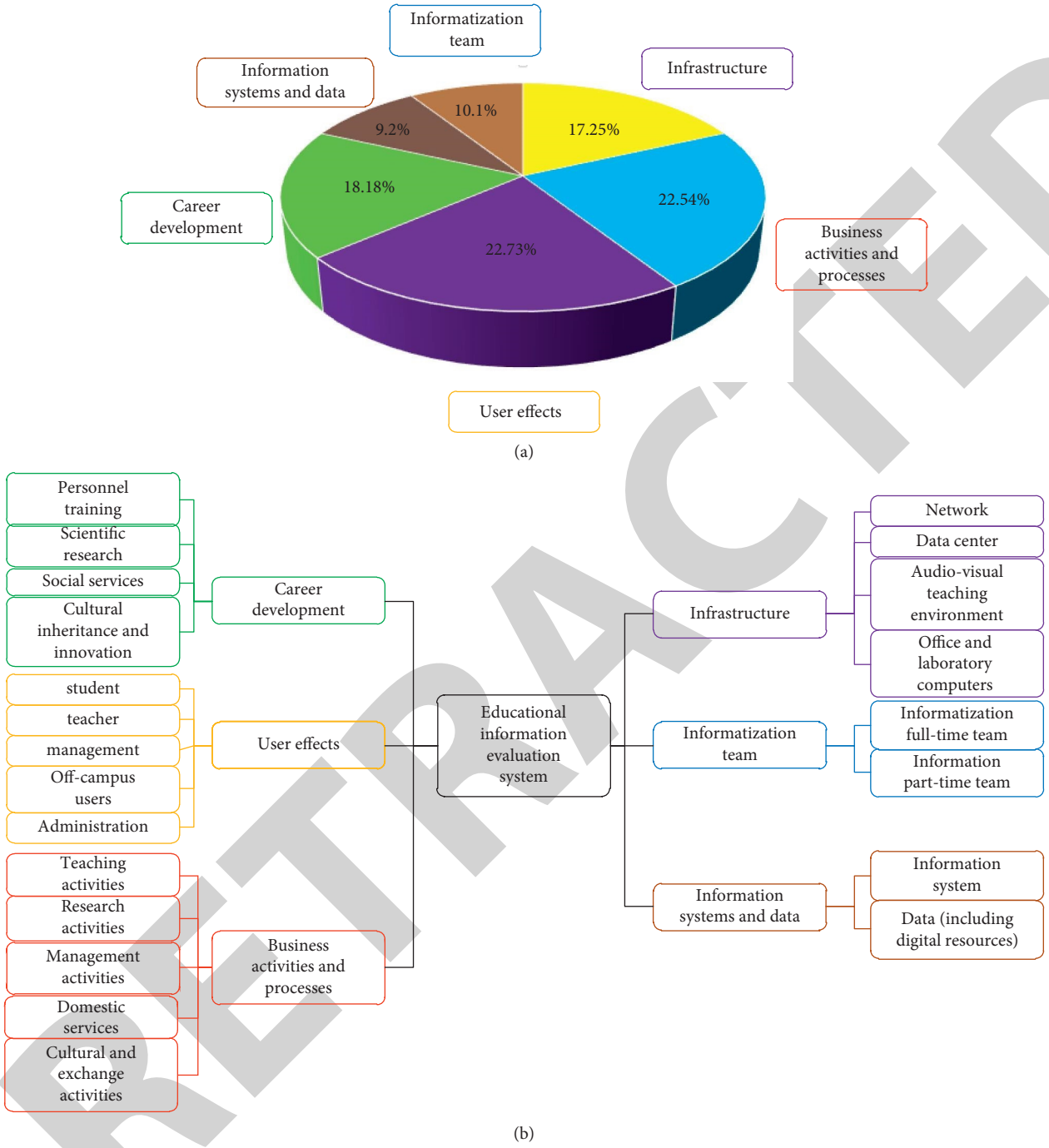

Figure 3: Performance evaluation indicators of education informatization: (a) proportion; (b) component.

education, preschool education, and educational administration are considered in the decomposition.

(1) Throughout the various education categories, personnel training, scientific research, social services, cultural inheritance, and innovation are the main goals of the development of education. Therefore, the secondary index "career development" is further decomposed into these four secondary indicators.

(2) Students, teachers, administrators, administrative departments, and off-campus users are the main service objects of education informatization. The performance evaluation of user effects in education informatization performance mainly considers the informatization experience of these five types of users. Therefore, the first-level indicator "user effect" is further broken down into these five secondary indicators.

(3) Through the analysis of various education businesses, we found that the business of education mainly includes five types of activities: teaching activities, scientific research activities, management

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activities, life services, and cultural and exchange activities. These five types of activities are supported, so these five types of activities are regarded as the second-level indicators of the first-level indicator "business activities and processes." By evaluating the support performance of education informatization for these 5 types of activities, the evaluation of education informatization's contribution to educational business activities supports performance with processes.

(4) Information infrastructure includes four types of content: network, data center, audiovisual teaching environment, and office and laboratory computer equipment, which reflects the hardware construction results of education informatization. Therefore, the first-level indicator "infrastructure" is broken down into these four. The secondary index evaluates the construction performance of education information infrastructure.

(5) Information system and data are important results of informatization construction, reflecting the achievements and effects of education information technology application. Therefore, the first-level index "information system and data" is decomposed into two second-level indicators, information system and data, and evaluates the performance of education informatization in terms of information systems and data.

(6) The informatization team includes not only a full-time informatization team—professional and technical personnel in the network information center, but also a part-time informatization team—management departments, departmental information officers, and network management teams. The informatization team is the executor of the construction of education informatization. The first-level indicator "informatization team" is decomposed into two second-level indicators, namely, a full-time informatization team and a part-time informatization team.

3.2. Evaluation Model. This section introduces the construction process of the PLS-BP evaluation model in detail. The principal components of independent variables are extracted by LPS method, and then, the extracted principal components are input into the network model. Moreover, we set the performance score as the output of the network model. Based on the above settings, PLS-BP prediction model can be obtained. Then, the neural network learning, parameter adjustment, model fitting, and testing are carried out, and then, the relevant prediction is carried out. The specific processing flow is described in detail below.

Assume that there are input variable $X=(X_1, X_2, \ldots, X_i)$, the middle layer output variable $Y=(Y_1, Y_2, \ldots, Y_j)$, and the output layer variable $Z=(Z_1, Z_2, \ldots, Z_j)$. In the same time, the expected output target variable $T=(T_1, T_2, \ldots, T_l)$. The W_{ij} and W_{jl} are the connection weights of input layer and middle layer, respectively. Corresponding to the learning samples $X_1, X_2, \ldots, X_i$, the output samples are $Z_1, Z_2, \ldots, Z_l$.

The implementation process of BP network is introduced below. Firstly, the number of nodes of three layers needs to be determined. There are many factors affecting the performance evaluation. This index has been summarized in section 3.1. Therefore, if the data of 22 indexes are directly selected for network learning and training, the number of input layer nodes can be determined to be 22. After the number of input layers is determined, the number of middle layer nodes needs to be set. Taking the optimal number of middle layer nodes can not only construct a good BP neural network structure, but also make the learning time meet the requirements, improve the fault tolerance and generalization ability of network training, and accelerate the convergence speed of data, so that the function calculation results approach the expected output and improve the prediction accuracy. At present, there is no generally applicable method and theory to determine the number of middle layer nodes, which generally adopts empirical equation. The empirical equation used in this paper is as follows.

$$q = n + p + a, \tag{7}$$

where n, q, p are the number of three-layer nodes of the prediction model, respectively, and a is a constant numerical value (usually take 1–10).

Firstly, 10 nodes in the middle layer are trained and tested. Then, add a number, try again until the convergence speed of the network to the data is no longer accelerated, and determine the optimal number of middle tier nodes. Through continuous attempts, the optimal number of middle layer nodes of the prediction model can be determined to be 18. After the above process is completed, the next step is to determine the node value of the output layer of the prediction model. The purpose of constructing the university education informatization performance evaluation model based on PLS-BP model is to grasp the current situation of different university education informatization performances as a whole, and its output result is the performance evaluation level. The prediction model structure designed in this paper has only one output result, that is, the predicted value of higher education informatization performance. Therefore, it can be determined that the node value of the output layer of the prediction model is 1. To sum up, the PLS-BP prediction model designed in this paper is $22 \times 18 \times 1$.

The next step is the initialization of the threshold and the connection weight of the PLS-BP prediction model to ensure that the large weighted input cannot saturate the network. Generally set the initial connection weight (Weight) and threshold value (Bias) of the PLS-BP prediction model to any number in the interval (–1, 1) to ensure that the weights and thresholds of each layer are initialized with small random numbers. The essential purpose is to gradually correct the threshold and weight of the network, so as to achieve the target error requirement of the network.

For the model in this paper, there are 22 inputs, and each input has an appropriate weight W to connect to the next

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layer of the network. However, W represents the strength of the connection of each layer of the PLS-BP prediction model. The network transfer function includes logarithmic sigmoid function, linear purelin function, and tangent simoid function. This article is a simulation analysis of the performance evaluation model of college education informatization. The middle layer uses the tangent logarithmic function sigmoid transfer function.

After determining the transfer function of the three-layer network structure of the PLS-BP prediction model, use the function initff to reinitialize the PLS-BP prediction model. The function initff can realize the reinitialization of BP neural network, and the command statement is "net = init(net);"". The output vectors of the middle layer and the output layer can be expressed by the (8) and (9).

$$Y = f_1\left(\sum_i W_{\mathrm{ij}} x_i + b_i\right), \tag{8}$$

$$Z = f_2\left(\sum_j W_{\mathrm{jl}} y_j + b_l\right), \tag{9}$$

where f_1 is the "tansig"; f_2 is the "purelin"; and b_i, and b_l are the confinement values of the middle layer and the output layer, respectively.

The error of the prediction model is $E = T\text{-}Y$. When E is less than the error we set, the program will terminate. Otherwise, the above operation will continue. The error set in this paper is $\varepsilon = 0.0001$.

The node error of the output layer is shown in the following equation.

$$\delta_l = (T - Z)Z(1 - Z). \tag{10}$$

Middle layer node error is

$$\delta_j = Y(1 - Y)\sum \delta_l W_{\mathrm{jl}}. \tag{11}$$

The weight correction amount of the middle layer neuron is

$$\Delta W_{\mathrm{jl}} = -\eta \frac{\partial E}{\partial W_{\mathrm{jl}}}. \tag{12}$$

The weight correction amount of the output layer neuron is

$$\Delta W_{\mathrm{ij}} = -\eta \frac{\partial E}{\partial W_{\mathrm{ij}}}. \tag{13}$$

where η is the network learning rate, with a value range of $0 < \eta < 1$. The learning rate n is related to the learning convergence rate of the prediction model (usually set $\eta = 0.01$).

The correction equation of connection threshold and weight can be found in the following. The weights between the three layers can be expressed by (14) and (15), respectively.

$$W_{\mathrm{ij}} = W_{\mathrm{ij}} + \alpha\delta_j X, \tag{14}$$

$$W_{\mathrm{jl}} = W_{\mathrm{jl}} + \alpha\delta_l X. \tag{15}$$

The thresholds between the three layers can be expressed by (16) and (17), respectively.

$$b_i = b_i + \beta\delta_j, \tag{16}$$

$$b_l = b_l + \beta\delta_l. \tag{17}$$

4. Results and Discussion

4.1. Standardized Inspection. When using the PLS method to extract the principal components for PLS regression analysis, the results of the three parameters of the informatization part-time team, cultural heritage innovation, and case personnel are consistent in 40 samples of four universities; that is, the change of the three parameters has a contribution rate of 0 to the overall,. The data come from the survey results of Beijing Academy of Social Sciences. Therefore, three parameters are eliminated on the basis of the original 22 indicators.

The number of principal components extracted is 3. The standardized factor scores of the extracted 3 principal components are shown in Figure 4.

From the above figure, it can be concluded that the first component has a large coefficient in equal variables. This part focuses on the assessment of basic settings and coordination of physical resource allocation; the second component has a large coefficient in equal variables. This part focuses on user effect, improvement of service level, and support; the third component has a large coefficient in equal variables, which can be regarded as a factor of career development.

4.2. Comparison Results and Analysis. The fitting and testing of the PLS-BP model take the extracted 3 principal components as the input. The 40 performance scores (scores ranging from 0 to 10 points) are obtained from the original expert consultation as the output. After 118 iterations of the model, the mean square error reached after training is 0.0000539.

In order to be able to more intuitively and clearly determine the development status of education informatization in various universities, the research reviews previous studies and adopts the classic "SMART" principle [31] to classify the education informatization performance of colleges and universities. A four-level division method is used, namely, excellent (≥8 points), good (≥6 points, <8 points), fair (ision metho<6 points), and poor (<3 points). To evaluate the performance of the PLS-BP model, the performance score obtained by the simulation of the model is compared with the performance score calculated by the traditional linear regression model and BP evaluation model, as shown in Figure 5.

As can be seen from the comparison results of scores in Figure 5(a), the results based on PLS-BP evaluation model are closer to the traditional results than those based on BP model. And as can be seen from the relative error in Figure 5(b), the maximum relative error based on PLS-BP evaluation model is 3.64%, while the maximum relative error

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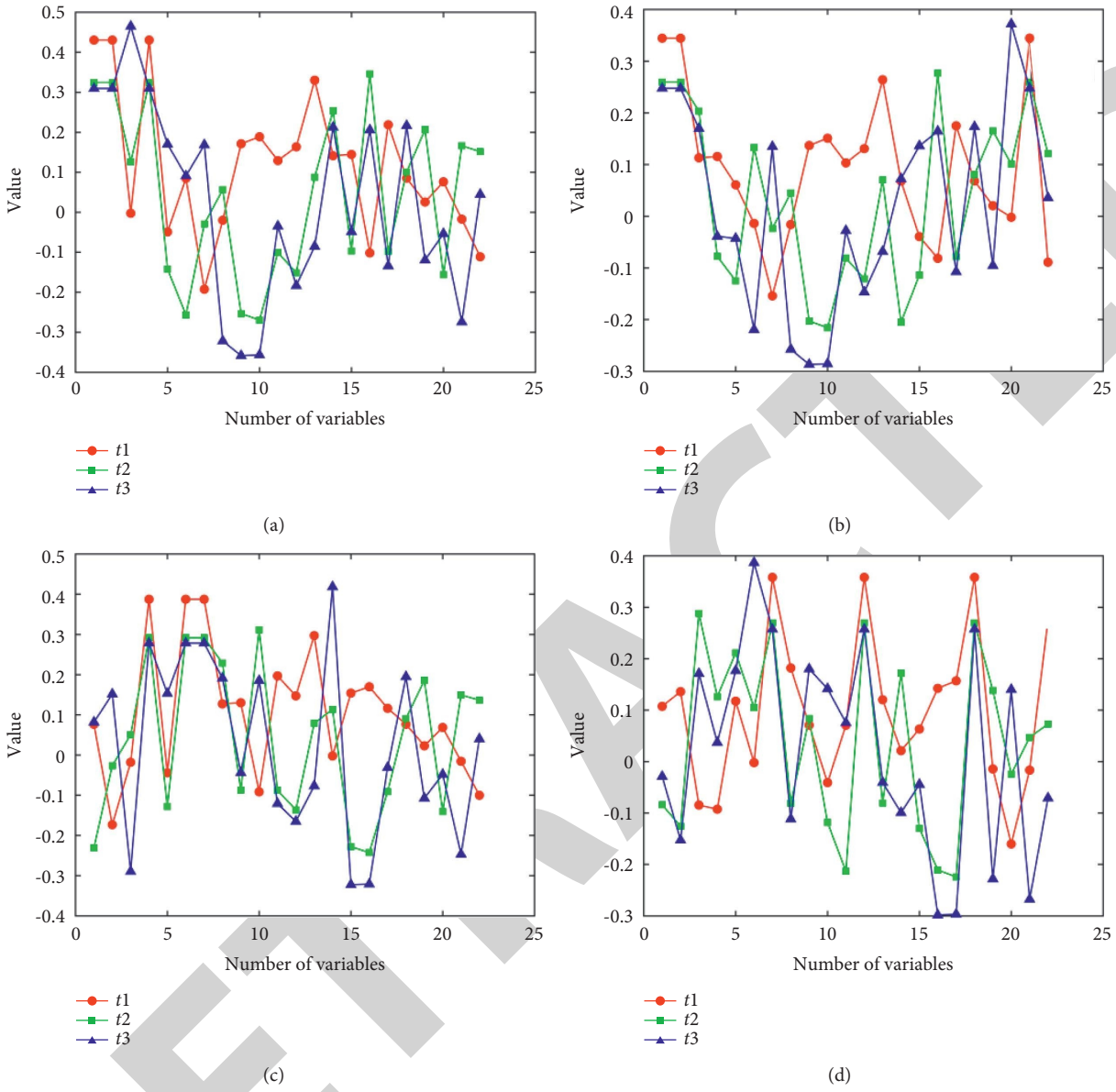

Figure 4: Standardized factor score: (a) University 1; (b) University 2; (c) University 3; (d) University 4.

based on BP model is 2.29%. The comparison results verify the accuracy of the evaluation model in this paper. To evaluate the performance of the PLS-BP model, the performance score obtained by the simulation of the model is compared with the performance score calculated by the traditional linear regression model. The comparison results can be found in Figure 6.

It can be seen from Figure 6 that the prediction results of PLS-BP model have the same trend as the performance evaluation results of traditional expert consultation, which shows that the application of PLS-BP model can better complete the nonlinear mapping from informatization performance evaluation index to performance score. Figure 7 shows the relative error between traditional performance score and PLS-BP model performance score.

Based on the comparison results of 40 data samples in Figures 6 and 7, the maximum relative error between traditional performance score and PLS-BP model performance score is 2.32%.

This model provides a new way for higher education informatization performance evaluation. The PLS-BP model can be solidified and applied to the performance evaluation of education informatization in other colleges and universities, so as to avoid the interference of human factors as much as possible; at the same time, it also proves that the application of PLS-BP model to evaluate the education informatization performance of colleges and universities is effective and feasible.

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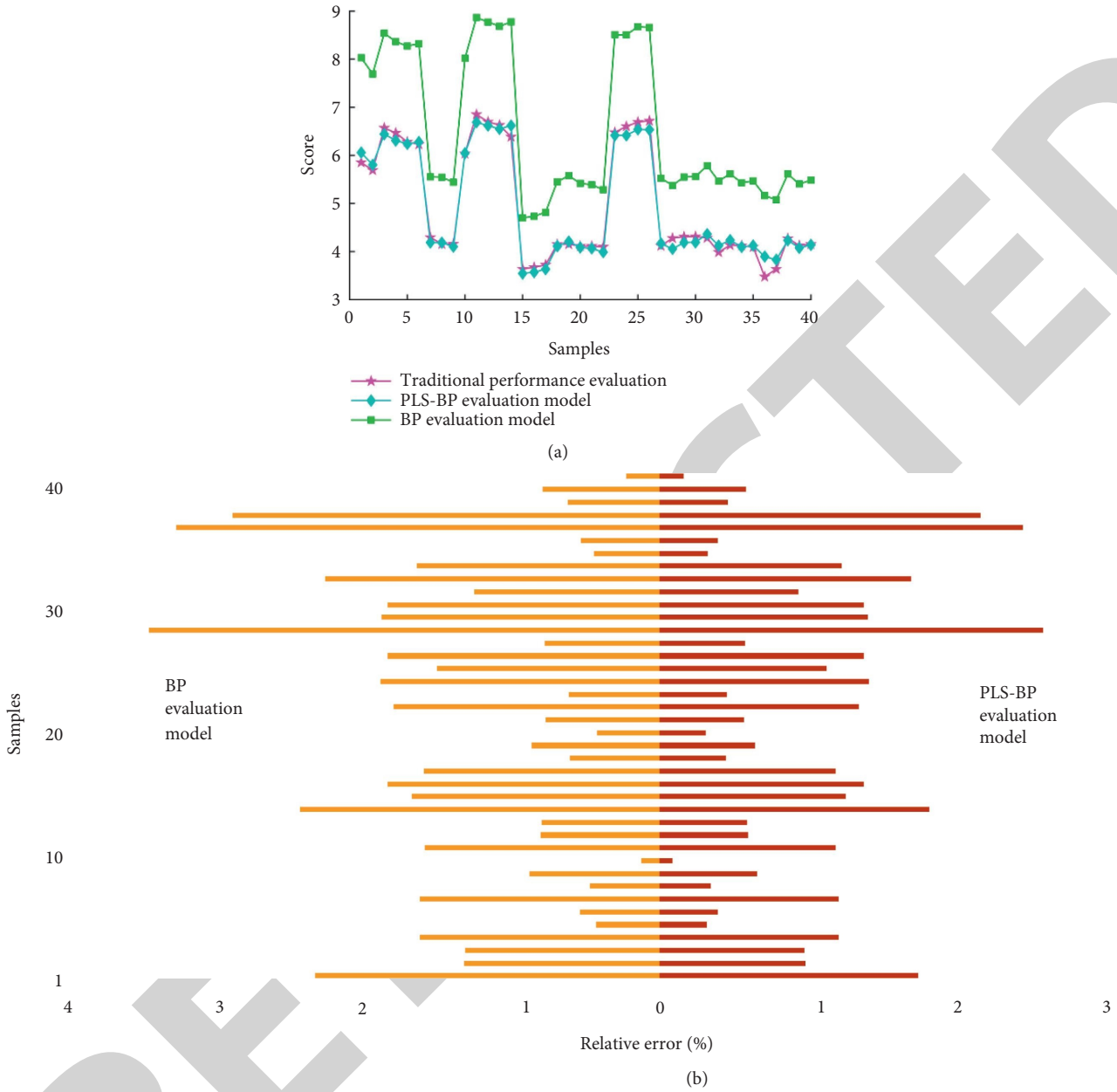

Figure 5: Comparison results of performance score: (a) scores; (b) relative error.

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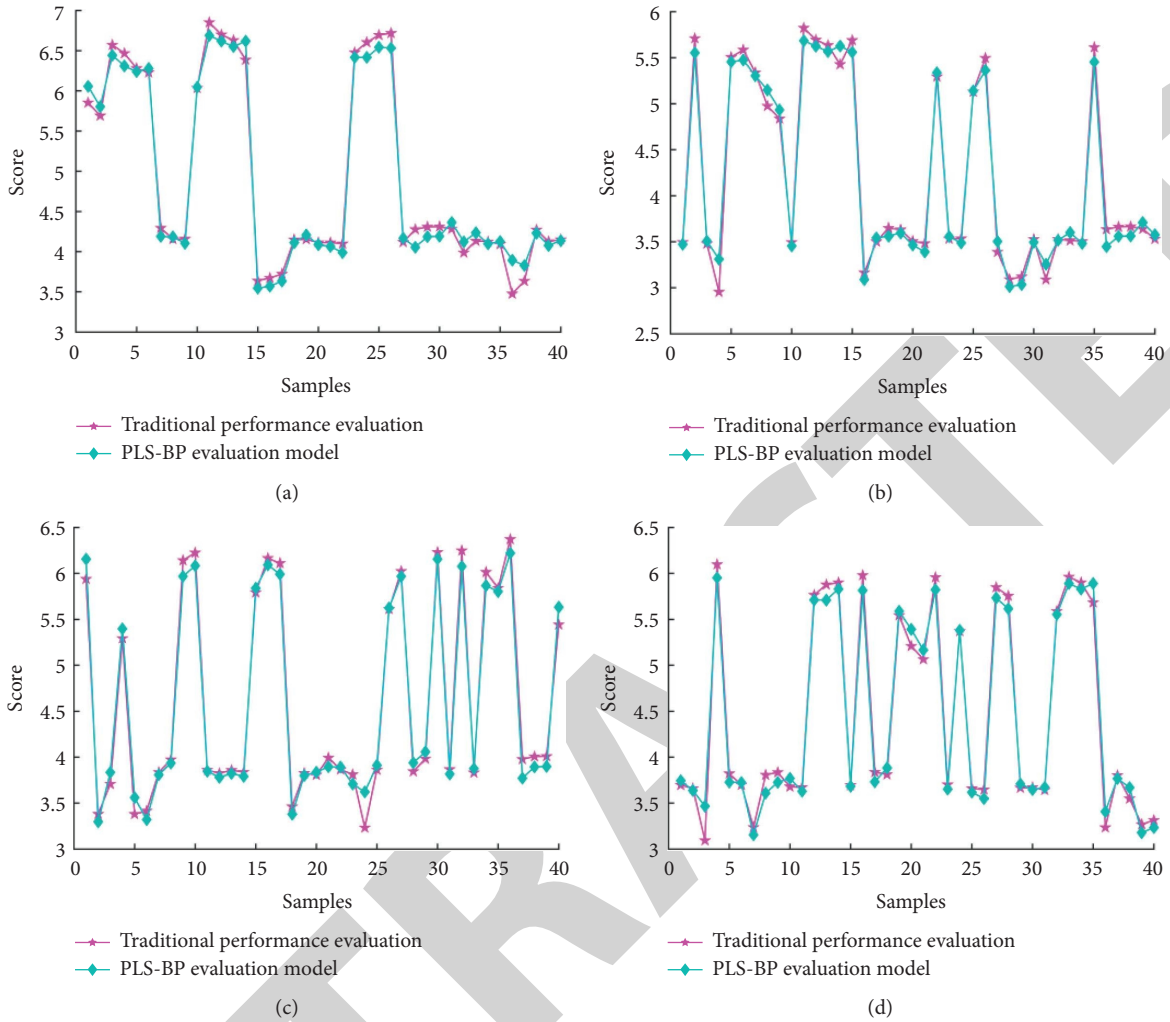

Figure 6: Comparison results of performance score: (a) University 1; (b) University 2; (c) University 3; (d) University 4.

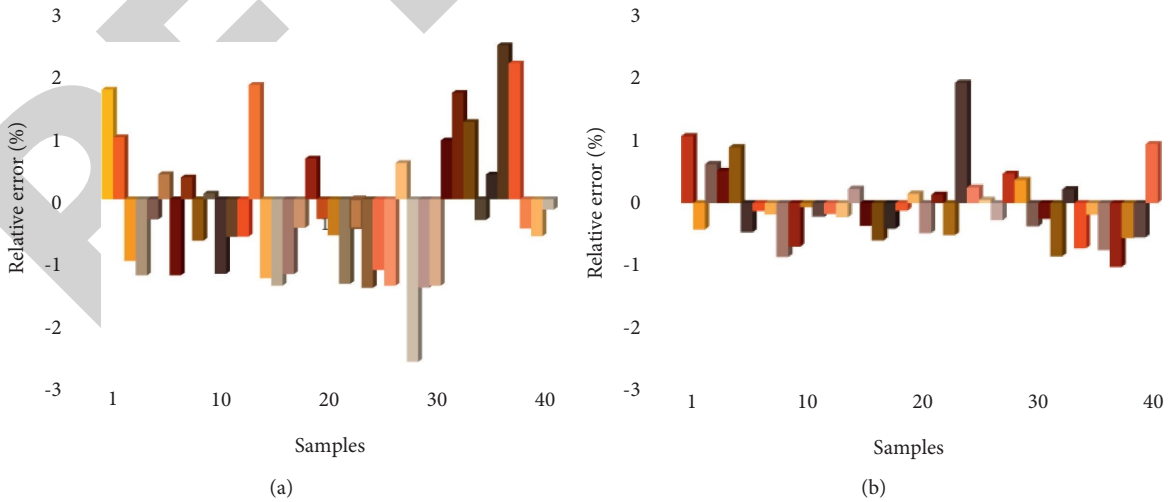

Figure 7: Continued.

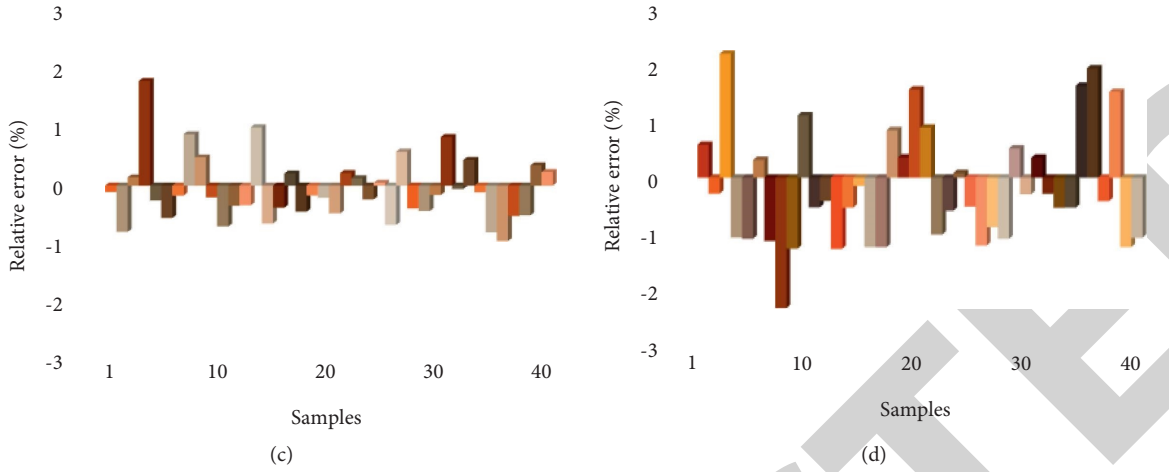

Figure 7: Relative error: (a) University 1; (b) University 2; (c) University 3; (d) University 4.

5. Conclusion

Combined with PLS method and BP neural network, a performance evaluation model of higher education informatization based on PLS-BP model is proposed. In order to evaluate the performance of PLS-BP model, the performance scores obtained by model simulation are compared with those calculated by traditional linear regression model and BP evaluation model. The comparison results show that the evaluation results based on PLS-BP model are closer to the traditional evaluation results than those based on BP model. Moreover, the maximum relative error based on PLS-BP evaluation model is 3.64%, while the maximum relative error based on BP model is 2.29%. Finally, this paper uses the evaluation model to evaluate the performance of four universities. The maximum relative error is 2.32%. The comprehensive comparison results show that the model can effectively realize the performance evaluation of education informatization in colleges and universities. It has significantly improved the intelligent level of university education informatization performance evaluation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Data Analysis of Fiscal Expenditure and GDP Based on Financial Budget Performance Evaluation Indicators

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The proportion of fiscal revenue in GDP and the multiplier of fiscal expenditure are important economic benefit indicators in the framework of a common index system for budget performance evaluation. The correlation between fiscal expenditure and GDP constitutes an important indicator to measure fiscal scale, and the scale and structure of fiscal expenditure play a guiding role in the distribution of social renewable production. At the same time, there is a certain mutual promotion between the two. This paper selects the data of China's GDP and fiscal expenditure from 1998 to 2019, analyzes the trend, respectively, and then carries out correlation and regression analysis. On this basis, it scientifically calculates the scale of China's GDP in the next five years and puts forward suggestions to optimize fiscal expenditure.

1. Introduction

In the document of Financial Budget No. 53 (2013), to comprehensively promote budget performance management and improve the unity and authority of performance evaluation, the Ministry of Finance formulated the framework of common indicators system for budget performance evaluation. The proportion of fiscal revenue in GDP is an important indicator of economic benefits [1], which is better measured. In fact, a better choice is to use fiscal spending as a share of GDP to measure. Fiscal participation in the distribution process of national production value needs to be reflected by fiscal expenditure because fiscal expenditure really shows where the funds flow and how much they flow out. The process of social reproduction is continuous, and resources need to be distributed among different undertakings, and the financial expenditure structure is its best embodiment. Therefore, financial expenditure has a significant impact on social reproduction. At the same time, fiscal expenditure also has the function of regulating the macroeconomy. Fiscal expenditure can stimulate the growth of GDP and promote economic development by affecting C (consumption) I (investment) x (export). Specifically, fiscal expenditure is divided into purchasing expenditure (recurrent and investment) and transfer expenditure. The traditional fiscal policy refers to purchasing expenditure, which can stimulate domestic investment. Transfer expenditure can increase residents' income, improve domestic consumption [2], and promote exports. This paper selects the data of China's GDP and fiscal expenditure from 1998 to 2019. Firstly, select one of the recurrent expenditure, investment expenditure, and transfer expenditure of fiscal expenditure to study its change, to reflect the change of fiscal expenditure structure, then analyze the change trend of GDP, and then use the regression model to explore the specific relationship between the two variables and predict the GDP trend in the next five years. It is forward-looking and finally puts forward relevant opinions to promote the appropriate growth of fiscal expenditure and optimize the structure of fiscal expenditure.

2. Theory and Literature Review

Fiscal expenditure, also known as public expenditure or government expenditure, is the government's control and use of social resources in a monetary form concentrated in the private sector to perform its own functions. "Fiscal expenditure" and "fiscal Spending" cannot be confused: in

the sense of fiscal budget, fiscal spending refers to the monetary amount that the government can control, while fiscal expenditure refers to the monetary amount actually spent by the government in a certain period of time. When the amount of the former is large, it is called the state of fiscal surplus; when the latter amount is large, it is called a fiscal deficit. The government's distribution activities mainly refer to fiscal expenditure, and the main way of fiscal impact on the social economy is also fiscal expenditure. On the one hand, the structure and scale of finance limit the scope of government activities. On the other hand, it also reflects the tendency of the government toward some industries and policies.

Gross domestic product (GDP) refers to the value of all final products and services produced in a country or region's economy in a certain period of time (a quarter or a year). It is often recognized as the best indicator to measure a country's economic situation. It can not only reflect a country's economic performance but also reflect a country's national strength and wealth.

In essence, the change of GDP reflects the situation of economic development in a period of time. As an important role of economic activity, the government's activities certainly play an important role in economic development. In the Keynesian view, the state's expenditure behavior will not only directly affect economic development such as consumption or investment but also indirectly affect economic development by affecting the behavior of individuals and groups in the market. To a large extent, fiscal expenditure is an important factor in GDP growth. What is the relationship between a region's GDP and its fiscal expenditure? Through consulting the research literature, this paper finds that the relationship between GDP and tax expenditure has been summarized by scholars as follows.

2.1. The Increase of Fiscal Expenditure Can Promote Economic Growth. Gao and Chaocai [3] studied the provincial fiscal expenditure data of China from 1990 to 2012. He believed that fiscal expenditure in various regions of China can promote economic growth, but the promotion effect is different in different regions. It is suggested that the government adopt differentiated fiscal expenditure policies according to local conditions. If fiscal expenditure keeps increasing, GDP generally also shows an upward trend. Fiscal expenditure achieves this by stimulating demand and consumption. At present, China's economic development falls behind compared with the developed countries and needs financial support in many aspects. Then fiscal expenditure will have a relatively large marginal utility, which means one unit of fiscal expenditure can cause more units of GDP growth and play a great role in promoting. Since China's fiscal expenditure has a great impact on the economy and it is necessary to develop the economy, it is required that the structure of China's fiscal expenditure be reasonable. At the same time, in the process of economic growth driven by fiscal expenditure, fiscal expenditure should maintain a reasonable scale because the fiscal deficit for a long period is bound to be unworkable. From a comprehensive point of view, only an appropriate scale and a reasonable structure of fiscal expenditure can promote endogenous economic growth. Then, economic construction expenditure remains the first priority, and the economy should be continuously developed on the basis of stabilizing the general level of economic development. Secondly, it is also necessary to appropriately increase the expenditure on science, education, culture, and health and social security, especially we should pay more attention to the education expenditure to narrow the income distribution gap and promote social equity.

2.2. Part of Fiscal Expenditure Is Not Necessarily Directly Related to Current GDP. Wei [4] concluded that the role of science, education, culture and health expenditure, social security, and employment expenditure was not obvious by analyzing the impact of fiscal expenditure scale and fiscal expenditure structure on economic growth in Shanxi Province in the past ten years. The impact of the increase of fiscal expenditure on GDP often lags behind. If the fiscal expenditure in the current period is the investment in fixed assets, the impact on GDP may be after a long period of time. For example, the expenditure on education is a long-term investment. The current investment in education does not necessarily directly promote the economic development of the current period but promotes the economic development of a certain period in the future. However, the investment in education in the early stage may have a great impact on the current economic development, the expenditure on transfer payments. It does not directly drive the economy but has a transfer payment multiplier, which is often less than 1, indicating that the impact of transfer payment projects on the economy can only be realized through the transmission of individual consumption behavior. To sum up, the growth of fiscal expenditure is often related to the growth of GDP. The growth is not completely synchronous, but we should boldly predict that the change trend of the two should be roughly the same. In the later stage, we will find the cointegration relationship between the two through analysis and then conduct regression analysis.

2.3. Fiscal Expenditure Is Also Affected by Economic Development. Jiang et al. [5] pointed out that economic growth can promote the growth of fiscal expenditure, and the increase of fiscal expenditure can also promote economic growth, but this promotion effect is slightly weaker. Economic factors will also affect fiscal expenditure in turn. The specific way is that affecting the scale of fiscal revenue can limit the scale of fiscal expenditure. The economic factors here mainly refer to the level of economic development, economic policy system, etc. China is still a developing country, and the scale and structure of fiscal expenditure are affected by the economic shape. We can observe that the structure of fiscal expenditure at the beginning of economic reform is clearly consistent with the characteristics of the planned economy period, which shows that infrastructure expenditure accounts for a relatively large proportion. The data in 1978 show that

infrastructure expenditure accounts for 40.3% of fiscal expenditure and economic construction expenditure account for 59.9%. When China's infrastructure construction is improved, the situation is completely different. In particular, it is verified that the basic trend of the change of China's fiscal expenditure structure must be closely related to the reform of the economic system, so it will also change with the change of the economic system.

The above research literature has reference significance for this paper. The following is a further discussion on establishing an econometric model.

3. Research on the Scale and Structure of Fiscal Expenditure

3.1. Analysis of the Change Trend of China's Fiscal Expenditure. The time series data histogram of China's fiscal expenditure from 1998 to 2019 is made according to the data of the statistical yearbook, as shown in Figure 1.

It can be seen that China's fiscal expenditure has shown a steady upward trend in the past 20 years. According to the growth rate of fiscal expenditure, it can be divided into one shock rising stage and two shock falling stages. 1998–2003 was the first period of shock and decline in the growth of fiscal expenditure, and the fiscal expenditure corresponding to this period increased from 1079.818 billion yuan to 2464.995 billion yuan; from 2003 to 2008, the growth rate of fiscal expenditure increased from 2464.995 billion yuan to 6259.266 billion yuan. During this period, the scale of fiscal expenditure in China continued to expand, the expenditure structure continued to be optimized and tended to be perfect and reasonable; 2008–2019 were the second shock decline stage of fiscal expenditure growth, and the corresponding fiscal expenditure increased from 6259.266 billion yuan to 23885.837 billion yuan.

3.2. Development and Change of Fiscal Expenditure Scale in China. We can see from Figure 2 that the scale of fiscal expenditure (the proportion of fiscal expenditure in GDP) has been increasing. Since 1998, China has implemented an active fiscal policy, and the fiscal scale has rebounded rapidly. Especially in 2000, the fiscal deficit rose sharply to 259.66 billion yuan, promoting the proportion of fiscal expenditure in GDP to 16%. In these five years, the fiscal scale has increased by 4.9%, with an average of 1% per year. In 2005, it turned into a prudent fiscal policy. In the following years, although the fiscal deficit was compressed, the fiscal revenue also increased due to the continuous rise of GDP, so the fiscal scale remained stable. At present, under the new economic normal, there is still downward pressure on economic development, and the growth rate of fiscal expenditure decreased significantly, from 21.6% in 2011 to 8.4% in 2015. However, in contrast, the growth rate of GDP is lower than that of fiscal expenditure, which leads to the increase of the growth elasticity coefficient and the marginal tendency of fiscal expenditure, so the fiscal scale is still rising slowly. 2016 is the first year to enter the decisive stage of building a well-off society in an all-around way, but the downward pressure is still large, and the growth rate of fiscal expenditure has decreased steadily.

3.3. Current Expenditure Item in Purchasing Expenditure Education Expenditure. Due to incomplete data, only the situation after 2007 is analyzed. The data is shown in Figure 3.

"Education is the foundation of the Centennial plan." The education level of a country's citizens reflects the national quality of the country. The Chinese government has always attached great importance to the issue of education investment. Government investment is still the main source of education funds at present. According to the outline of education planning, the proportion of national financial education expenditure in GDP should be increased and reach the goal of 4% in 2012. At present, this goal has already been realized and exceeded [6]. At present, the proportion of China's education expenditure in GDP is stable at about 15%. Moreover, the absolute value of education investment has been increasing, and the stable proportion in recent years also shows that the change rate of education expenditure is consistent with the growth rate of GDP. Of course, the overall often covers up some characteristics of the sample. With the overall investment rising, the investment in education has an obvious order of priority. The investment in higher education is far greater than that in basic education, resulting in the inability of the benefit of expenditure to reach a high level, which needs to be further optimized.

3.4. Investment Expenditure Item in Purchasing Expenditure Agriculture, Forestry, and Water Expenditure. The "three rural issues" have been concerned by the state and focused on by fourteen times in the No. 1 central document in 2017. Domestic scholars also pay attention to the relationship between fiscal expenditure and farmers' income and consumption levels. Through regression analysis, Kong and Qiang [7] concluded that the government expenditure on agriculture has increased the disposable income of rural residents and promoted the growth of rural consumption. There is a significant positive correlation between rural consumption demand and GDP growth. In their study, Li [8] found that although the impact of fiscal expenditure on the growth of farmers' income is not significant in the short term, it can significantly drive the rise of farmers' income in the long term. With Granger's analysis method of causality and cointegration, Wang and Wang [9] analyze the impact of agricultural financial expenditure on Farmers' income and come to the conclusion that for every 100 million yuan increase in agricultural financial expenditure, farmers' per capita net income increases by 1.88 yuan; that is, increasing agricultural financial expenditure is the reason for farmers' income growth, and striving to increase agricultural financial expenditure is an effective way to increase farmers' income at present. The results analyzed by various scholars show that the expenditure on agriculture can promote economic development, increase farmers' income in the long run, and help to narrow the gap between the rich and the

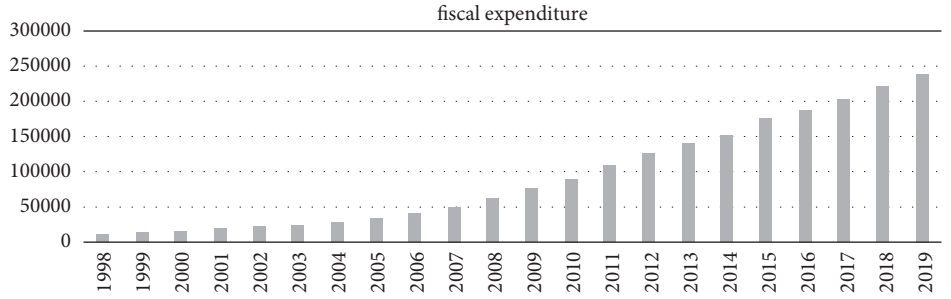

Figure 1: Change trend of China's fiscal expenditure from 1998 to 2019.

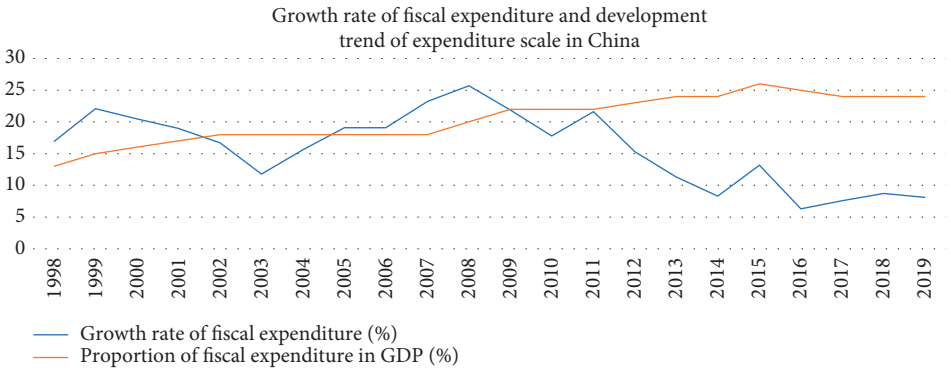

Figure 2: Growth rate of fiscal expenditure and development trend of expenditure scale in China from 1998 to 2019.

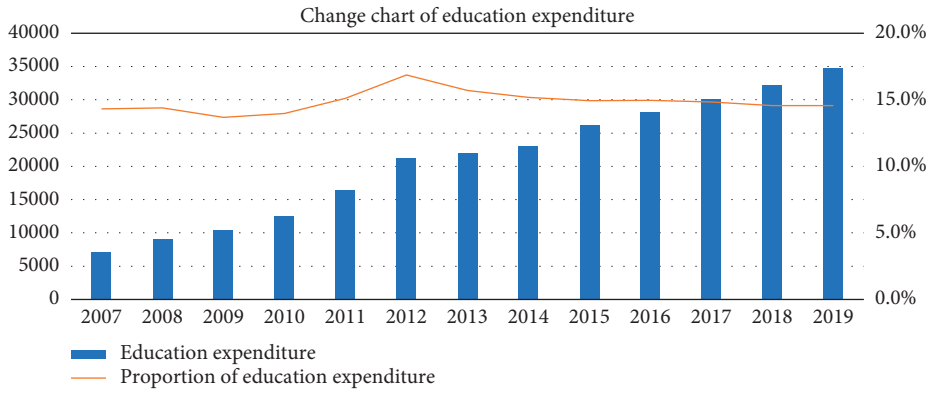

Figure 3: Trends of Education expenditure in China from 2007 to 2019.

poor. Through the analysis of Figure 4, in the current dual situation, China should continue to increase support for agriculture.

3.5. Transfer Expenditure-Social Security and Employment Expenditure. People often think that the market is the most effective, but there are still some failures in the market, and there are serious social problems such as unbalanced income distribution. The transfer payment items in fiscal expenditure are to ensure the products that the market cannot provide and adjust the unbalanced income distribution. As can be seen from Figure 5 the chart, after a short decline from 2007 to 2009, social security and unemployment security expenditure items have increased steadily. In the era of comprehensively winning the well-off society, with the balance of distribution becoming an important topic, social security and unemployment security expenditure items have increased steadily. At present, it is stable at about 12%, which accounts for a large proportion of financial expenditure.

3.6. Summary. Gwana's law puts forward that with the economic development, the government financial expenditure is increasing, which includes both absolute expenditure and relative expenditure [10]. Among them, the increase of absolute expenditure refers to the continuous increase of the total government financial expenditure, and

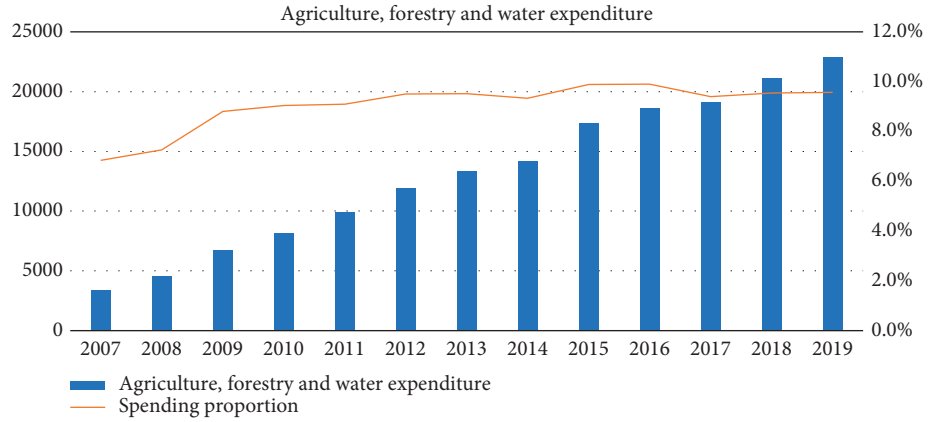

Figure 4: Trends of expenditure on agriculture, forestry, and water in China from 2007 to 2019.

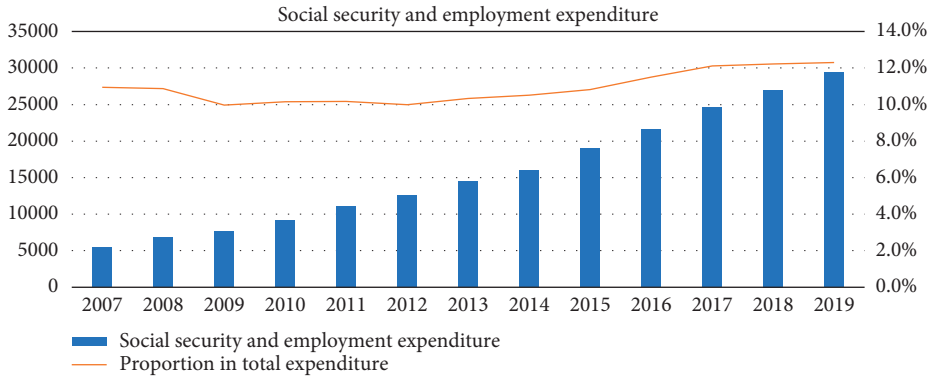

Figure 5: Change trend of social security and employment expenditure in China from 2007 to 2019.

the increase of relative expenditure is that the proportion of government financial expenditure in GDP is increased with the increase of per capita GDP.

Based on the above data, the growth of China's fiscal expenditure scale conforms to this law. At the same time, the absolute value of the three main fiscal expenditure items analyzed above has maintained an upward trend, and the relative proportion has also increased steadily in recent years. It is also observed that the growth of education expenditure in the proportion of GDP is large. The analysis is similar to today's "mass entrepreneurship and innovation." At the same time, the rural revitalization plan also promoted the rise of agricultural financial expenditure, and the pressure of social security funds also forced the financial expenditure to maintain a certain growth rate. However, we ignore other data. In terms of horizontal comparison, China's expenditure structure is still unreasonable, the administrative fee is still too high, the mobilization of resources by fiscal expenditure is still insufficient, and the redistribution function of fiscal expenditure is not strong enough. There is still a lot of room for improvement in the follow-up.

4. Analysis of GDP Change Trend

As can be seen from Figure 6, the total data of China's GDP is rising. However, the growth rate fluctuated greatly, peaked in 2007, but fluctuated downward in the future. According to the analysis, Premier Zhu Rongji took office in 1998 and opened the activity of "cleaning up the triangular debt." In that year, the number of small and medium-sized enterprises decreased by nearly 1/3, and then the GDP growth rate decreased in the following year. However, in the later stage, due to the improvement of the political atmosphere and the recovery of production, the GDP growth rate rose. After China's accession to the WTO in 2001, the growth of foreign trade led to rapid economic development, and the total GDP and growth rate rose rapidly [11]. Premier Wen Jiabao took office in 2003. In the first four years of his 10-year term of office, driven by the 30% month-on-month growth of foreign trade, the upward trend of GDP continued [12]. After the world economic crisis in 2008, the GDP growth rate fluctuated downward. In 2013, Premier Li Keqiang took office, and the downward pressure on GDP remained unabated. By 2019, the data showed that the GDP growth rate was 7.8%. When the epidemic struck in 2020, it is predicted that GDP growth will further decline, with a target of 5% in 2020.

5. Regression and Prediction

5.1. Data Collection. This paper selects five economic indicators: China's GDP, China's GDP growth rate, China's fiscal expenditure, China's fiscal expenditure growth rate, and the proportion of fiscal expenditure in GDP over the calendar years 1998–2019. The specific data are shown in Table 1.

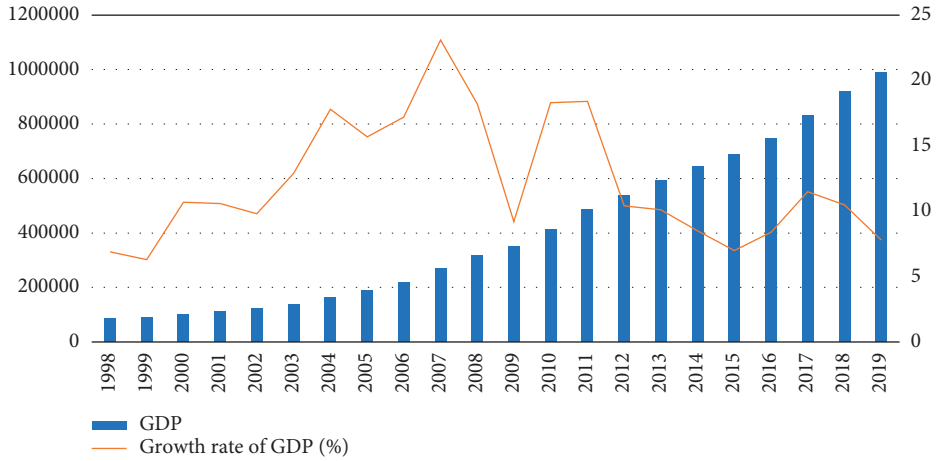

Figure 6: Analysis of GDP change trend.

Table 1: China's GDP and fiscal expenditure data from 1998 to 2019 (unit: 100 million yuan).

Year	GDP	Growth rate of GDP (%)	Fiscal expenditure	Growth rate of fiscal expenditure (%)	Proportion of fiscal expenditure in GDP (%)
1998	85195.5	6.9	10798.18	16.9	13
1999	90564.4	6.3	13187.67	22.1	15
2000	100280.1	10.7	15886.50	20.5	16
2001	110863.1	10.6	18902.58	19.0	17
2002	121717.4	9.8	22053.15	16.7	18
2003	137422.0	12.9	24649.95	11.8	18
2004	161840.2	17.8	28486.89	15.6	18
2005	187318.9	15.7	33930.28	19.1	18
2006	219438.5	17.2	40422.73	19.1	18
2007	270092.3	23.1	49781.35	23.2	18
2008	319244.6	18.2	62592.66	25.7	20
2009	348517.7	9.2	76299.93	21.9	22
2010	412119.3	18.3	89874.16	17.8	22
2011	487940.2	18.4	109247.79	21.6	22
2012	538580.0	10.4	125952.97	15.3	23
2013	592963.2	10.1	140212.10	11.3	24
2014	643563.1	8.5	151785.56	8.3	24
2015	688858.2	7.0	175877.77	13.2	26
2016	746395.1	8.4	187755.21	6.3	25
2017	832035.9	11.5	203085.49	7.6	24
2018	919281.1	10.5	220904.13	8.7	24
2019	990865.1	7.8	238858.37	8.1	24

Data source: China Statistical Yearbook 1998–2019.

5.2. Analysis of the Change Trend of China's GDP Growth Rate and Fiscal Expenditure Growth Rate. Make a broken line diagram of the time series data of China's GDP growth rate and fiscal expenditure growth rate from 1998 to 2019 in Table 1, as shown in Figure 7.

From the image alone, it can be found that China's GDP growth precedes the change of fiscal expenditure growth rate, and there is a lag between them, with a lag of about 1 year. The reason is that the relative growth of GDP in the previous period produced higher fiscal revenue, so the fiscal expenditure in the current period increased accordingly; the relative reduction of GDP in the previous period produced relatively less fiscal revenue, so the fiscal expenditure in the current period decreased accordingly. The typical period of time lag effect is as follows: one year after the shock rise of GDP growth rate from 2002 to 2007, the fiscal expenditure growth rate oscillated upwards from 2003–2008, and the range of the two is the same; one year after the GDP growth rate decreased and rebounded in 2007–2010, the fiscal expenditure growth rate decreased and rebounded in 2008–2011. The two directions are the same, and the change range of the latter is roughly half that of the former. Due to the existence of fixed investment, annual continuous investment, and other fiscal expenditures, when the GDP

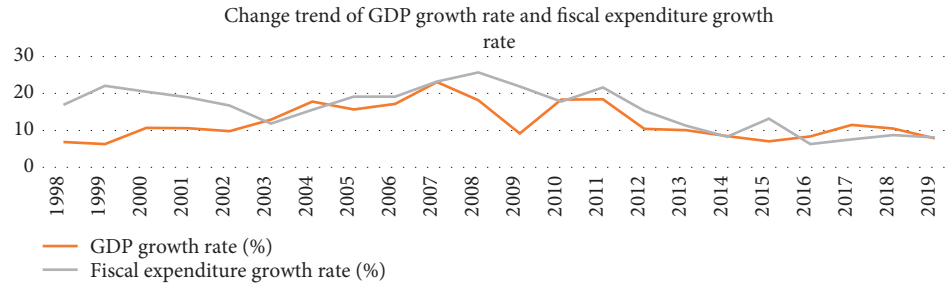

Figure 7: Change trend of China's GDP growth rate and fiscal expenditure growth rate from 1998 to 2019.

growth rate decreased in the previous period, the fiscal expenditure of the current period cannot be reduced by the same range.

5.3. Regression Model Construction. To empirically test the correlation between China's GDP and fiscal expenditure and make regression analysis, this paper constructs the following econometric model:

$$\text{GDP1} = \alpha + \beta E1 + \mu. \tag{1}$$

Among them, the explained variable is GDP1: adjusted gross national product; the explanatory variable is $E1$: it is the financial expenditure after smoothing; the disturbance term is μ, which indicates other effects.

From the initial analysis of the above two steps, it can be found that China's GDP and fiscal expenditure showed a gradual upward trend from 1998 to 2019, and the growth trend was roughly the same. Therefore, we suspect that there is a positive correlation between them. With the help of Econometrics View software, the correlation between them is analyzed as follows. According to the data in Table 1, we first make a regression curve, in which the abscissa e (expenditure) represents fiscal expenditure and the ordinate is GDP. It can be seen from the scattered distribution that there is an obvious positive correlation between China's fiscal expenditure and GDP, and then observe the correlation between them by fitting the regression line, as shown in Figure 8.

It can be seen that most scatter points fall on the fitting regression line, indicating that there is a strong positive correlation between fiscal expenditure and GDP. Next, the correlation between the two is quantified by estimating the correlation coefficient, and the results are shown in Table 2.

The results show that the correlation coefficient between China's fiscal expenditure and GDP from 1998 to 2019 is as high as 0.998337, which is highly positive.

It can be observed from Figure 9 that both China's GDP data and fiscal expenditure data from 1998 to 2019 are time series data with obvious trends, but the trend direction and range are the same. Therefore, direct regression cannot be carried out. Otherwise, the problem of "pseudo regression" will appear. Then we need to take the logarithm of the two and smooth them, and then carry out the unit root test, respectively. If the two variables are of the same order, then we need to further carry out the cointegration analysis.

Taking the logarithm will have a certain smoothing effect on the data. Therefore, taking the logarithm of GDP will be smoothed to generate a new variable GDP1. Similarly, taking the logarithm of fiscal expenditure will be smoothed to generate a new variable $E1$.

$$\begin{aligned} \text{GDP1} &= \ln(\text{GDP}), \\ E1 &= \ln(E). \end{aligned} \tag{2}$$

First, perform a unit root test on GDP1 sequence:.

Models 3, 2, and 1 tests were carried out on the original values, and the p values of the results were 0.2597, 0.1159, and 0.9157, respectively, which accepted the assumption that H0 was "the original value was nonstationary;" Then, the first-order difference of the sequence is tested by models 3, 2 and 1, respectively. The p values of the results are 0.4199, 0.5268, and 0.4855, respectively, which accept the assumption that H0 is "the first-order difference is nonstationary;" then conduct model 3 on the second-order difference of the sequence, and the p value of the test result is 0.0004. Therefore, rejecting the assumption that H0 is "the second-order difference is nonstationary," then we say that the GDP1 sequence is an integration of order 2, that is, GDP1 ~ I (2). The stability test result is shown in Table 3. (All taken $a = 5\%$).

Similarly, Carry Out the Unit Root Test for $E1$ Sequence

Models 3, 2, and 1 tests were carried out on the original values, and the p values of the results were 0.9826, 0.4965, and 0.8952, respectively, which accepted the assumption that H0 was "the original value was nonstationary;" then the first-order difference of the sequence is tested by model 3, 2 and 1 respectively. The p values of the results are 0.0533, 0.4955, and 0.2070, respectively, which accept the assumption that H0 is "the first-order difference is nonstationary;" the second-order difference of the sequence is tested by model 3, and the p value of the test result is 0.0341. Therefore, the hypothesis that H0 is "the second-order difference is nonstationary" is rejected. The second-order single integer of $E1$ sequence is $E1 \sim I$ (2). The stationarity test result is shown in Table 4. (All taken $a = 5\%$).

Through the above stationarity test of the GDP1 and $E1$ time series, it is concluded that GDP1 and $E1$ are second-order single integers. Next, GDP1 and $E1$ are regressed, and the results are shown in Table 5.

The regression equation is obtained from the regression results in the figure:

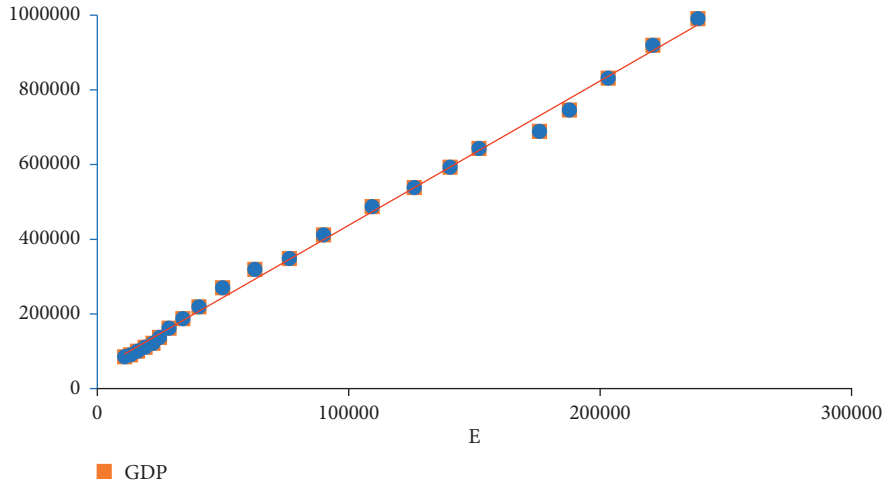

Figure 8: Scatter plot and fitting regression line of fiscal expenditure and GDP.

Table 2: The correlation coefficient between fiscal expenditure and GDP.

	GDP	*E*
GDP	1	0.998337
E	0.998337	1

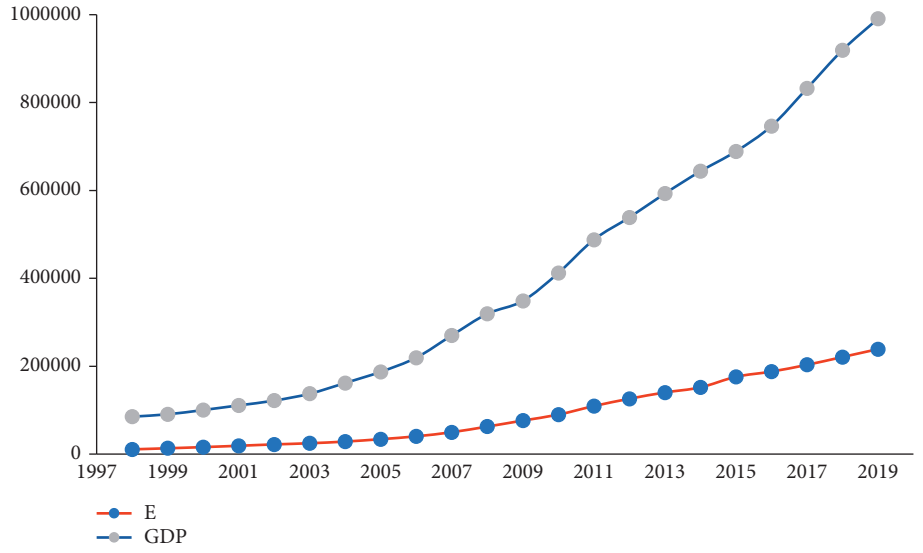

Figure 9: Trend chart of the fiscal expenditure versus GDP.

$$\widehat{\text{GDP1}} = 3.64 + 0.82E1. \quad (3)$$

The two coefficients are not 0, the explanatory variable is very significant, and R2 is 0.996419, indicating that the model fits well.

Then, on the basis that the above unit root test conclusion is a second-order single integer, the stationarity test is carried out for the residuals of GDP1 and $E1$: Mr. Cheng is a new variable R (residual sequence of regression).

$$r = \text{resid}. \quad (4)$$

The p value of the model 3 test result of the original value of the sequence is 0.1267, accept the hypothesis that H0 is "the original value is nonstationary," and then carry out the model 2 test on the original value of the sequence, the p value of the result is 0.0197, reject the hypothesis that H0 is "the original value is nonstationary" (any model can be judged as stable if it rejects the original hypothesis), that is, the residual sequence is stable, so the above relationship is reliable. The stability test results are shown in Table 6.

Table 3: Stationarity test results of China's GDP data from 1998 to 2019.

Null hypothesis: D(GDP1,2) has a unit root Exogenous: constant, linear trend Lag length: 1 (automatic-based on AIC, maxlag = 4)			
Augmented dickey-fuller test statistic		*t*-Statistic −6.282976	Prob* 0.0004
Test critical values	1% level	−4.571559	
	5% level	−3.690814	
	10% level	−3.286909	

*MacKinnon (1996) one-sided *p*-values.Warning: probabilities and critical values calculated for 20 observations and may not be accurate for a sample size of 18Augmented Dickey-Fuller test equationDependent variable: D(GDP1.3)Method: least Squares.

Table 4: Stationarity test results of fiscal expenditure adjustment data in China from 1998 to 2019.

Null hypothesis: *D*(*E*1,2) has a unit root Exogenous: constant, linear trend Lag length: 4 (automatic-based on AIC, maxlag = 4)			
Augmented dickey-fuller test statistic		t-Statistic −3.992231	Prob* 0.0341
Test critical values	1% level	−4.728363	
	5% level	−3.759743	
	10% level	−3.324976	

*MacKinnon (1996) one-sided *p*-values. Warning: probabilities and critical values calculated for 20 observations and may not be accurate for a sample size of 15 augmented Dickey-Fuller test equation dependent variable: *D*(*E*1,3) method: least squares.

Table 5: Regression results of China's GDP and fiscal expenditure data from 1998 to 2019.

Dependent variable: GDP1 Method: least squares Date: 11/30/20 time: 21 : 44 Sample: 1 22 Included observations: 22				
Variable	Coefficient	Std. Error	t-Statlstic	Prob*
C	3.636767	0.121032	30.04794	0.0000
*E*1	0.815901	0.010938	74.59486	0.0000
R-squared	0.996419			
Adjusted *R*-squared	0.996240	Mean dependent var		12.62911
S.E. of regression	0.050667	S.D. dependent var		0.826231
Sum squared resid	0.051342	Akaike info criterion		−3.040585
Log likelihood	35.44643	Schwarz criterion		−2.941399
F-statistic	5564.393	Hannan-quinn enter		−3.017220
Prob (F-statistic)	0.000000	Durbin-watson stat		0.674709

5.4. Forecast China's GDP in the Next Five Years. According to the above prediction and regression equation of China's fiscal expenditure in the next five years, China's GDP in the next five years is estimated as shown in Table 7:

Table 6: The stationarity test results of residuals of GDP and fiscal expenditure data from 1998 to 2019.

Null hypothesis: *R* has a unit root Exogenous: constant Lag length: 0 (automatic-based on AIC, maxlag = 4)			
Augmented dickey-fuller test statistic		t-Statistic −3.469158	Prob* 0.0197
Test critical values	1% level	−3.788030	
	5% level	−3.012363	
	10% level	−2.646119	

*MacKinnon (1996) one-sided *p*-values.

Table 7: Forecast of China's GDP in the next five years (unit: 100 million yuan).

Years	GDP (亿元)
2020	1051154.88
2021	1122422.66
2022	1198522.37
2023	1290318.96
2024	1382782.04

Note. GDP is derived from the fiscal expenditure of the corresponding year through the regression equation, and the fiscal expenditure of the current year is calculated from the average growth rate of fiscal expenditure.

6. Policy Recommendations

Based on the above analysis results, the following suggestions are put forward to improve the relationship between China's fiscal expenditure and GDP.

6.1. The Government's Economic Policy Must Maintain Continuity and Stability. From the above analysis, it can be seen that the change trend of fiscal expenditure and GDP is almost synchronous and even plays a leading role in guiding the change of GDP. At the same time, fiscal expenditure also constitutes an important part of economic accounting. Therefore, to ensure the continuity and stability of economic development, it is necessary to maintain the continuity and stability of fiscal expenditure.

6.2. Ensure that the Growth of Fiscal Expenditure Is Commensurate with Economic Development. According to the current forms, we must implement the supply side structural reform, maintain a certain scale growth of fiscal expenditure, ensure the speed of economic growth, and maintain the intensity of the expenditure on individual key projects. First of all, we should appropriately expand the scale of the fiscal deficit. Under the current epidemic situation, supply side reform is imminent. Fiscal expenditure should be matched with it to continuously stimulate demand and increase effective supply. Secondly, we should effectively use the surplus of the previous year, make the existing stock funds active, and ensure the adequacy of the financial budget in the process of reducing the tax burden of enterprises [13]. The surplus funds are mainly used to make up for the lack of social security and maintain social stability [14]. At the same

time, we should also strengthen the reform of the budget management system, turn the government fund budget into a general public budget so that it can be arranged uniformly, to increase the scale of financial expenditure.

6.3. Increase Expenditure on Key Projects and Optimize the Expenditure Structure. While controlling the moderate growth of fiscal scale, we should also pay attention to the optimization of fiscal expenditure structure and strengthen its expenditure proportion for expenditure projects that promote large economic development. According to the research of [10], Qi and Yue, the contribution of social protection expenditure is the largest, 71.66%. The second is the proportion of health care expenditure, with a contribution of 34.15%, and the contribution of education expenditure is 10.47%. For these three items, the government should not only increase expenditure but also pay attention to the balance of expenditure within the project. At present, China's investment in higher education is strong, but it ignores the investment in basic education to a certain extent, which seriously affects the efficiency of this expenditure. Of course, the contribution to the economy is not the only criterion. Although the contribution of environmental protection expenditure to the economy is negative, we should also increase its expenditure. On the one hand, the output of such expenditure is difficult to measure, so it is possible to ignore its contribution in the calculation. On the other hand, just on the surface, President Xi also said, "Green water and green mountains are golden mountains and silver mountains." This shows that environmental improvement makes a great contribution to people's non-economy. At the same time, China's environmental expenditure accounts for only 4-5%, which is far from the standard of developed countries. In conclusion, we should continue to increase expenditure on some key projects to continuously optimize the expenditure structure and promote economic growth [15].

6.4. Maintain the Declining Trend of Administrative Expenses and Jointly Optimize the Expenditure Structure. With the development of the economy, the affairs of the government have become complicated, and the corresponding administrative fees will naturally increase. In the previous years, with the activity of "beat tigers and flies," administrative fees became less. Of course, administrative fees cannot disappear, and their increase is also proved by history. However, while administrative expenditure is bound to grow in absolute terms, we should keep its relative number declining, cooperate with the financial expenditure to turn to other key projects, and further optimize the expenditure structure.

6.5. We Should Give Full Play to the Strength of All Sectors of Society in the Construction of Social People's Livelihood. The original financial idea of package contracting has put great pressure on financial expenditure, which often makes the rational use of funds lose direction. The government cannot do everything. The way of financial expenditure needs to be innovated. Under the condition of a socialist market economy, we should strengthen the idea of taking from the people and using them for the people; on the one hand, continue to play the positive role of finance; on the other hand, allow social funds into some areas of financial management. Our social needs are diverse and rich in levels. For those needs that can be provided by the market, the government should open its arms and actively mobilize the enthusiasm of all sectors of society. Of course, while transferring part of investment expenditure to society, we should retain the expenditure in those areas with strong externalities and pay attention to the efficiency of fiscal expenditure to make better use of the determined scale funds. The popular PPP model (public private partnership) is the practice of this idea, such as "Beijing line 4," the quasipublic good, which is also a case of the PPP project. Therefore, the government can get rid of heavy affairs and gradually change from the past provider of infrastructure public services to a regulator, which not only pursues quality but also reduces the pressure on the government in terms of budget. Of course, to standardize the operation of this model, there must be more perfect legal support.

6.6. Continuously Strengthen the Construction of the System. While increasing financial investment, we must strengthen the cooperation of system construction. Otherwise, even if the investment continues to increase, it is difficult to give full play to the effectiveness of the goal. We must establish and improve relevant mechanisms for a series of problems existing in the management system and the problems found in the operation to ensure the development of social undertakings.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

There are no conflicts of interest in this article.

Acknowledgments

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Research Article

Evaluation of Comprehensive Ability of Accounting Applied Talents Based on GFAHP-Cloud Model

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Through the objective and fair evaluation of the comprehensive ability of accounting talents cultivated in colleges and universities, on the one hand, it is beneficial to provide direction for cultivating accounting applied talents in colleges and universities, and on the other hand, it can also provide reference for enterprises to select talents. Firstly, this study constructs an evaluation index system for the comprehensive ability of accounting applied talents and selects 15 indicators from three aspects of knowledge level, ability level, and moral level. Secondly, the group fuzzy analytic hierarchy process is used to determine the index weight. Finally, a fuzzy comprehensive evaluation model based on the cloud model is constructed and tested in practice. This study hopes to make an objective and fair evaluation for accounting talents by quantitatively evaluating the comprehensive ability of accounting applied talents.

1. Introduction

With the transformation of world economy from industrial economy to knowledge economy and the rapid development of economy and society in China, accounting applied talents play an important role in economic and social development as practical and applied human resources [1, 2]. Therefore, the ability and quality of accounting applied talents are facing various new challenges. The evaluation of accounting applied talents is the basic link of the overall training, development, and use of accounting applied talents, which play a connecting role [3]. So, it is of great theoretical and practical significance to evaluate the comprehensive ability of accounting applied talents cultivated in colleges and universities objectively and fairly.

First, it is beneficial for schools to formulate training plans [4, 5]. The teachers can objectively find the advantages and disadvantages of students through reasonable comprehensive evaluation. It can not only give full play to the advantages of students, but also make up for the disadvantages through targeted teaching, so that each student can enjoy the learning process and truly learn knowledge. Second, it is beneficial for enterprises to select and recruit talents. If there is a complete and reasonable evaluation system of accounting applied talents, enterprises can choose some position interns according to the evaluation results. Interns recruited in this way are more in line with the requirements of enterprise work and the employment direction of students [6–8]. This directional selection of talents is based on the needs of enterprises and students to work matching, which can not only reduce the cost of human resources, but also save students' time, so as to achieve a win-win goal of job seekers and interviewers [9]. Third, it is conducive to the implementation of people-oriented development concept. The people-oriented development concept mainly means full respect for the wishes of students and teachers in colleges and universities [10, 11]. It can fully consider the wishes of students and teachers through the implementation of objective and fair university talent evaluation mechanism and truly implement the people-oriented development concept.

However, there are still many deficiencies in the comprehensive ability evaluation of accounting applied talents. On the one hand, there is a lack of an evaluation system for the comprehensive ability of accounting applied talents, and the existing evaluation index system cannot fully reflect the

characteristics of accounting applied talents [12]. On the other hand, the current society is mainly aimed at the evaluation of accounting professional ability, which cannot scientifically and comprehensively evaluate the comprehensive ability of accounting talents. Moreover, although the current research results have promoted the reform of accounting education and the improvement of the quality of accounting talents to varying degrees, the orientation of the training objectives of accounting talents is not clear enough, and there is no evaluation model for the comprehensive ability of accounting talents from a comprehensive perspective. Therefore, it is necessary to study the comprehensive ability evaluation method of accounting applied talents.

By analyzing the existing research results and evaluation methods, we found that previous studies mostly used qualitative research methods, but lacked quantitative assessment and evaluation. Therefore, the main contribution of this study has two aspects. On the one hand, this study constructs the comprehensive ability evaluation index system of accounting applied talents from three aspects of knowledge level, ability level, and moral level. On the other hand, this study puts forward a kind of fuzzy comprehensive evaluation method, which uses group fuzzy analytic hierarchy process and cloud model to evaluate the comprehensive ability of accounting applied talents. Its advantage is that it can significantly reduce the interference of subjective factors to a certain extent and quantitatively analyze nonquantitative factors. In addition, the determination and calculation of index weights at all levels are also more scientific. This method has higher accuracy than the traditional fuzzy comprehensive evaluation method, and the results are closer to the actual situation.

This study is divided into five parts. The first part describes the research background and significance. The second part summarizes the relevant literature research. The third part constructs the comprehensive ability evaluation index system of accounting applied talents from three aspects of knowledge level, ability level, and moral level. The fourth part describes the modeling process of group fuzzy analytic hierarchy process and cloud model fuzzy comprehensive evaluation method. Finally, taking "class A" as an example, it is found that the method proposed in this study can more accurately evaluate the comprehensive ability of accounting applied talents.

2. Related Work

To improve the comprehensive quality and ability of accounting practitioners, researchers realize that the implementation of accounting talent evaluation system is very important, which is helpful to improve the service quality of accounting industry and promote its steady development in the era of big data. At present, the research on accounting talents mainly includes training mode and ability evaluation. For example, Liu [13] proposed a talent innovation training model suitable for China after comparing it with European and American countries, including four aspects: scientific research, teaching methods, school-enterprise cooperation, and innovation projects. Finally, the applicability of this model was proved by taking the accounting profession as an example. After analyzing the problems existing in the process of cultivating accounting talents, Song [14] put forward the innovation of cultivating accounting talents from the aspects of teaching content and environment, teachers, and teaching evaluation system, so that accountants can better adapt to the changes brought by artificial intelligence. With the advent of the era of big data, Zhang [15] believed that accounting personnel training mode should keep pace with the times. By analyzing the problems existing in the traditional mode of accounting teaching, this study put forward a digital teaching effect monitoring mode, emphasizing the cultivation of students' practical ability. Other scholars analyze and evaluate the comprehensive ability of accountants from different angles. For example, Zhu et al. [16] constructed an evaluation index system from four aspects of learning ability, professional level, management ability, and self-discipline and then used the questionnaire survey method to study the competency of accounting applied talents. The results showed that the comprehensive ability of accounting applied talents in China is at a good level.

There are many evaluation methods about talent ability. For example, Lan [17] constructed the evaluation index system of innovative ability of talents from four aspects: learning ability, innovative thinking ability, observation ability, and self-confidence and then evaluated it by matter-element extension method. The results showed that this method can reflect the strength of talent innovation ability from different perspectives. Guo and Yang [18] constructed the evaluation index system of urban talent aggregation ability from the perspective of urban economic development level, construction and environmental conditions, education and medical and health services, living standards, and career development platform and then used principal component analysis to conduct empirical research. He et al. [19] constructed an evaluation index system for the teaching ability of university scientific research talents according to the requirements and actual situation of cultivating students in colleges and universities and then used BP neural network and fuzzy mathematics theory to evaluate it. Through empirical research, it is found that this method can be applied to the actual evaluation process and can improve the evaluation efficiency to a certain extent. The same is to evaluate the teaching ability, and Gao [20] innovatively introduced data mining into evaluation and found that the method can more truly reflect the teaching ability of teachers through empirical research.

3. Design of Comprehensive Ability Evaluation Index System for Accounting Applied Talents

3.1. Principle of Design. Since the selection of indicators is related to whether the evaluation results are comprehensive and accurate, some principles should be followed in the construction of the index system, so as to ensure that the final evaluation results are feasible. By searching and reading relevant literature, this study finds that the selection of fair

evaluation index of comprehensive ability of talent training should have the following principles:

(1) Comprehensive principle: we need to take into account all aspects related to the comprehensive ability of personnel training, so we should conduct a comprehensive assessment from the aspects of morality, ability, physical quality, and mental health of college students majoring in accounting.

(2) Typical principle: we need to ensure that each selected evaluation index has a certain typical representativeness, on the basis of simply indicating the inherent meaning of the evaluation object. We should reflect the performance of college accounting students in different aspects as accurately as possible.

(3) Operative principle: we need to ensure that there is a correlation between the selected indicators, so the results will be more accurate when the experts score the importance of the two indicators, so that the final calculated index weight is more convincing.

3.2. Index System Establishment. This study summarizes the literature on the comprehensive ability evaluation of accounting personnel training and combines the opinions and suggestions of experts and professors to fully understand the comprehensive ability evaluation system of accounting applied talents. Then, according to the basic idea of analytic hierarchy process, the relationship between the internal factors of the system is analyzed, and the comprehensive ability evaluation index system of accounting applied talents is established as shown in Figure 1.

4. GFAHP-Cloud Model for Comprehensive Ability Evaluation of Accounting Applied Talents

4.1. GFAHP for Criteria Weight Determination. The index system established in this study has a clear hierarchical structure, so the analytic hierarchy process (AHP) is selected as the basic method for the comprehensive ability evaluation of accounting applied talents. However, the traditional AHP method has two main problems in determining the weight. On the one hand, in the case of many indicators, complex index system, and wide range of knowledge involved, individual decision-makers are limited by personal ability, knowledge, and experience, which can easily lead to deviation between the weight judgment results and the actual situation. On the other hand, when experts use the 1–9 scale method to score, it is easy to appear difficult to express fuzzy cognition [21, 22].

Therefore, this study selects group fuzzy analytic hierarchy process (GFAHP) to determine the index weight. On the one hand, the triangular fuzzy number is introduced to improve the analytic hierarchy process so that each index has a fuzzy evaluation interval. This interval can be used to compare the relative importance of the elements, which may leave a margin for the uncertainty of the experts. The existence of this interval reflects the influence of the uncertainty of the relative importance of experts among elements on the evaluation results to a certain extent. On the other hand, when this method gives the judgment matrix, it is not given by an expert but by a group of experts to give their individual judgment matrix and then assembles each judgment matrix to form a group judgment matrix. The aggregation of individual judgment matrix needs to introduce expert opinion consistency weight and expert authority weight. The expert consistency weight is aggregated by clustering analysis method, and the expert authority weight is aggregated by group decision-making. This takes into account both the concentration of expert opinions and the authority of experts, so as to avoid inaccurate decision-making results due to the subjective preferences of an expert [23].

4.1.1. Triangular Fuzzy Number. Let a fuzzy be set as $\widetilde{X}$ on the domain V if

(1) The membership function of $\widetilde{X}$ can be expressed as $\mu_{\widetilde{x}}(x)$: $V \longrightarrow [0,1]$

$$\mu_{\widetilde{x}}(x) = \begin{cases} 0, & x < a, \\ \dfrac{x-a}{b-a}, & a \le x \le b, \\ \dfrac{c-x}{c-b}, & b \le x \le c, \\ 0, & x > c. \end{cases} \tag{1}$$

In the formula, $a \le b \le c$, a, b, c denote the lower bound, intermediate value, and upper bound of $\widetilde{X}$, respectively.

(1) Existence $x_0 \in R$ makes $\mu_{\widetilde{X}}(x_0) = 1$

(2) For any $\lambda \in (0,1)$, $\widetilde{X}_\lambda = \left\{x | \mu_{\widetilde{X}}(x) \ge \lambda\right\}$ is a convex set

$\widetilde{X}$ is called triangular fuzzy number and can be denoted as $\widetilde{X} = (a, b, c)$.

Assuming that $\widetilde{X}1 = (a_1, b_1, c_1)$ and $\widetilde{X}_2 = (a_2, b_2, c_2)$ are two triangular fuzzy numbers, the possibility degree of $X_1 \ge X_2$ is defined as follows:

$$\left\{ V(X_1 \ge X_2) = \begin{cases} 1, & b_1 \ge b_2, \\ \dfrac{a_2 - c_1}{(b_1 - c_1) - (b_2 - a_2)}, & b_1 \le b_2, c_1 \ge a_2, \\ 0, & \text{otherwise.} \end{cases} \right\} \tag{2}$$

The possibility degree of $X \ge X_1, X_2, \ldots, X_n$ is defined as follows:

$$V(X \ge X_1, X_2, \ldots, X_n) = \min V(X \ge X_i) i = 1, 2, \ldots, n. \tag{3}$$

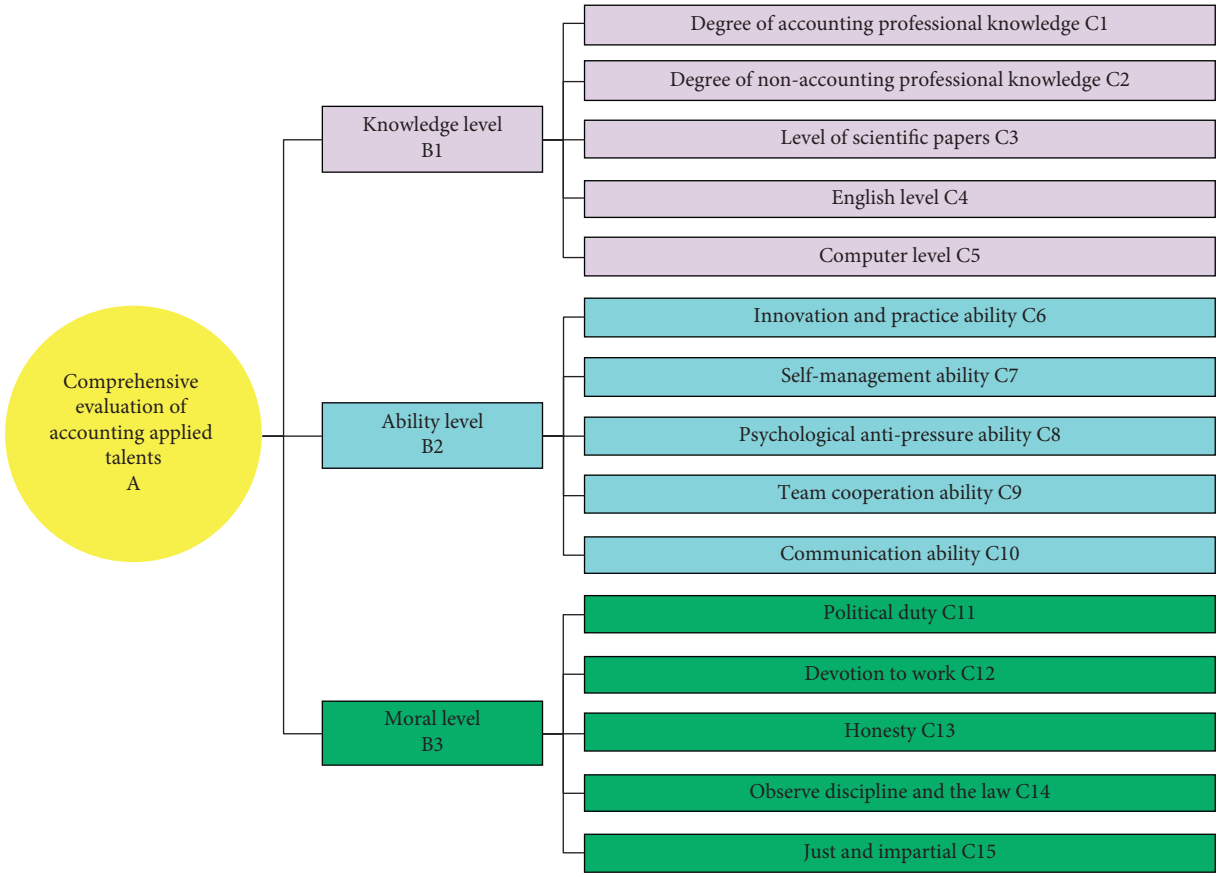

Figure 1: Evaluation index system of comprehensive ability of accounting applied talents.

4.1.2. GFAHP

(1) Construct Fuzzy Judgment Matrix

(1) Define the mapping of comment sets and fuzzy numbers. Table 1 shows the comment set and its corresponding fuzzy numbers.

(2) Decision-makers provide judgment matrices separately. The experts score according to the scale and label in Table 1. The importance judgment matrix of indicators is as follows:

$$\tilde{X}^k = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & a_{11} & a_{nn} \end{pmatrix}. \tag{4}$$

In the formula, a_{ij} is the comment set in Table 1, indicating the importance of the index i relative to the index j under the same criterion layer, and k represents the k^{th} expert.

(3) Weight average of decision-makers. The formula for calculating the weighted average of expert scoring is as follows:

Table 1: Mapping between comment set and fuzzy number.

Evaluation scale	Label	Fuzzy number	Label	Fuzzy number
Completely equal	P	(1, 1, 1)	DP	(1, 1, 1)
Equal importance	C	(1/2, 1, 3/2)	DC	(2/3, 1, 2)
A little important	L	(1, 3/2, 2)	DL	(1/2, 2/3, 1)
General important	G	(3/2, 2, 5/2)	DG	(2/5, 1/2, 2/3)
Very important	V	(2, 5/2, 3)	DV	(1/3, 2/5, 1/2)
Extremely important	E	(5/2, 3, 7/2)	DE	(2/7, 1/3, 2/5)

Note. P and DP represent the opposite important relationship.

$$a_{ij} = \left(\sum_{k=1}^{n} \frac{a_k}{n}, \sum_{k=1}^{n} \frac{b_k}{n}, \sum_{k=1}^{n} \frac{c_k}{n} \right), \quad k = 1, 2, \ldots, n. \tag{5}$$

In the formula, lk, mk, uk represent the expert to each index score, and n represents the number of experts.

(2) Consistency Test of Judgment Matrix. Firstly, the triangular fuzzy judgment matrix is transformed into the consistency judgment matrix by the defuzzification method. In this study, formula (6) is used for defuzzification.

$$\text{Deff}(\tilde{M}) = \frac{a + 4b + c}{6}. \tag{6}$$

Secondly, the matrix consistency index is calculated by formula (7), where λ max is the largest eigenvalue in comparison matrix, and m is the order of the matrix.

$$CI = \frac{\lambda_{\max} - m}{m - 1}. \tag{7}$$

Finally, the matrix consistency ratio is calculated by formula (8). The value of RI is shown in Table 2.

$$CR = \frac{CI}{RI}. \tag{8}$$

If $CR \le 0.1$, it is considered to pass the consistency test; otherwise, the decision-maker needs to readjust the judgment matrix.

(3) Calculate Weights. Firstly, according to formula (9), the comprehensive fuzzy weight value of the factor i in the k layer of the criterion layer is calculated.

$$\tilde{w}_i^K = \sum_{j=1}^{n} a_{ij}^K \times \left(\sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij}^K \right)^{-1}, \quad i = 1, 2, \ldots, n. \tag{9}$$

Then, formula (10) is used to defuzzify the comprehensive fuzzy weight value and normalize it to calculate the weight value of each factor in the k layer.

$$w_i^K = V\left(\tilde{w}_i^K \ge \tilde{w}_1^K, \ldots, \tilde{w}_{i-1}^K, \tilde{w}_{i+1}^K, \ldots, \tilde{w}_n^K\right), \quad i = 1, 2, \ldots, n. \tag{10}$$

Finally, according to formula (11), the weight value of factor m relative to the total goal is obtained, where W_i represents the weight value of element i; W_{ij} represents the weight value of the sub-element j of element i to element i; and wjm represents the weight value of the child element k of element j to element j.

$$W_m = W_i W_{ij} W_{jm}. \tag{11}$$

In summary, the general idea of the group fuzzy analytic hierarchy process model is shown in Figure 2.

4.2. Cloud Model. The cloud model theory has the advantages of describing the randomness and uncertainty of fuzzy evaluation system and can transform qualitative concepts and quantitative values [24]. Based on the advantages of cloud model theory, this study combines cloud theory and fuzzy comprehensive evaluation model to improve the accuracy of comprehensive ability evaluation of accounting applied talents.

4.2.1. Basic Theory of Cloud Model. The basic theory of cloud is as follows: assuming that U is a specific range of numerical changes, T is a qualitative concept with a certain correspondence with U, and the membership degree $CT(x)$ of the element x ($x \in X$) to the concept represented by T is a one-to-many probability distribution, then the distribution of membership degree constitutes a mapping from the universe U to the interval [0, 1], and the macro is the cloud. The cloud droplets are the basic unit of clouds. A certain number of

Table 2: RI values under different orders.

Order	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

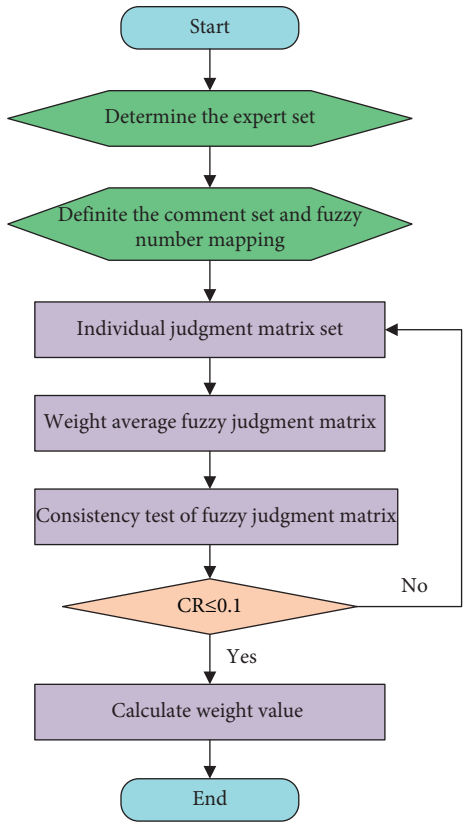

Figure 2: General idea of GFAHP model.

cloud droplets quantify the characteristics of qualitative concepts through their 3 digital features [25]. These three numerical characteristics are expected value, entropy, and hyper-entropy respectively, as shown in Figure 3.

Ex represents the center value of the concept in the domain, which is the position of the macroscopic peak of the cloud. Taking Figure 3 as an example, the expected value is 50, indicating that the cloud droplets at 50 in the numerical domain have the largest membership degree, and the sample points corresponding to the cloud droplets are the most representative. En is the measurement of conceptual ambiguity, which reflects the bilateral boundary of qualitative concepts in the domain in a quantitative form and reflects the fuzziness of qualitative concepts. He is a measure of entropy randomness, reflecting the uncertainty of samples. The small hyper-entropy indicates that the uncertainty close to or away from the corresponding concept center is relatively small, reflecting the internal correlation between fuzziness and randomness. The concept of cloud is not a definite membership curve, but a qualitative concept represented by it. The cloud model integrates fuzziness and randomness through the above three digital features, and each cloud droplet represents a mapping of qualitative concepts in the quantitative domain.

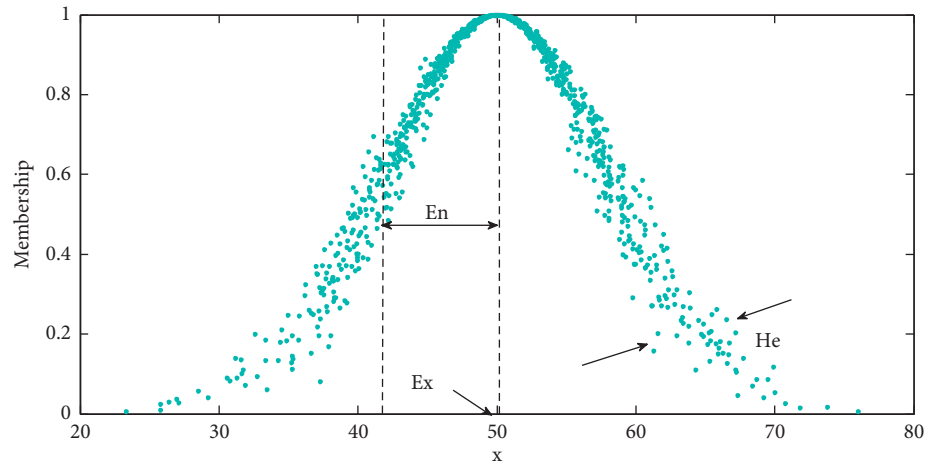

Figure 3: Digital feature diagram of cloud.

4.2.2. Cloud Model Process

(1) Because the corresponding evaluation values of different grades have bilateral value ranges, using cloud model to approximate the evaluation value can avoid the randomness and fuzziness ignored by previous numerical values and can form a more intuitive evaluation standard cloud. The calculation formula is as follows [26]:

$$Ex = \frac{C_{\max} + C_{\min}}{2},$$
$$En = \frac{C_{\max} - C_{\min}}{6}, \tag{12}$$
$$He = k.$$

(2) Because most of the variables in the evaluation index system are expressed in the way of language description, it is difficult to quantify by certain numerical value and only through experienced experts to score the qualitative description. After each expert gives the score of each indicator, the group decision cloud is calculated according to the following formulas:

$$Ex = \frac{\sum_{i=1}^{n} x_i}{n}, \tag{13}$$

$$En = \sqrt{\frac{\pi}{2}} \times \frac{1}{n} \sum_{i=1}^{n} |xi - Ex|, \tag{14}$$

$$He = \sqrt{\frac{\sum_{i=1}^{n} (x_i - Ex)^2}{n-1} - En^2}. \tag{15}$$

(3) After determining the standard cloud and weight coefficient, it is necessary to evaluate the comprehensive ability of accounting applied talents. The comprehensive evaluation results can be obtained by substituting the weight coefficient into the following formulas to calculate the cloud digital characteristics:

$$Ex = \sum_{i=1}^{n} Ex_i \cdot \lambda_i, \tag{16}$$

$$En = \sqrt{\sum_{i=1}^{n} En_i^2 \cdot \lambda_i}, \tag{17}$$

$$He = \sum_{i=1}^{n} He_i \cdot \lambda_i. \tag{18}$$

In summary, the cloud model fuzzy comprehensive evaluation method process is shown in Figure 4.

5. Example Analysis

5.1. Weight Calculation. This study adopts group fuzzy analytic hierarchy process to determine index weight. First of all, three experts are invited to score according to the importance of indicators. The three experts give the importance judgment matrix of each indicator layer, as shown in Appendix A. Then, the weighted average fuzzy judgment matrix and the maximum eigenvalues and eigenvectors of the matrix are calculated. After normalizing the feature vector, the index weight of the criterion layer is calculated, and finally, the final weight of each index can be obtained according to formula (11). The final results of the index weights are shown in Table 3 and Figure 5. Finally, the consistency of each judgment matrix is tested. If all of them pass one-time test, the index weight results are effective. According to the following results, it can be seen that the

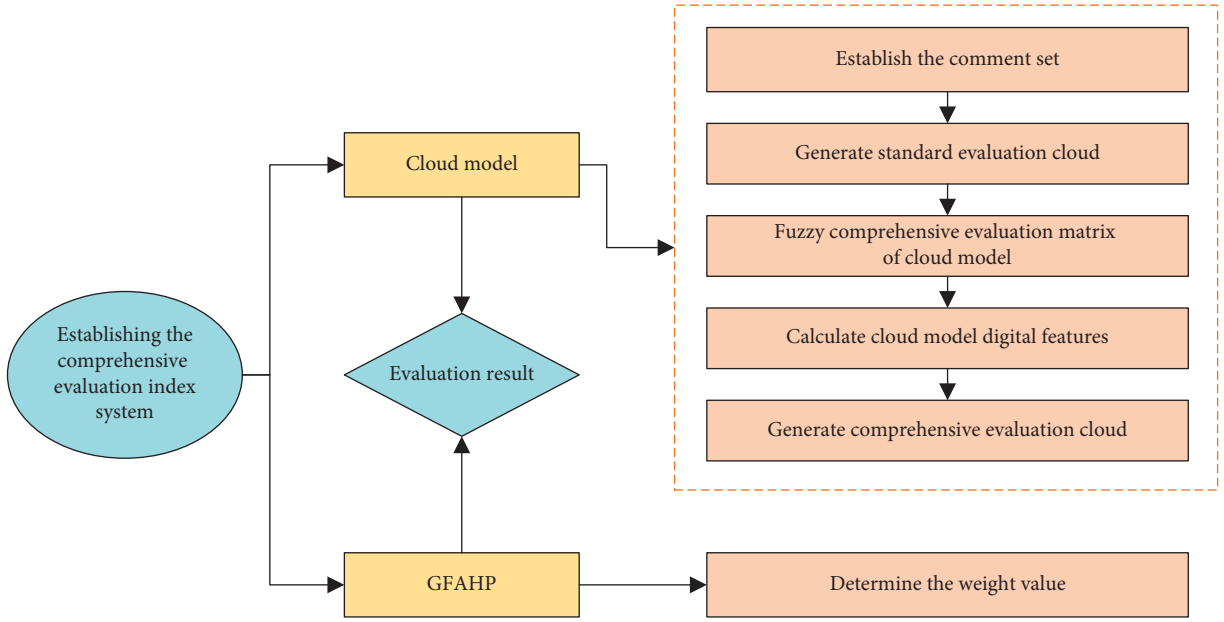

Figure 4: Flow chart of cloud model fuzzy comprehensive evaluation method.

Table 3: Calculation results of evaluation index weight.

Criterion layer	Weight	Indicator layer	Weight	Ultimate weight
		*C*1	0.3022	0.0546
		*C*2	0.1539	0.0278
*B*1	0.1806	*C*3	0.1557	0.0281
		*C*4	0.1848	0.0334
		*C*5	0.2034	0.0367
		*C*6	0.2397	0.0724
		*C*7	0.1228	0.0371
*B*2	0.3021	*C*8	0.1390	0.0420
		*C*9	0.3027	0.0915
		*C*10	0.1958	0.0592
		*C*11	0.1320	0.0683
		*C*12	0.2923	0.1512
*B*3	0.5173	*C*13	0.2336	0.1209
		*C*14	0.1887	0.0976
		*C*15	0.1533	0.0793

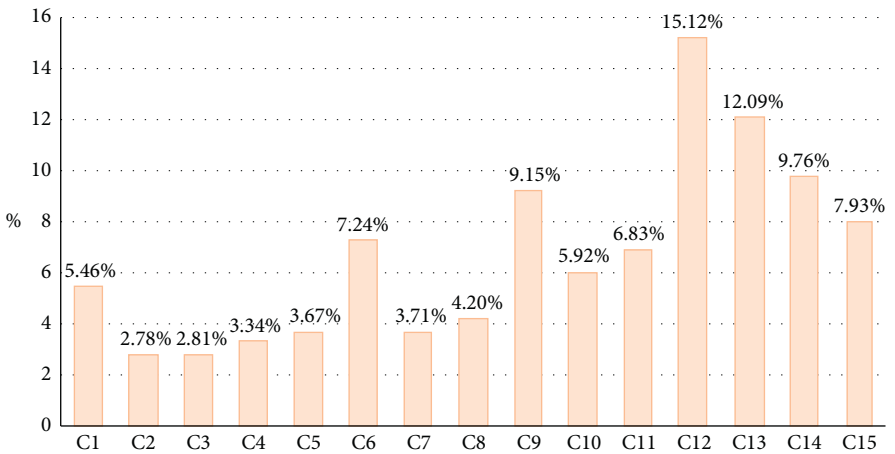

Figure 5: Weight of comprehensive ability evaluation index of accounting applied talents.

Table 4: Cloud model of comprehensive ability evaluation standard for accounting applied talents.

Comment rate	Rating range	Digital characteristic
Very good	(8, 10]	(9, 0.33, 0.05)
Good	(6, 8]	(7, 0.33, 0.05)
General	(4, 6]	(5, 0.33, 0.05)
Poor	(2, 4]	(3, 0.33, 0.05)
Very bad	(0, 2]	(1, 0.33, 0.05)

judgment matrix given by the experts in this study has passed the one-time test, so the results are effective.

$$
\begin{pmatrix}
 & B1 & B2 & B3 \\
B1 & (1.0000, 1.0000, 1.0000) & (0.4333, 0.5556, 0.7778) & (0.3333, 0.4000, 0.5000) \\
B2 & (1.3333, 1.8333, 2.3333) & (1.0000, 1.0000, 1.0000) & (0.3778, 0.4667, 0.6111) \\
B3 & (2.0000, 2.5000, 3.0000) & (1.6667, 2.1667, 2.6667) & (1.0000, 1.0000, 1.0000)
\end{pmatrix},
$$

$CI = 0.0326 \quad CR = 0.0563,$

$$
\begin{pmatrix}
 & C1 & C2 & C3 & C4 & C5 \\
C1 & (1.0000, 1.0000, 1.0000) & (1.8333, 2.3333, 2.8333) & (1.5000, 2.0000, 2.5000) & (1.1667, 1.6667, 2.1667) & (1.0000, 1.5000, 2.0000) \\
C2 & (0.3556, 0.4333, 0.5556) & (1.0000, 1.0000, 1.0000) & (0.5000, 0.6667, 1.0000) & (0.5000, 0.6667, 1.0000) & (1.0000, 1.5000, 2.0000) \\
C3 & (0.4000, 0.5000, 0.6667) & (1.0000, 1.5000, 2.0000) & (1.0000, 1.0000, 1.0000) & (0.5000, 0.7778, 1.1667) & (0.4333, 0.5556, 0.7778) \\
C4 & (0.4667, 0.6111, 0.8889) & (1.0000, 1.5000, 2.0000) & (0.8889, 1.3333, 2.0000) & (1.0000, 1.0000, 1.0000) & (0.5000, 0.6667, 1.0000) \\
C5 & (0.5000, 0.6667, 1.0000) & (0.5000, 0.6667, 1.0000) & (1.3333, 1.8333, 2.3333) & (1.0000, 1.5000, 2.0000) & (1.0000, 1.0000, 1.0000)
\end{pmatrix},
$$

$CI = 0.0752 \quad CR = 0.0672,$

$$
\begin{pmatrix}
 & C6 & C7 & C8 & C9 & C10 \\
C6 & (1.0000, 1.0000, 1.0000) & (1.5000, 2.0000, 2.5000) & (1.5000, 2.0000, 2.5000) & (0.5000, 0.6667, 1.0000) & (0.6667, 1.1667, 1.6667) \\
C7 & (0.4000, 0.5000, 0.6667) & (1.0000, 1.0000, 1.0000) & (0.5556, 0.7778, 1.3333) & (0.3778, 0.4667, 0.6111) & (0.5000, 0.6667, 1.0000) \\
C8 & (0.4000, 0.5000, 0.6667) & (0.8333, 1.3333, 1.8333) & (1.0000, 1.0000, 1.0000) & (0.3556, 0.4333, 0.5556) & (0.5000, 0.6667, 1.0000) \\
C9 & (1.0000, 1.5000, 2.0000) & (1.6667, 2.1667, 2.6667) & (1.8333, 2.3333, 2.8333) & (1.0000, 1.0000, 1.0000) & (1.1667, 1.6667, 2.1667) \\
C10 & (0.6111, 0.8889, 1.6667) & (1.0000, 1.5000, 2.0000) & (1.0000, 1.5000, 2.0000) & (0.4667, 0.6111, 0.8889) & (1.0000, 1.0000, 1.0000)
\end{pmatrix},
$$

$CI = 0.0324 \quad CR = 0.0289,$

$$
\begin{pmatrix}
 & C11 & C12 & C13 & C14 & C15 \\
C11 & (1.0000, 1.0000, 1.0000) & (0.4000, 0.5000, 0.6667) & (0.4000, 0.5000, 0.6667) & (0.5000, 0.6667, 1.0000) & (0.6111, 0.8889, 1.6667) \\
C12 & (1.5000, 2.0000, 2.5000) & (1.0000, 1.0000, 1.0000) & (1.0000, 1.5000, 2.0000) & (1.1667, 1.6667, 2.1667) & (1.5000, 2.0000, 2.5000) \\
C13 & (1.5000, 2.0000, 2.5000) & (0.5000, 0.6667, 1.0000) & (1.0000, 1.0000, 1.0000) & (0.6667, 1.1667, 1.6667) & (1.1667, 1.6667, 2.1667) \\
C14 & (1.0000, 1.5000, 2.0000) & (0.4667, 0.6111, 0.8889) & (0.6111, 0.8889, 1.6667) & (1.0000, 1.0000, 1.0000) & (0.6667, 1.1667, 1.6667) \\
C15 & (0.6667, 1.1667, 1.6667) & (0.4000, 0.5000, 0.6667) & (0.4667, 0.6111, 0.8889) & (0.6111, 0.8889, 1.6667) & (1.0000, 1.0000, 1.0000)
\end{pmatrix},
$$

$CI = 0.0381 \quad CR = 0.0340.$

(19)

As can be seen from Table 3, moral level accounts for the highest proportion, followed by ability level. It shows that when training and selecting accounting applied talents, we should pay more attention to their ideology and moral character. Ability and knowledge can be improved through follow-up study, but thought determines one's basic quality. Besides, it can be seen from Figure 5 that the proportion of devotion to work and honesty are more than 10%, followed by more important are team cooperation ability and compliance with the law, and the proportion of these two are close to 10%, indicating that the cultivation of these abilities is very important in the cultivation of accounting applied talents.

5.2. Comprehensive Evaluation. This study aims to establish a relatively fair comprehensive ability evaluation model of accounting applied talents in the era of big data, so the evaluation object can be all students in accounting major, taking "class A" as an example.

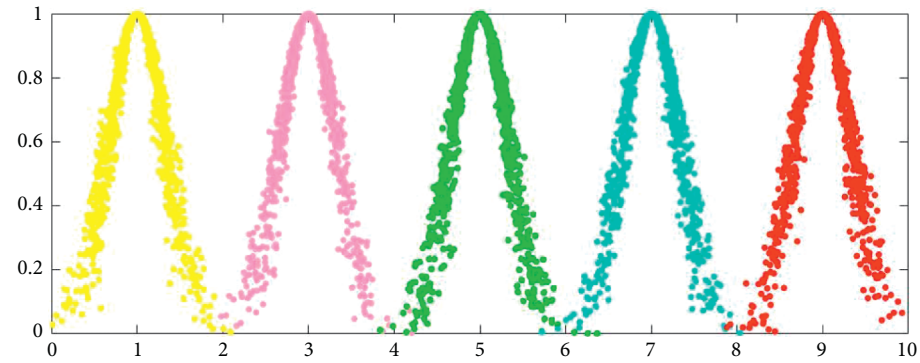

Figure 6: Cloud model diagram of comprehensive ability evaluation standard for accounting applied talents.

Table 5: Results of the expert's scoring for the classmate.

Indexes	Experts									
	1	2	3	4	5	6	7	8	9	10
C1	7	5	8	7	8	7	8	6	7	8
C2	3	3	4	6	5	5	6	4	3	4
C3	5	4	7	6	6	6	7	6	7	5
C4	8	5	6	7	7	7	7	8	7	7
C5	6	5	7	7	8	7	6	7	7	6
C6	5	4	7	7	7	6	6	6	7	4
C7	5	5	9	8	9	7	7	7	8	6
C8	7	6	8	9	8	7	7	8	8	8
C9	8	6	8	8	7	7	8	7	8	8
C10	8	6	8	9	8	7	8	7	8	7
C11	9	9	7	8	8	7	9	9	7	9
C12	9	6	7	8	8	6	6	7	7	7
C13	8	7	9	9	8	7	7	8	8	6
C14	9	6	8	8	9	8	8	8	8	9
C15	7	6	8	8	8	8	8	8	8	7

Table 6: Cloud digital characteristics of comprehensive ability evaluation index for accounting applied talents.

Indexes	Ex	En	He
C_1	7.1000	0.9024	0.4244
C_2	4.3000	1.2032	0.5368
C_3	5.9000	0.9275	0.3664
C_4	6.9000	0.7019	0.6189
C_5	6.6000	0.8523	0.3420
C_6	5.9000	1.1781	0.4367
C_7	7.1000	1.4037	0.7220
C_8	7.6000	0.8523	0.3420
C_9	7.5000	0.7520	0.3763
C_{10}	7.6000	0.8523	0.3420
C_{11}	8.2000	1.0027	0.2939
C_{12}	7.1000	0.9275	0.3664
C_{13}	7.7000	0.9525	0.2034
C_{14}	8.1000	0.6768	0.6462
C_{15}	7.6000	0.7019	0.4545

Firstly, we establish a collection of comments. This study selects the set of comments as follows: V = {very good, good, general, poor, very bad}. Then, according to the formula, the numerical scoring interval of the comprehensive ability of accounting applied talents is transformed into the digital characteristic value of the cloud model. The calculation results are shown in Table 4. To make the evaluation results more intuitive, 1000 cloud droplets are randomly generated by the forward cloud generator, and the standard evaluation cloud is drawn by MATLAB Software, as shown in Figure 6.

Secondly, we determine the fuzzy relation comprehensive evaluation matrix. Ten experts in the financial

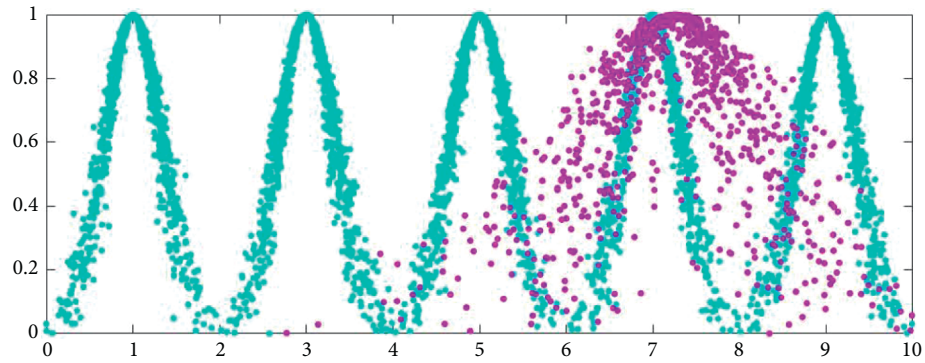

Figure 7: Comparison of standard cloud model and evaluation results cloud model results.

field are invited to score students in all aspects. The experts determine professional knowledge and learning ability according to class attendance, specific scores, and the number of subject studies. Besides, they determine moral level and other abilities according to the state of life and learning process and the evaluation of surrounding people. According to the above standards, the experts score results combined with their own experience, and the scoring results are shown in Table 5. Then, the cloud digital characteristics of the comprehensive ability evaluation index of accounting applied talents are calculated, as shown in Table 6.

Finally, the evaluation value of class A's comprehensive ability is calculated according to the formula. The evaluation result of class A's comprehensive ability is represented by three cloud digital features, which are 7.2486, 0.9181, and 0.4082, respectively. By drawing and comparing the standard cloud model and the evaluation result cloud model with MATLAB Software, we can see the comprehensive ability level of class A more clearly and intuitively. The blue curve in Figure 7 is the standard cloud model, and the purple curve is the cloud model of the comprehensive ability evaluation result of class A.

As can be seen from the schematic diagram of the evaluation results, the cloud image of the actual cloud model is mainly distributed between the "good" and "very good" regions, which is biased towards "good" and basically covers the "good" level of cloud model. Therefore, it can be considered that the accounting comprehensive ability of class A is at the "good" level. The numerical characteristics of entropy and hyperentropy in the comprehensive evaluation cloud are 0.9181 and 0.4082, and the values are large. It is reflected in the cloud image that the cloud droplet distribution is relatively dispersed and the cloud image is wide, indicating that the fuzziness and discreteness of the comprehensive ability evaluation results are large and the data have certain randomness.

6. Conclusions

The comprehensive ability evaluation of accounting applied talents plays an important role in the training and employment of accounting applied talents, but the comprehensive ability evaluation of accounting applied talents is a systematic project with its own complexity. Therefore, this study constructs the evaluation index system from the three methods of knowledge level, ability level, and moral level. Then, the index weight is determined by the group fuzzy analytic hierarchy process, and the comprehensive ability of accounting applied talents is comprehensively evaluated by cloud model fuzzy comprehensive evaluation method. To a certain extent, it solves the uncertainty of talent comprehensive evaluation and overcomes the shortcomings of previous evaluation methods. Through case study, we find that the universities and enterprises should pay attention to moral level when training and selecting accounting applied talents. Then, based on the principle of people-oriented, job matching is carried out according to students' own advantages to achieve a win-win situation between candidates and interviewees. The construction and evaluation of this model scientifically quantify the comprehensive ability of accounting applied talents, which can help us determine the comprehensive quality of accounting talents objectively and fairly. It is not only beneficial to provide direction and suggestion for colleges and universities to cultivate accounting talents, but also can provide reference for enterprises to select accounting talents. However, due to the limitations of the evaluation object data, the construction of the index system is impossible to exhaust all aspects and the subjective preference of expert scoring and many other factors, and the universality of the evaluation model proposed in this study still needs continuous improvement so as to improve. In the future, we can construct the comprehensive ability evaluation

index system of accounting applied talents from more aspects and use the weight calculation method combining qualitative and quantitative to determine the combination weight, so as to evaluate the comprehensive ability of accounting applied talents more scientifically.

Appendix

A

Expert 1 (E1)

$$\begin{pmatrix} E1 & B1 & B2 & B3 \\ B1 & P & DG & DV \\ B2 & G & P & DV \\ B3 & V & V & P \end{pmatrix}\begin{pmatrix} E1 & C1 & C2 & C3 & C4 & C5 \\ C1 & P & V & G & L & L \\ C2 & DV & P & DL & DL & L \\ C3 & DG & L & P & C & DL \\ C4 & DL & L & DC & P & DL \\ C5 & DL & DL & L & L & P \end{pmatrix}\begin{pmatrix} E1 & C6 & C7 & C8 & C9 & C10 \\ C6 & P & G & G & DL & L \\ C7 & DG & P & DL & DG & DL \\ C8 & DG & L & P & DG & DL \\ C9 & L & G & G & P & L \\ C10 & DL & L & L & DL & P \end{pmatrix}\begin{pmatrix} E1 & C11 & C12 & C13 & C14 & C15 \\ C11 & P & DG & DG & DL & DL \\ C12 & G & P & L & L & G \\ C13 & G & DL & P & C & L \\ C14 & L & DL & DC & P & C \\ C15 & L & DG & DL & DC & P \end{pmatrix}. \tag{A.1}$$

Expert 2 (E2)

$$\begin{pmatrix} E2 & B1 & B2 & B3 \\ B1 & P & DG & DV \\ B2 & G & P & DG \\ B3 & V & G & P \end{pmatrix}\begin{pmatrix} E2 & C1 & C2 & C3 & C4 & C5 \\ C1 & P & G & G & L & L \\ C2 & DG & P & DL & DL & L \\ C3 & DG & L & P & DL & DG \\ C4 & DL & L & L & P & DL \\ C5 & DL & DL & G & L & P \end{pmatrix}\begin{pmatrix} E2 & C6 & C7 & C8 & C9 & C10 \\ C6 & P & G & G & DL & C \\ C7 & DG & P & DC & DV & DL \\ C8 & DG & C & P & DV & DL \\ C9 & L & V & V & P & L \\ C10 & DC & L & L & DL & P \end{pmatrix}\begin{pmatrix} E2 & C11 & C12 & C13 & C14 & C15 \\ C11 & P & DG & DG & DL & DC \\ C12 & G & P & L & G & G \\ C13 & G & DL & P & L & G \\ C14 & L & DG & DL & P & C \\ C15 & C & DG & DG & DC & P \end{pmatrix}. \tag{A.2}$$

Expert 3 (E3)

$$\begin{pmatrix} E1 & B1 & B2 & B3 \\ B1 & P & DL & DV \\ B2 & L & P & DG \\ B3 & V & G & P \end{pmatrix}\begin{pmatrix} E3 & C1 & C2 & C3 & C4 & C5 \\ C1 & P & V & G & G & L \\ C2 & DV & P & DL & DL & L \\ C3 & DG & L & P & DL & DG \\ C4 & DG & L & L & P & DL \\ C5 & DL & DL & G & L & P \end{pmatrix}\begin{pmatrix} E3 & C6 & C7 & C8 & C9 & C10 \\ C6 & P & G & G & DL & C \\ C7 & DG & P & DL & DG & DL \\ C8 & DG & L & P & DV & DL \\ C9 & L & G & V & P & G \\ C10 & DC & L & L & DG & P \end{pmatrix}\begin{pmatrix} E1 & C11 & C12 & C13 & C14 & C15 \\ C11 & P & DG & DG & DL & DC \\ C12 & G & P & L & L & G \\ C13 & G & DL & P & C & L \\ C14 & L & DL & DC & P & L \\ C15 & C & DG & DL & DL & P \end{pmatrix}. \tag{A.3}$$

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known conflicts of interests or personal relationships that could have appeared to influence the work reported in this study.

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