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Research Article

Evaluation of Regional Rural e-Commerce Development Potential with Intuitive Fuzzy Information Theory

Tao Yang

Shaanxi Polytechnic Institute, Xianyang, Shaanxi, China

Correspondence should be addressed to Tao Yang; 20061129@sxpi.edu.cn

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In recent years, China's Internet industry has developed rapidly, and the Internet has penetrated into all aspects of people's daily lives. As an emerging transaction model, rural e-commerce is an important channel for precise poverty alleviation. To be specific, rural e-commerce can greatly change the lives of rural people in one way or other ways, thus allowing rural consumers to purchase high-quality and inexpensive goods without having to leave home. In other words, the introduction of national e-commerce into rural areas has changed the lifestyle of rural residents, providing them with great convenience in their daily lives. According to statistics, the level of rural e-commerce development in coastal areas is much higher than that in the mainland, while inland areas are hesitant to develop. Rural areas are a crucial component of Chinese society, and the rural economy is also the main driving force of China's agricultural economy. In an environment where e-commerce is gradually penetrating various fields, the development of rural e-commerce in China has become more urgent with the new and growing rural demand. To be specific, the development of rural e-commerce has become a hot topic in recent years, and it is necessary to gather efforts from all sides to explore and innovate, so as to promote the healthy and orderly growth of rural e-commerce in China. As one of the effective ways to solve the problems of agricultural industry development and farmers' affluence, rural e-commerce has played an increasingly obvious role in industrial development, poverty alleviation, employment, and solving the problems of selling agricultural products. At the same time, the proportion of national online sales of agricultural products is also increasing year by year. Many rural areas have abundant natural resources, rich history and culture, and a pleasant ecological environment. As a result, a great number of rural areas are well suited for e-commerce development in terms of the overall environment and physical resources. In recent years, the development of rural e-commerce in China has been very rapid, but it has also revealed many problems. Therefore, an in-depth study of the regional factors affecting the development of rural e-commerce is helpful to provide a reference for its better development. Based on the analysis of the current situation of rural e-commerce development, this study collects and organizes the indexes of influencing factors of rural e-commerce. The index system of influencing factors of rural e-commerce development is constructed through data collection and so on. After that, this study adopts the regional fuzzy information theory to evaluate the potential of rural e-commerce development, so as to obtain the main influencing factors of rural e-commerce development.

1. Introduction

Rural e-commerce refers to the process and steps of trading agricultural products combined with the Internet based on digitization and informatization [1]. After that, with the help of the Internet technology platform, it is possible to give support to the overall management of production, sale, distribution, and after-sales of agricultural and consumer products. As a result, the consumer and supply markets for agricultural products can conduct electronic trading activities in rural commercial markets [2]. Rural e-commerce relies on relevant rural resources and industries and extends to various services through the "Internet +," platform, thus developing in a coordinated manner online and offline [3]. To be specific, rural e-commerce can electronize, virtualize, and intellectualize the traditional agricultural production and operation, marketing of agricultural products, transportation of agricultural products, and demand for

agricultural materials with the support of Internet technology. Furthermore, rural e-commerce can extend the industrial chain, thus promoting the coordinated development of various industries [4]. In addition, it can improve various functional services in rural markets and build a close business cluster. As a result, e-commerce is an opportunity for the rural economy to gain secondary development [5]. In recent years, as China's information technology continues to penetrate and penetrate deeply into the agricultural and rural areas, the penetration rate of the Internet in rural areas has soared. As an essential part of "Internet+", the role and effect of rural e-commerce in rural society and economy are becoming more and more significant [6]. Therefore, integrating rural e-commerce into rural revitalization in many aspects and at a deeper level can not only promote local employment and entrepreneurship but also drive the development of tertiary industries such as rural tourism and logistics [7, 8].

Rural e-commerce can not only subvert the traditional sales mode and consumption mode but also change the traditional production mode, giving rise to the overall change of the rural industrial chain [9]. With the help of the Internet platform, farmers can sell their goods directly to sellers without going through a third party. This effectively reduces the flow of agricultural products, thus saving the huge costs associated with distribution [10]. Especially with the epidemic of COVID-19, economic recovery is very difficult [11]. However, rural e-commerce is in line with the principle of no contact, the trend of live selling trend. At the same time, some experts point out that the development of rural e-commerce is of great significance and far-reaching [12, 13]. More specifically, it can not only promote the transformation and upgrading of the rural economy but also deeply open up the rural market. As a result, driven by the background of "Internet + ," many traditional industries have been able to combine with it for synergistic development, which has also led to the rapid development of rural e-commerce [14]. As a result, e-commerce has played a significant role in helping rural agricultural products to fly out of the countryside to the whole country. The promotion of rural e-commerce is one of the ways to alleviate the problem of difficulty in selling agricultural products [15]. In addition, it can also further improve farmers' income and broaden the channels for them to increase their income. At the same time, some scholars also clearly point out that the integration of the Internet and agriculture can not only help sell agricultural products but also solve rural employment [16]. Therefore, rural e-commerce is an effective way to alleviate poverty. Figure 1 demonstrates the process of rural e-commerce development in China.

The O2Omodel mainly applies the Internet as the medium of communication and advertises products [17]. The O2O model is an effective integration of online shopping and traditional markets. The main process of the O2O model is shown in Figure 2. The flow of information is often faster through the Internet [18]. Since information is more widely disseminated, it can further increase the level of consumption and spending power, thus enlisting potential consumers. At the same time, merchants can further increase the number of products sold by adjusting their offers according to the store's inventory [19]. In addition, the merchant can also release the latest discount service promotions in real-time through the public number and circle of friends [20]. The O2O model can quickly provide richer and more comprehensive discount information. For example, group buying and seller discounts can not only meet the diverse needs of consumers but also save money on transportation and other costs.

In recent years, with the rapid development of network communication technology, the network hardware facilities in most rural areas of China have been continuously updated and improved [21]. The continuous development of advanced technologies has greatly contributed to the rapid development of e-commerce in rural China. Due to the continuous innovation of rural e-commerce development models, the volume of rural e-commerce transactions has also been increasing [22]. Since the first half of 2016, large e-commerce enterprises have been investing in the construction of rural information service stations and building platform ecosystems to gradually achieve the purpose of sinking e-commerce to villages. In this context, the two-way distribution system of "industrial products going to the countryside and agricultural products going up" is gradually taking shape [23]. However, there are many complicated problems in the actual sinking process. As a result, the implementation of O2O mode in rural areas needs further improvement. At present, China's rural e-commerce is in a rapid development stage, and its potential is much greater than that of urban areas. With the accelerated urbanization, the transportation condition in rural areas will definitely be improved. Therefore, rural areas will become the next hot spot for e-commerce development. The development of the rural e-commerce O2O model has become an emerging economic development model. This model is intertwined with the development of China's agricultural industry chain and is gradually influencing the development trend of China's rural economy [24]. To be specific, it can change agricultural production methods and has an important impact on the growth of the agricultural economy, the employment of farmers, and the construction of rural information infrastructure.

Actually, China is a vast country, and the topography, general environment, and infrastructure development are not the same from place to place. As a result, the development of rural e-commerce models also varies, and the factors influencing rural e-commerce development may also vary [25]. Based on this, it is meaningful to understand and study the main factors affecting rural e-commerce development and their degree of influence from the perspective of the participants engaged in the general environment of rural e-commerce. At the same time, the study of rural e-commerce is in line with the trend of the times [26]. Since the government proposed the concept of "Internet+" in 2015, the Central Government's document No. 1 has put forward many implementation opinions on the work of the three rural areas in recent years. Among them, the implementation opinions on rural e-commerce point out that we should support enterprises to participate in the construction of

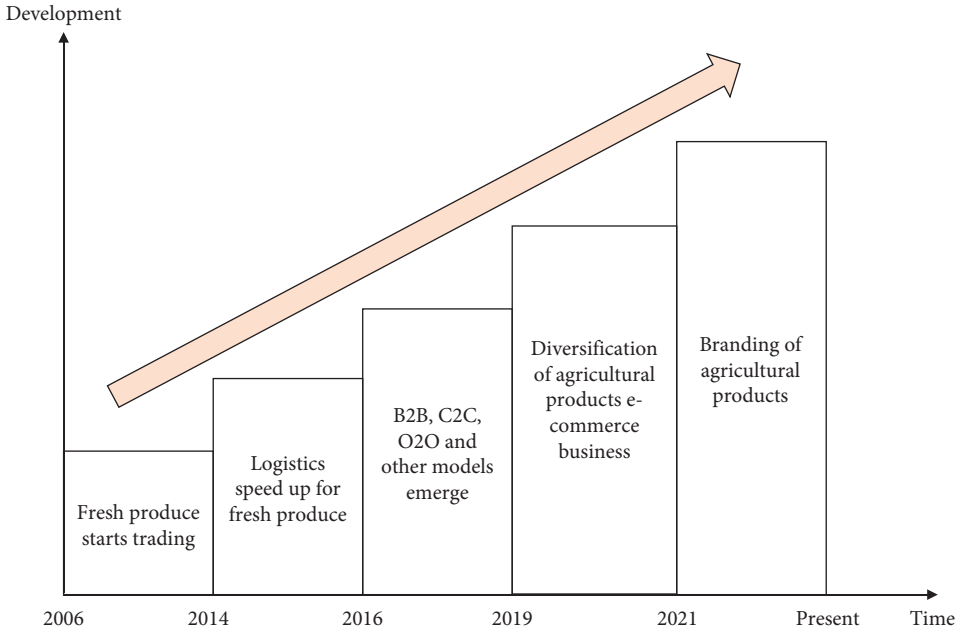

Figure 1: Process of rural e-commerce development in China.

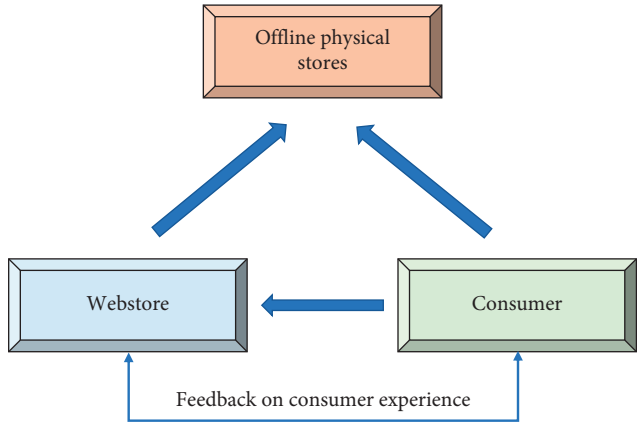

Figure 2: The main process of the O2O model.

e-commerce platforms, carry out a demonstration of e-commerce into villages and e-commerce services, promote "Internet+" modern agriculture, and implement digital countryside strategy and agricultural products out of villages and into cities.

Through the establishment of three-level information service stations in counties, towns, and villages, rural e-commerce can integrate various rural resources [27]. In particular, it can gather rural-related information, service business fields, and agricultural specialty products into a network platform and carry out a series of business activities through the network. In rural e-commerce activities, a series of information mainly revolves around agricultural production, rural economy, and farmers' life and promotes fast, convenient, and efficient rural business communication through electronic systems [28]. Therefore, rural e-commerce is a new type of trade. In rural e-commerce, the commodities traded mainly include agricultural products, agricultural by-products, and farmers' living materials. Services include market demand reflection, price fluctuation information, and agricultural, rural, and farmer information services such as rural tourism, resource utilization, tourism and leisure agriculture, and trade services [29]. As a result, rural e-commerce is a comprehensive platform built using web-based information technology to provide services to businesses and consumer organizations in the agricultural sector.

The development of the O2O mode of rural e-commerce is a new business model that uses information technology to complete transaction activities. This model is direct, fast, and low-cost and breaks the barriers of time and space. Therefore, it is of great significance for rural e-commerce research. In terms of theoretical significance, as a new research topic that has emerged in recent years, a large number

of research results have been published at home and abroad. However, in China, the special situation of rural China is different from that of foreign countries. Therefore, there are still some gaps in the systematic study of rural e-commerce development. From a practical point of view, the development of rural e-commerce can solve the problem of poor agricultural information and guide agricultural production. To be specific, this study can organically integrate the preproduction, production, and postproduction aspects of agricultural production, thus effectively solving the problem of asymmetric information between agricultural production and the market, thus providing a broader space for the flow of agricultural products and eliminating the situation that agricultural products are not sold and farmers do not increase their income despite a good harvest.

2. Intuitive Fuzzy Information Theory

Intuitionistic fuzzy information theory is mainly based on affiliation theory, which can transform qualitative language into quantitative evaluation. Therefore, this method can be used to synthesize the alternatives using other quantitative ranking methods. In fact, in other words, intuitionistic fuzzy information theory is better applied to complex problems with multiple attributes. Due to the late emergence of rural e-commerce, the relevant data resources and professional experience may not be perfect. As a result, the evaluation process of rural e-commerce is suitable for the characteristics of intuitionistic fuzzy information theory. To be specific, in the evaluation index system of rural e-commerce logistics service provider selection, indicators such as logistics distribution capacity and value-added logistics services are subject to various factors, so the intuitionistic fuzzy information theory can be used to make a general evaluation of these indicators.

2.1. Intuitionistic Fuzzy Set. In order to address the fuzzy and multidimensional characteristics of consumers' perceived trust, intuitionistic fuzzy sets can be adopted to characterize the complex perceived trust of customer-consumers. The intuitionistic fuzzy set has three dimensions, which are fuzzy affiliation, fuzzy nonaffiliation, and hesitation. As a result, these three dimensions can correspond to perceived trust, perceived mistrust, and perceived uncertainty. Therefore, this study applies the intuitionistic fuzzy set to represent consumers' perceived trust and constructs a rural e-commerce potential evaluation model based on it. Intuitive fuzzy sets add new attribute parameters, which can reflect the fuzzy characteristics of the objective world more specifically. As a result, intuitionistic fuzzy sets are widely used in the field of multiattribute decision-making.

Let X be a given theoretical domain, then an intuitionistic fuzzy set S on X is as follows:

$$S = \{\langle x, m_S(x), n_S(x)\rangle | x \in X\}, \tag{1}$$

where $m_S(x)$ refers to the subordinate function of S and $n_S(x)$ denotes the unaffiliated function of S.

After that, let the following equations denote the intuitionistic fuzzy number:

$$\begin{aligned} \theta &= (m_\theta, n_\theta), \\ \gamma &= (m_\gamma, n_\gamma). \end{aligned} \tag{2}$$

Then, we can obtain the following relationships:

$$\begin{aligned} \theta \oplus \gamma &= (m_\theta + m_\gamma - m_\theta \times m_\gamma, n_\theta \times n_\gamma), \\ \theta \otimes \gamma &= (m_\theta \times m_\gamma, n_\theta + n_\gamma - n_\theta \times n_\gamma). \end{aligned} \tag{3}$$

Compared with traditional fuzzy methods, intuitionistic fuzzy sets can combine three perspectives of affiliation, nonaffiliation, and hesitation. As a result, intuitionistic fuzzy sets are more flexible in dealing with fuzzy information. In recent years, more and more scholars have applied the theory of intuitionistic fuzzy sets to the evaluation field and obtained fruitful research results. In addition, there are similar fuzzy mathematical methods such as interval intuitionistic fuzzy numbers, intuitionistic trapezoidal fuzzy numbers, and intuitionistic triangular fuzzy numbers.

2.2. Process of Rural e-Commerce. According to international standards, there are various forms of e-commerce. Some of them are scientifically forward-looking, while others are special in the sense of following the trend. From the domestic mainstream, e-commerce is currently divided into A2C (Figure 3) and B2C (Figure 4). However, O2O model is undoubtedly another major operation mode after these modes. As a result of the deep and mature application of information technology, Internet technology, 4G penetration, 5G promotion, big data development, cloud computing, and other technologies are important prerequisites to promote the broadening of the O2O market and provide an important guarantee for its development. In today's life, consumers are accustomed to booking online and paying by code in advance before they decide to go to the movies, eat, or travel. This shows a new form of payment in our lives, thus effectively saving our time and facilitating our lives.

The main difference between O2O and other forms is that it allows for the delivery of goods or services through a logistics company that acts as a link between the consumer and the operator. This form can save logistics costs and time costs.

2.3. Evaluation Model of Rural e-Commerce Development Potential. For quantitative indicators, such as logistics and distribution cost, the service cost per unit weight of products of each logistics service provider is used as the reference basis for attribute evaluation. As a result, different rating levels and their corresponding intuitionistic fuzzy numbers can be selected according to the service cost. For qualitative indicators, such as logistics and distribution capacity, the number of distribution centers, sorting equipment capacity, and informationization degree of the logistics service provider are applied as the reference for attribute evaluation. At the same time, different opinions of experts are collected to obtain a comprehensive evaluation of the attribute. For

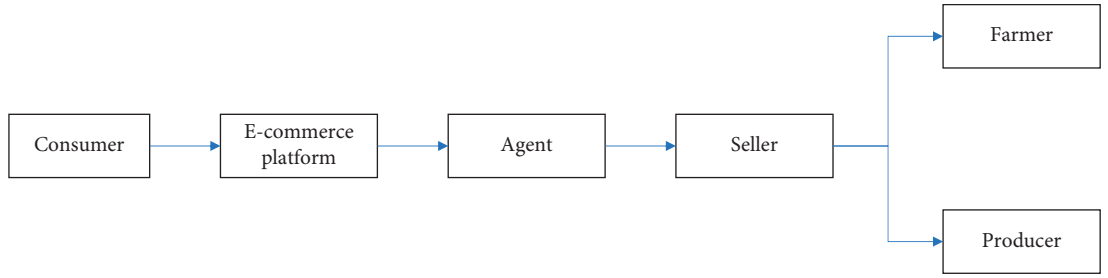

Figure 3: The main process of the A2C model.

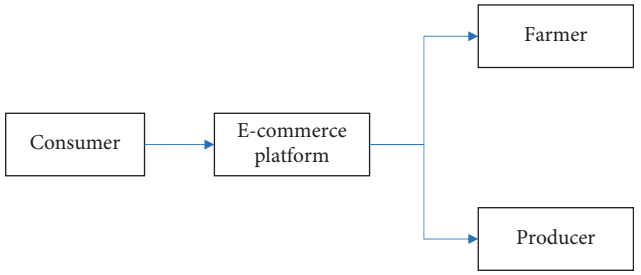

Figure 4: The main process of the B2C model.

example, if a group of experts evaluates a rural e-commerce company, 75% of the experts are satisfied, 5% are dissatisfied, and 20% are neutral or ambiguous, the corresponding intuitive fuzzy numbers are 0.75, 0.05, and 0.20. In summary, the attribute values of linguistic variables are illustrated in Table 1.

Next, let the following equation denote the matrix of intuitive fuzzy numbers:

$$\overline{Y} = \left(\langle \overline{m}_{ij}, \overline{n}_{ij} \rangle\right)_{k\times l}, \tag{4}$$

where

$$\begin{aligned} \overline{m}_{ij} &= \frac{m_{ij}}{\sqrt{\sum_{i=1}^{k}\left[\left(m_{ij}\right)^2 + \left(n_{ij}\right)^2\right]}}, \quad i = 1, 2, \ldots, k;\ j = 1, 2, \ldots, l, \\ \overline{n}_{ij} &= \frac{n_{ij}}{\sqrt{\sum_{i=1}^{k}\left[\left(m_{ij}\right)^2 + \left(n_{ij}\right)^2\right]}}, \quad i = 1, 2, \ldots, k;\ j = 1, 2, \ldots, l. \end{aligned} \tag{5}$$

Due to limited expertise in the problem domain, lack of relevant data and time constraints, and so on, experts cannot fully grasp the full decision information of attribute weights. In order to overcome this limitation, this study introduces the conventional multiattribute decision-making by the outlier maximization method into the intuitionistic fuzzy set. As a result, each attribute weight can be expressed as follows:

$$\omega_i = \frac{\sum_{i=1}^{k}\sum_{k=1}^{l}\left(\left|m_{ij} - mkj\right| + \left|n_{ij} - n_{kj}\right|\right)}{\sqrt{\sum_{k=1}^{l}\left(\left|m_{ij} - m_{kj}\right| + \left|n_{ij} - n_{kj}\right|\right)^2}}, \ i = 1, 2, \ldots, k. \tag{6}$$

Table 1: Attribute values of linguistic variables.

Linguistic variable	Intuitive fuzzy number
Best	(1.00, 1.00, 1.00)
Better	(0.70, 0.20, 0.10)
Neutral	(0.50, 0.40, 0.10)
Worse	(0.10, 0.70, 0.20)
Worst	(0.10, 0.90, 0.00)

Thus, the Euclidean distance of the intuitionistic fuzzy set can be calculated as follows:

$$\begin{aligned} E\left(S_j, S^+\right) &= \sqrt{\frac{1}{2}\sum_{i=1}^{k}\left[\left(\overline{m}_{ij} - \mu_i^+\right)^2 + \left(\overline{n}_{ij} - n_i^+\right)^2 + \left(\overline{\pi}_{ij} - \pi_i^+\right)^2\right]}, \\ E\left(S_j, S^-\right) &= \sqrt{\frac{1}{2}\sum_{i=1}^{k}\left[\left(\overline{m}_{ij} - \mu_i^-\right)^2 + \left(\overline{n}_{ij} - n_i^-\right)^2 + \left(\overline{\pi}_{ij} - \pi_i^-\right)^2\right]}. \end{aligned} \tag{7}$$

Therefore, the relative closeness of each alternative S_j to the intuitionistic fuzzy positive ideal solution S^+ is as follows:

$$C_i = \frac{E_2\left(S_i, S^-\right)}{E_2\left(S_i, S^+\right) + E_2\left(S_i, S^-\right)}, \ i = 1, 2, \ldots, k. \tag{8}$$

The greater the relative proximity, the better the corresponding rural e-commerce evaluation.

3. Case Study

In order to explore the effect of intuitive fuzzy information theory applied in the evaluation of regional rural e-commerce development potential, this research selects e-commerce transaction data of a rural area as a case to study.

3.1. E-Commerce Trading Situation. With the maturity of infrastructure construction and related information technology, the volume of rural e-commerce transactions in the country has become larger and larger in recent years. According to the data provided by a rural commerce bureau, the overall trend of online transactions and online retail sales in this rural area in the past four years has been on the rise. The specific online transactions and online retail sales are shown in Table 2 and Figure 5.

The overall e-commerce development of the farm is good from 2018 to 2021. To be specific, the online transaction volume shows linear growth. At the same time, online retail sales in rural area are also on the rise, but at a smaller rate. In general, both are on an upward trend. This also indicates that China has started a boom in innovation and entrepreneurship against the background of improving information technology and infrastructure development. All this makes the development of rural e-commerce even more dynamic.

3.2. Questionnaire Data Analysis. The population of this paper is the e-commerce-related participants living in rural areas. To be specific, it includes farmers engaged in rural e-commerce, logistics personnel in the distribution process, and policy communicators and propagandists. As we can see from the participants in the development of rural e-commerce, the participants in each aspect of rural e-commerce are the main participants. According to the concept of rural e-commerce in the previous section, rural e-commerce mainly serves rural areas, agriculture, and farmers. As a result, this study selects farmers, logistics and distribution personnel, policymakers, and communicators in the process of rural e-commerce development as the research subjects and issues questionnaires to conduct a survey and research. This study is based on the current situation of e-commerce development in a rural area, combined with the existing literature, to summarize the specific research variables, so as to construct the specific measurement questions of the design questionnaire. In this study, 400 questionnaires were distributed and 378 valid questionnaires were collected online and on paper, with a 94.5% return rate. By compiling and analyzing the data collected by this questionnaire, the results of the specific sample data situation are shown in Table 3.

The trend of e-commerce is growing faster and faster with the arrival of the 5G era. At the same time, due to the epidemic, people are not able to go out as much as they usually do. Therefore, in order to reduce direct contact, community e-commerce has also started to develop rapidly. Compared to the development of microbusinesses in previous years, online live video shopping and community order shopping have become the norm, allowing people to solve their daily needs without leaving home. The update of Internet information technology and infrastructure improvement has also played a positive role in promoting the development of rural e-commerce, which is a new opportunity for the development of rural e-commerce.

Table 2: Online transaction volume and retail sales of a certain rural area.

Year	Transaction volume (billion yuan)	Retail sales (billion yuan)
2018	31.43	6.69
2019	47.65	9.37
2020	64.21	14.21
2021	77.72	17.98

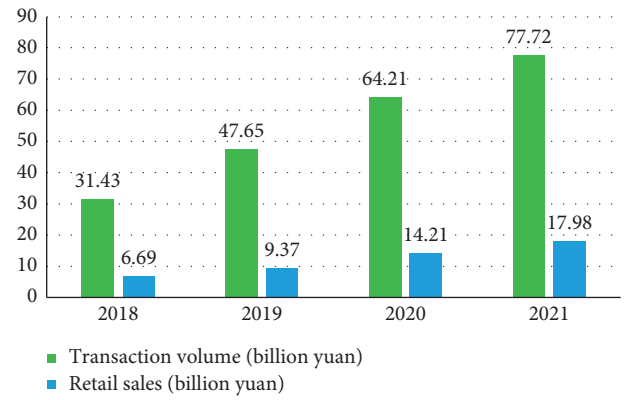

Figure 5: Online transaction volume and retail sales of a certain rural area.

3.3. Evaluation with Intuitive Fuzzy Information Theory. Based on the intuitionistic fuzzy matrix introduced in Section 2.3, the analysis of the variables involved in the collected questionnaires leads to the following results as shown in Table 4.

Based on the above results, it can be measured that among the factors influencing the development of rural e-commerce, the main influencing factors are policy, geographic location, logistics, and infrastructure, as illustrated in Figure 6.

The population, as the subject of transactions in rural e-commerce activities, is subject to various factors such as age and literacy. Therefore, farmers need to conduct appropriate publicity and vigorous work related to e-commerce training. Such initiatives can help them develop a basic understanding of e-commerce at an intuitive level. At the same time, e-commerce associations should make efforts to promote the use of information technology and e-commerce in rural areas and agricultural products. This will better serve the development of local e-commerce platforms, the formation of professional e-commerce teams, and the introduction of teams and better lead the development and growth of agricultural e-commerce enterprises.

Because of their seasonal and regional characteristics, agricultural products are limited in production and cultivation in time and space. Therefore, by developing rural e-commerce channels for agricultural products, more and more people can have access to cross-regional agricultural products. However, primary agricultural products,

Table 3: Results of the specific sample data situation.

Variable	Option	Number
Age	Under 20	54
	21–30	215
	31–40	21
	41–50	56
	Above 51	32
Education level	Specialty	104
	Undergraduate	189
	Master and above	85
Whether experience in online sales	Yes	102
	No	276
Online matter	Shopping	197
	Study	32
	Play games	76
	Watch videos	33
	See news	40

Table 4: Analysis of the variables involved in the collected questionnaires.

	C_1	C_2	C_3	C_4
S_1	(0.31, 0.29)	(0.32, 0.28)	(0.38, 0.39)	(0.24, 0.25)
S_2	(0.33, 0.24)	(0.37, 0.27)	(0.37, 0.32)	(0.26, 0.32)
S_3	(0.29, 0.21)	(0.25, 0.35)	(0.40, 0.33)	(0.33, 0.31)
S_4	(0.27, 0.32)	(0.28, 0.29)	(0.21, 0.25)	(0.21, 0.32)

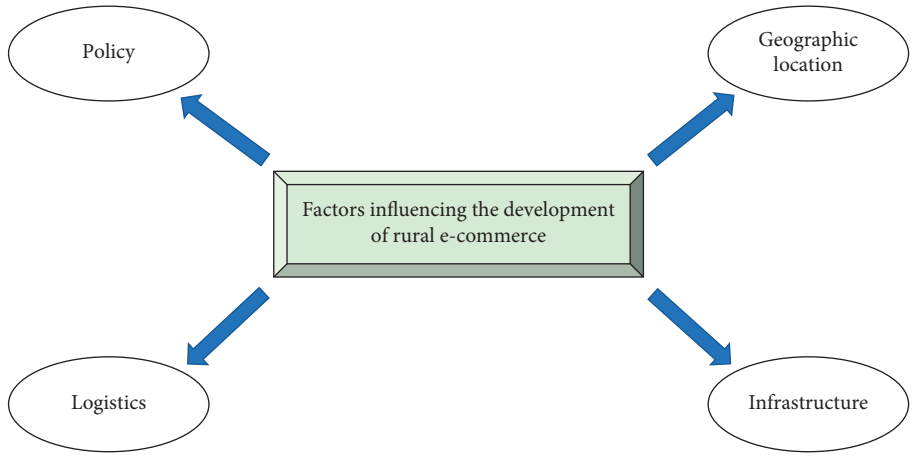

Figure 6: Factors influencing the development of rural e-commerce.

especially fresh agricultural products, are often not easy to store and transport, so there is a need to further develop the agricultural processing industry. To be specific, extending the chain by refining agricultural products is quite necessary, thus making them easier to store and transport and improving their overall efficiency. This series of measures can improve the animal flow industry's development and reduce logistics transaction costs. In addition, it can also alleviate the situation of low platform credit and high and difficult transportation costs due to the perishability of fresh agricultural products.

4. Conclusion

At present, the growth of the agricultural economy no longer relies solely on the number of material inputs, but instead on the mobility of information, human intelligence, and knowledge inputs. In the future, the smart economy will take up an increasing proportion. The development of China's rural e-commerce industry is not only conducive to solving the problem of smooth flow of agricultural information but also conducive to promoting the transformation and development of agricultural information industrialization. At

present, the agricultural economy faces problems such as an imperfect product circulation system, unsound agricultural and rural data, and lack of systemic functions. As a result, the development of the rural e-commerce industry is conducive to fundamentally solve the problem of blocked circulation of agricultural products in China. The study found that infrastructure is an important factor in the development of rural e-commerce. As the e-commerce environment changes and is updated, the immediate demand for product quality and fresh produce is increasing. In this context, new requirements for infrastructure development are being put forward. In the face of technological updates and iterations, network facilities, road construction, and hardware facilities are all being updated accordingly. This is to promote and enhance the development of rural e-commerce.

However, due to limited capacity, there may be many factors that deserve further study and consideration. Specifically, this study has some limitations in the selection of indicators. There is incompleteness in the selection of overall influencing factors. As a result, influencing factors can be selected comprehensively according to the development process of rural e-commerce and the specific situation of the research area in future research.

Data Availability

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

Acknowledgments

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