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Research Article

The Efficiency of China's Hub Economy and Its Influencing Factors: A Two-Stage Analysis Based on the Super SBM-Malmquist-Tobit Model

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Hub economy is a kind of emerging economic form. Developing a hub economy is essential to strengthen domestic and foreign connectivity and build a powerful country in transportation. This paper designs a two-stage analysis framework for the evaluation and impact study of the input-output efficiency of the hub economy based on the super SBM model, Malmquist model, and Tobit model. In the first stage, the Super SBM and Malmquist models are used to measure the static and dynamic efficiency of the hub economy. In the second stage, the Tobit model is used to analyze the factors influencing the efficiency of the hub economy. Among them, the explained variable in the second stage is the measurement result of technical efficiency in the first stage. The empirical results of 30 provinces and cities in China from 2012 to 2021 show that (1) the technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE) of China's hub economy are 0.585, 0.740, and 0.820, respectively, which do not reach the effective state; (2) the technical efficiency change index (Effch), technical progress change index (Techch), and total factor productivity change index (Tfpch) of China's hub economy are 0.994, 0.945, and 0.939, respectively, indicating that the corresponding efficiencies show a downward trend; and (3) industrial structure, innovation, and technology are significantly and positively correlated with the efficiency of the hub economy; policy and enterprises are significantly negatively correlated with the efficiency of the hub economy; and education does not correlate with the efficiency of the hub economy.

1. Introduction

Hub economy is an emerging economic phenomenon in China and a new form of regional economic development [1, 2]. The hub economy generated by the hub was initially developed around the transportation hub [1]. Transportation hubs, such as ports, railways, highways, and airports, are the material basis for the development of the hub economy [2]. With the development of the economy and society, it has further evolved into economic, science, technology, information, financial, innovation, and knowledge hubs [1, 2]. Currently, the development of the hub economy in most regions of China is still in the initial stage, that is, the stage of the transportation hub economy [2].

Regarding policy practice, the Chinese government attaches great importance to the construction of the hub economy. In 2022, the General Office of the State Council issued the 14th Five-Year Plan for the Development of Modern Logistics. According to the plan, by 2025, the operation system of channel + hub + network will be basically formed, and the development of the hub economy will achieve results. In 2018, the Development and Reform Commission and the Ministry of Transport jointly issued the National Logistics Hub Layout and Construction Plan. According to the plan, by 2035, relying on logistics hubs nationwide, a number of hub economic growth poles with international influence and distinctive hub economies will be formed. In 2019, the Central Committee of the Communist Party and the General Office of the State Council

issued the Outline for a Powerful Country in Transportation. According to the outline, building a multilevel, integrated, comprehensive transportation hub system and vigorously developing the hub economy is necessary. In addition, many provinces and cities in China regard the development of hub economies such as Shanghai, Jiangsu, and Henan as one of the regional development strategies [3]. Some countries and regions have been focusing on hub-based economic construction in the international context. They include Frankfurt in Germany, Amsterdam in the Netherlands, Memphis in the United States, and other regions [3, 4].

Regarding theoretical exploration, there are also many related studies on the hub economy. Among them, foreign scholars have paid extensive attention to the economic issues of different types of hubs, such as technology hubs, innovation hubs, and logistics hubs [5–7]. Domestic scholars have widely paid attention to the theoretical exploration of hub economy. Specifically, based on the current situation of the development of China's hub economy, the problems, countermeasures, connotation, extension, evaluation, and impact of the hub economy are studied [4, 8–12].

Although the relevant research results of the hub economy are relatively wealthy, the following three shortcomings remain. First, most regions lack statistical systems and evaluation systems related to the hub economy [2]. Although existing studies have evaluated the competitiveness of the hub economy, they focus on establishing indicators and improving the evaluation system [9]. It is not easy to obtain data for some indicators and conduct quantitative analysis. Second, there are few studies on the influencing factors of the hub economy [8], especially the analysis and research on the factors influencing the efficiency of the hub economy. Finally, there is a lack of precise and scientific references for policymaking [1, 13]. Some regions in China have a vague understanding of the development system and mechanism of the hub economy. The lack of accurate and scientific planning leads to repeated investment, overcapacity, and weak competitiveness.

In order to make up for the shortcomings of the existing research, this paper carries out the evaluation and impact study of the input-output efficiency of the hub economy. Specifically, a targeted two-stage analysis framework is designed based on Super SBM model, Malmquist model, and Tobit model. In the first stage, the Super SBM and Malmquist models are used to measure the static and dynamic efficiency of the hub economy. In the second stage, the Tobit model is used to analyze the factors influencing the efficiency of the hub economy. Among them, the explained variable in the second stage is the measurement result of technical efficiency in the first stage. The empirical research data come from the statistical yearbook of 30 provinces and cities in China from 2012 to 2021. Finally, policy recommendations for the development of the hub economy based on the empirical findings are proposed, which can provide a reference for formulating policy planning for the hub economy.

The research contributions of this paper are mainly as follows: first, based on the Super SBM model, Malmquist model, and Tobit model, a two-stage analysis framework for the evaluation and impact study of the input-output efficiency of the hub economy is proposed. This two-stage analysis framework can quantitatively evaluate the input-output efficiency of the hub economy. Among them, the Super SBM model is used to measure the efficiency of the hub economy, while the Malmquist model is used to measure the change index of the efficiency of the hub economy. In addition, the quadrant analysis method is used to divide the development status of the hub economy in different regions. These explorations make up for the deficiency of the existing research on the evaluation of the hub economy [2]. Second, this paper uses the Tobit model to measure the impact of industrial structure, technology, innovation, education, enterprises, and policies on the input-output efficiency of the hub economy, which enriches the relevant literature on the impact of the hub economy [8]. Third, this study can provide a reference for policymaking in the hub economy, thus improving its efficiency. The results of static and dynamic research on the efficiency of the hub economy can help national and local decision-makers better grasp the current situation of the input and output of the hub economy. The research results on the influencing factors of the efficiency of the hub economy can help the national and local government management departments better grasp the external environmental factors of the efficiency improvement of the hub economy. It makes up for the lack of effective reference in the current policymaking of the hub economy [1, 13].

2. Literature Review

2.1. Research on the Economic Problems of Different Types of Hubs. There are many types of hubs, including economic hubs, financial hubs, network hubs, science and technology hubs [3], logistics hubs [14], and transportation hubs [8]. The new complex hub economy based on these hubs has gradually become the determining factor in stimulating the new driving force of regional economic development [2]. Cattaneo et al. [15] argued that economic activities benefit from proximity to transportation and logistics hubs. Thierstein and Conventz [16] pointed out that hub airports have gradually become the economic growth poles of cities and have further developed into information and knowledge exchange hubs and corresponding competence centers. Rikap and Flacher [5] discussed the sustainability of the knowledge and innovation hub strategy, taking Singapore as an example. Atiase et al. [6] analyzed the cases of science and technology hubs in Nigeria, South Africa, Kenya, and other regions. It is found that science and technology hubs are in a leading position in creating new knowledge and innovative solutions and are more effective in creating economic and social value relative to higher education institutions. Trappey et al. [7] studied successful logistics reference models and systems used by six independent industrial sectors, which can provide a reference for constructing integrated logistics hubs. Foreign scholars mainly focus on the economic problems of various hubs and rarely conduct theoretical exploration based on the emerging economic form of China's hub economy.

2.2. Theoretical Exploration of Hub Economy. Domestic scholars pay more attention than foreign scholars to the theoretical exploration of China's hub economy, an emerging economic form.

2.2.1. Research on the Problems and Countermeasures of Hub Economy. At present, China's hub economy as a whole is in the initial formation stage [8]. The development of hub economy faces the following problems and obstacles [9, 12]: (1) lagging development planning, (2) unbalanced matching of regional hub energy levels, (3) unreasonable hub industrial structure, (4) severe homogeneous competition, (5) slow development of intelligent transportation and green transportation, (6) low standardization degree of multimodal transport, (7) low matching degree between virtual hub and physical hub, (8) low coordination degree of regional hubs, and (9) limited positioning of transportation hub city. The means to enhance the competitiveness of the hub economy are as follows [9, 14]: (1) building comprehensive transportation hubs, (2) improving the ability of factor resource allocation, (3) building a modern industrial system with hub preference, (4) promoting the coordinated development of hub area and hinterland economy, and (5) promoting the integrated development of logistics hub service and comprehensive transportation.

2.2.2. Research on the Connotation of Hub Economy. Hub economy is the reflection of the growth pole theory [1]. Gao [17] believed that the hub economy theory is upgrading the channel, transit, and entrepot economies. Under the current economic and social environment, it has extended to create many economic models, such as station economy, airport economy, port economy, adjacent rail economy, and adjacent station economy. Li et al. [18] believed that the connotation of a high-speed railway hub economy is mainly reflected in the realization of node value, place value, and communication value. Tian and Huang [4] argued that the connotation of hub economy was an economic model. This economic model utilizes the distribution function of transportation and geographical hubs to attract and gather resource elements such as raw materials, technology, capital, information, and labor. Finally, it will achieve the goal of developing industries and winning multiple economic radiations. Zhao [8] believed that the hub economy was a development model. The model is framed and centered on hubs, with aggregation and diffusion as the main features. Finally, it aims to construct and reconstruct the supply chain, industrial chain, and industrial cluster of products and production factors.

2.2.3. Research on the Extension of Hub Economy. The development process of the hub economy mainly includes transitioning from a single hub to a comprehensive hub, from a physical hub to a virtual hub, from a regional hub to an international hub, and from an urban hub to a hub city [17]. Zhao [8] believed that the development stages of the hub economy include the formation stage of initial change, the formation stage of secondary intensification, the development stage of industrial rise, and the maturity stage. Wen [2] believed that the hub economy generally needs to go through five stages: transportation hub, factor hub, hub industry, hub city, and international hub. Gong [12] believed that the attributes of the hub economy mainly include economic openness, industrial radiation, resource agglomeration, hub driving, and industrial integration. The internal relationship of hub economy is essentially the internal relationship between hub and economy, including linkage, matching, and iterative relationships. Chu [19] believed that the internal effects of the hub economy mainly include polarization, diffusion, snowball, and opening effects. Li [3] believed that the internal driving force of the hub economy is technological change and institutional innovation. The critical condition of the hub economy is to reduce the transaction cost of factor resources and promote the efficient flow of factor resources. The core and essence of the hub economy is to reshape the regional industrial division of the labor system and realize the cross-border integration and transformative change of economic organization form. Developing a hub economy can gather elements, integrate resources, build an efficient and low-cost hub service network, enhance the vitality of the real economy, and promote the coordinated development of regions Gao [17]; Ran and Qiao [11] believed that the hub economy also has the unique advantage of integrating regional markets and can promote the construction of a unified national market. Li [20] believed that it is necessary to develop a hub economy based on improving and expanding the function of passenger and cargo transportation hubs to build a coordinated development pattern of large, medium, and small cities in China.

2.2.4. Evaluation and Impact Study of Hub Economy. The evaluation system of the competitiveness of the hub economy mainly includes transportation hub infrastructure, comprehensive transportation system, hub industry development, and hub radiation and driving capacity [9]. The variables of the temporal and spatial characteristics of connecting flights significantly impact the hub connection of Beijing Capital Airport [21]. The factors that influence Ruili in China to become the hub of China-Myanmar cooperative relations are the port economy, border trade, national planning, increased investment, and natural geographical location [22]. The influencing factors of hub economy development include self-organized market factors and other-organized government factors. Among them, the number of laborers, public infrastructure, institutional innovation, and technological level are significant influencing factors of the hub economy [8].

In general, the results of the existing research enrich the theoretical system of the hub economy. However, there are still three shortcomings. First, most regions lack statistical systems and evaluation systems related to the hub economy [2]. Although existing studies have evaluated the competitiveness of hub economies, they focus on establishing indicators and improving the evaluation system [9]. It is difficult to obtain data for some indicators, which increases

the difficulty of quantitative evaluation of the hub economy. Second, there are few studies on the influencing factors of the hub economy [8], especially the research on the factors influencing the input-output efficiency of the hub economy. Finally, there is a lack of adequate references for policy-making in the hub economy [1, 13]. Some regions in China have a vague understanding of the development system and mechanism of the hub economy. The lack of accurate and scientific planning leads to repeated investment, over-capacity, and weak competitiveness.

In order to make up for the above shortcomings, based on the existing research, this paper studies the evaluation and influencing factors of the input-output efficiency of the hub economy. Based on the Super SBM, Malmquist, and Tobit models, this paper designs a two-stage analysis framework. In the first stage, the nonangle and nonradial Super SBM model is used to measure technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE) of the hub economy. The Malmquist model is used to measure the changes in technical efficiency (Effch), technological progress (Techch), pure technical efficiency (Pech), scale efficiency (Sech), and total factor productivity (Tfpch) of the hub economy. TE, PTE, and SE are used to analyze the static characteristics of the efficiency of the hub economy. Effch, Techch, Pech, Sech, and Tfpch are used to analyze the dynamic characteristics of the efficiency of the hub economy. In the second stage, the Tobit model is used to analyze the factors influencing the efficiency of the hub economy. Among them, the explained variable in the second stage is the measurement result of the technical efficiency of the hub economy in the first stage. Based on the regression results, the influencing mechanism of different influencing factors on the efficiency of the hub economy is revealed. This paper uses the panel data of 30 provinces and cities in China from 2012 to 2021 for empirical research. This study provides support for the implementation of China's hub economy strategy and provides a reference for relevant government departments to make policies.

The remainder of this research paper is organized as follows. Section 3 gives the research idea and solution framework and explains the basic forms and application principles of Super SBM, Malmquist, and Tobit models. Section 4 clarifies the input indicators, output indicators, impact indicators, and the assumptions of the corresponding impacts of the hub economy and presents the data sources and the corresponding descriptive statistical results. In Section 5, the empirical analysis is carried out from three aspects: static evaluation, dynamic evaluation, and influencing factors. Section 6 presents the conclusions. Section 7 provides implications and points out limitations and future research directions.

3. Research Design and Methodology

Referring to previous studies [23, 24], this paper designs a two-stage analysis framework based on Super SBM, Malmquist, and Tobit, as shown in Figure 1. This analysis framework is used to evaluate the efficiency of China's hub economy and analyze its influencing factors. The first stage is to evaluate China's hub economy's static and dynamic efficiency. The second stage is to analyze the factors influencing the efficiency of China's hub economy. The explained variable in the second stage is the result of the evaluation of technical efficiency in the first stage. The input factors of the hub economy include transportation, logistics, and information. The output factors of the hub economy include connectivity, informatization, the degree of opening to the outside world, and economic benefits. The factors influencing the efficiency of a hub economy include policy, industrial structure, education, enterprises, innovation, and technology. The evaluation indexes of the static efficiency of the hub economy include TE, PTE, and SE. The evaluation indexes of the dynamic efficiency of the hub economy include Effch, Techch, Pech, Sech, and Tfpch.

3.1. Super SBM Model. Data envelopment analysis (DEA) is mainly used to measure and evaluate input-output efficiency. This method can obtain the weight of input and output through the data itself, which is more objective. Among them, the CCR model calculates the TE of the decision-making unit (DMU) proposed by Charnes, Cooper, and Rhodes in 1978. The CCR model assumes constant returns to scale (CRS) of production technology. However, in actual production, the DMU is usually not in the optimal scale production state. In response, Banker, Charnes, and Cooper proposed a DEA model for estimating SE, called the BCC model, in 1984. This model assumes variable returns to scale (VRS) and obtains PTE excluding the impact of scale. Finally, the SE of DMU is separated through the following equation [25]:

$$\mathrm{SE} = \frac{\mathrm{TE}}{\mathrm{PTE}}. \tag{1}$$

The CCR and BCC models are angular and radial efficiency calculation models. The measurement of inefficiency only includes the equal-proportional reduction or increase of all inputs or outputs. However, ineffective DMUs include slack improvements in addition to equal-proportional improvements. Tone proposed the slack-based measure model (SBM) in 2001 to solve the problem of slack variables not being included in the inefficiency measure of radial models. This model measures inefficiency from both input and output perspectives.

Furthermore, the efficiency calculation results of the traditional DEA model cannot rank the DMUs at the production frontier. In order to make up for this drawback, Tone proposed the SBM super efficiency model (Super SBM) in 2002, thus realizing the ranking of DMUs in the frontier [25]. This study introduces the Super SBM model to evaluate the static efficiency of the hub economy.

The Super SBM model based on the CRS assumption is shown in the following equation:

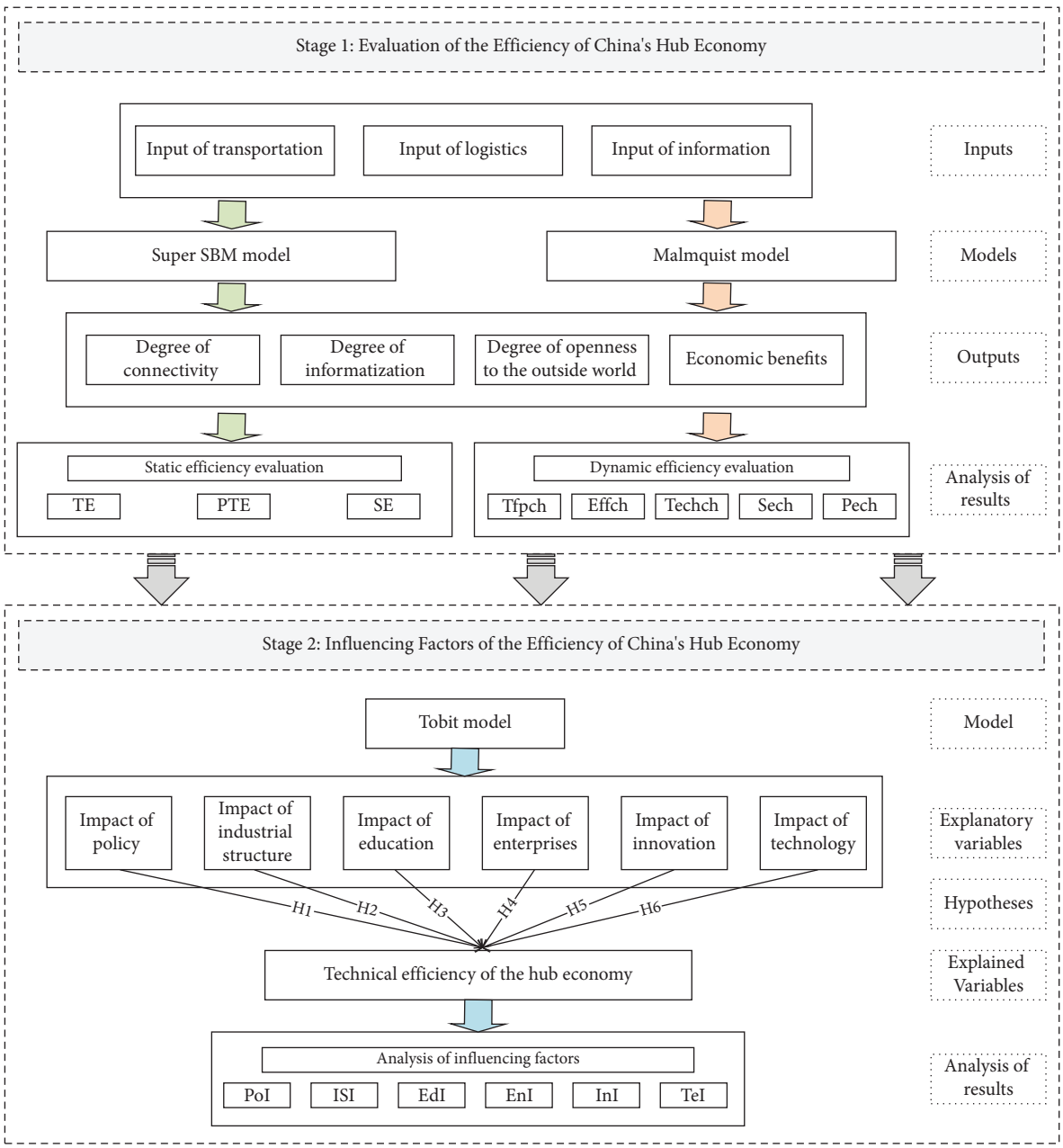

Figure 1: Two-stage analysis framework based on the super SBM-Malmquist-Tobit model.

$$\min \rho_{SE} = \frac{1 + (1/m)\sum_{i=1}^{m}\left(s_i^- / x_{ik}\right)}{1 - (1/s)\sum_{r=1}^{s}\left(s_r^+ / y_{rk}\right)},$$

$$\text{s.t.} \sum_{j=1, j\neq k}^{n} x_{ij}\lambda_j - s_i^- \leq x_{ik}, \tag{2}$$

$$\sum_{j=1, j\neq k}^{n} y_{rj}\lambda_j + s_r^+ \geq y_{rk}\lambda, s^-, s^+ \geq 0\, i = 1, 2, \ldots, m;\ r = 1, 2, \ldots q;\ j = 1, 2, \ldots n\,(j \neq k).$$

The Super SBM model based on the VRS assumption needs to add equation (3) to the above equation.

$$\sum_{j=1, j\neq k}^{n} \lambda_j = 1, \tag{3}$$

where ρ_{SE} is the evaluation efficiency of the DMU. x_{ik} is the ith input value of the kth DMU (similarly for x_{ij}). y_{rj} is the rth output value of the jth DMU (similarly for y_{rk}). λ_j is the weight of each element of the jth DMU. s^- and s^+ are slack variables of input and output, respectively. m is the number of input indicators. q is the number of output indicators. n is the number of DMUs.

Furthermore, TE represents the comprehensive efficiency of resource allocation ability and resource use efficiency. TE > 1 indicates that the TE of the hub economy of the DMU is effective, and the resource allocation ability and resource use efficiency reach the frontier. Otherwise, it is invalid. PTE represents the production efficiency affected by management and technology factors, reflecting the institutional arrangement and management level. PTE > 1 indicates that the PTE of the hub economy of the DMU is effective, the institutional arrangement is excellent, and the management level is high. Otherwise, it is invalid. SE represents the production efficiency affected by the scale factor, reflecting the return to scale of production and the efficiency of resource allocation. SE > 1 indicates that the SE of the hub economy of the DMU is effective, and the production scale return is optimal. Otherwise, it is invalid.

3.2. Malmquist Model. The Super SBM model can only use cross-sectional data to evaluate the static efficiency of the hub economy, while the Malmquist model can evaluate the dynamic change trend of the hub economy in different periods. The Malmquist model was proposed by Malmquist in 1953. Fare used the DEA method to calculate the Malmquist index in 1992. This method can be used to analyze Tfpch for panel data containing observations at multiple points. Production is a long, continuous process in which the production technology changes. This method makes up for the disadvantage that the traditional DEA model cannot calculate and analyze productivity with time [25]. Therefore, the Malmquist model is introduced to evaluate the dynamic evolution trend of the hub economy. The Malmquist model from period t to period $t + 1$ is shown in the following equation:

$$\begin{aligned} M_i(x_{t+1}, y_{t+1}; x_t, y_t) &= \left[\frac{D_i^t(x_{t+1}, y_{t+1})}{D_i^t(x_t, y_t)} \times \frac{D_i^{t+1}(x_{t+1}, y_{t+1})}{D_i^{t+1}(x_t, y_t)}\right]^{(1/2)} \\ &= \left[\frac{D_i^{t+1}(x_{t+1}, y_{t+1})}{D_i^{t+1}(x_t, y_t)}\right] \times \left[\frac{D_i^t(x_{t+1}, y_{t+1})}{D_i^{t+1}(x_{t+1}, y_{t+1})} \times \frac{D_i^t(x_t, y_t)}{D_i^{t+1}(x_t, y_t)}\right]^{(1/2)}, \end{aligned} \tag{4}$$

where D represents the distance function between DMUs; t represents the period; and x and y represent the input and output vectors, respectively.

Tfpch can be decomposed into Effch and Techch, and Effch can be decomposed into Sech and Pech, as shown in the following equation:

$$\text{Tfpch} = \text{Effch} \times \text{Techch} = \text{Sech} \times \text{Pech} \times \text{Tech ch}. \tag{5}$$

In a certain period, Tfpch > 1 indicates that the utilization rate of total factor inputs is improved. Otherwise, it indicates a decline. Techch > 1 represents the progress of technology, that is, the improvement of technology level through the introduction and innovation of technology. Otherwise, it represents a regression. Effch > 1 represents the improvement of technical efficiency, that is, the improvement of technology utilization efficiency. Otherwise, it indicates a decline. Sech > 1 represents the improvement of scale efficiency, that is, the increase in returns to scale. Otherwise, it indicates a decline. Pech > 1 represents the improvement of pure technical efficiency, that is, the improvement of management level and the optimization of institutions. Otherwise, it indicates a decline.

3.3. Tobit Model. In order to explore the influencing factors of the efficiency of China's hub economy, this paper uses the Tobit model to conduct regression analysis on the influencing factors. The Tobit model is a model applied to limited explained variables whose value ranges are limited [26]. If some observations are systematically removed from the sample, the explained variable will be truncated [27]. The Tobit model is suitable for the analysis of influencing factors of this kind of data. The basic form of the Tobit model [28] is shown in equation (6). This study takes the TE values of 30 regions from 2012 to 2021 calculated by the Super SBM model based on CRS assumption as the explained variable. The lower limit of the value range is 0, which is the left-hand restricted variable, so the Tobit model is used to explore its influencing factors.

$$\begin{aligned} y_i^* &= x_i\beta + u_i, \\ u_i &\sim N\left(0, \sigma^2\right), \\ y_i &= \begin{cases} y_i^*, & y_i^* > 0, \\ 0, & y_i^* \leq 0. \end{cases} \end{aligned} \tag{6}$$

When the latent variable $y_i^* \leq 0$, the explained variable $y_i = 0$. When $y_i^* > 0$, the explained variable $y_i = y_i^*$. x_i is the vector of independent variables. y_i^* is the vector of truncated dependent variables. β is the vector of regression parameters. u_i is the disturbance term. At the same time, it is assumed that the disturbance term u_i follows a normal distribution with mean equal to 0 and variance equal to σ^2.

4. Data Sources and Basic Assumptions

4.1. Input Indicators. The input indicators refer to the human, material, financial, and other resources invested in building a hub economy, as shown in Table 1.

4.1.1. Input of Transportation. Transportation hubs are the main platforms that centralize and disperse the factor resources of the hub economy [12]. The construction and improvement of a comprehensive transportation system are the core elements of forming a hub economy [10]. Therefore, the related inputs used for constructing transportation channels, hubs, and networks are considered to be one of the input indicators of the hub economy. The investment in fixed assets of the whole society in transportation, storage, and postal industries is used to represent the transportation input.

4.1.2. Input of Logistics. Logistics hubs are the leading platforms for storage, packaging, loading and unloading, processing, and handling of factor resources of the hub economy, and logistics hub services are inseparable from comprehensive transportation [14]. Related employment personnel support the operation and management of the logistics system. Therefore, employment personnel in the logistics system are one of the input indicators of the hub economy. Logistics input is represented by the sum of the number of employees in the railway transport industry, road transport industry, water transport industry, air transport industry, loading, unloading, and other transport service industry, and postal service industry.

4.1.3. Input of Information. The combined application of information and transportation provides a good idea for improving the service level of a comprehensive transportation hub and economic development. Using big data ideas and technologies to serve the construction, management, and operation of transportation hubs is significant in improving the service level of comprehensive transportation hubs [29]. It can be seen that information construction input is also one of the input indicators of the hub economy, so the number of Internet broadband access ports is used to represent information input.

4.2. Output Indicators. The output indicators refer to the economic and related benefits generated after investing specific resources to build the hub economy, as shown in Table 1.

4.2.1. Degree of Connectivity. Air passenger traffic, air cargo traffic, and flight frequency directly affect local economic development and indirectly have a more positive spillover effect on neighboring cities connected by the airport hub network [30]. Such direct impact and indirect spillover effect are the output benefits of the hub economy. It can be seen that the degree of connectivity can represent the output of the hub economy, so passenger turnover and cargo turnover are used to represent the output of connectivity.

4.2.2. Degree of Openness to the Outside World. Based on the port economy data of North Korea, it can be concluded that the dependence on hub ports is not only a local restriction factor but also a factor for trade growth [31]. It can be seen that trade growth is an output benefit of the hub. Therefore, the total import and export volume of domestic destinations and source places can represent the trade output index, the output of the degree of openness to the outside world.

4.2.3. Degree of Informatization. The hub economy is formed based on the hub, which has a strong attraction to production factors such as information [10]. Furthermore, the hub economy shows a certain level of informatization. It can be seen that the degree of informatization of the hub area is also one of the output indicators of the hub economy, so the software business income is used to represent the output of the degree of informatization.

4.2.4. Economic Benefits. The internal relationship of the hub economy is essentially the internal relationship between the hub and economy, including the linkage relationship, matching relationship, and iteration relationship [12]. Moreover, hub economy is a kind of economic development mode, and the corresponding economic benefits are one of the essential representations. Therefore, the gross regional product represents the output of economic benefits.

4.3. Influencing Factor Indicators and Corresponding Assumptions. The influencing factor indicators refer to other environmental factors that differ from the DEA's input and output indicators [19]. The following hypotheses are made based on the analysis of relevant influencing factors of the hub economy. The factors influencing the efficiency of the hub economy are shown in Table 1.

H1: financial expenditure on local transportation has a significant positive impact on the efficiency of the hub economy.

The government policy support of the hub economy is some special public goods provided by the public sector for the industry, which can be measured by the financial expenditure of local transportation [8]. Therefore, the financial expenditure of local transportation is used to represent the policy impact (PoI) on the efficiency of the hub economy.

Table 1: Input-output index system and influencing factor index system.

Type	First level	Second level
Input	Input of transportation	Investment in fixed assets of the whole society in transportation, storage, and postal services industries (100 million CNY)
	Input of logistics	Total number of employed persons in the railway transport industry, road transport industry, water transport industry, air transport industry, loading, unloading, and other transport service industry, and postal service industry (person)
	Input of information	Number of internet broadband access ports (ten thousand units)
Output	Degree of connectivity	Passenger turnover (100 million person-km) and cargo turnover (100 million ton-km)
	Degree of informatization	Software business revenue (100 million CNY)
	Degree of openness to the outside world	Total import and export volume at domestic destinations and source places (thousand dollars)
	Economic benefits	Gross regional product (100 million CNY)
Impact	Impact of policy	Fiscal expenditure on local transportation (100 million CNY)
	Impact of industrial structure	Proportion of the added value of the tertiary industry in gross regional product
	Impact of education	Education expenditure (ten thousand CNY)
	Impact of enterprises	Number of legal entities (unit)
	Impact of innovation	The grant volume of domestic patent applications (item)
	Impact of technology	Technology market turnover (100 million CNY)

Note. Indicators such as the number of Internet broadband access ports, passenger turnover, cargo turnover, software business revenue, total import and export volume of domestic destinations and source places, gross regional product, fiscal expenditure on local transportation, number of legal entities, grant volume of domestic patent applications, technology market turnover, number of employees in the railway transport industry, number of employees in the road transport industry, and number of employees in the postal industry can be obtained directly from the China statistical yearbook. Due to changes in statistical caliber, missing data, and other reasons, indicators such as investment in fixed assets of the whole society in transportation, storage, and postal services, number of employees in water transport industry, number of employees in air transport industry, number of employees in loading, unloading, and other transport services industry, proportion of added value of tertiary industry in gross regional product, education expenditure, and total number of employees representing logistics input need to be estimated according to the existing data of China statistical yearbook.

H2: the ratio of the added value of the tertiary industry to the gross regional product has a significant positive impact on the efficiency of the hub economy.

In the competitiveness evaluation of the hub economy, the proportion of the added value of the tertiary industry in the gross regional product is an essential indicator of the development of the hub industry [9]. Therefore, the ratio of the added value of the tertiary industry to the gross regional product is used to represent the impact of industrial structure (ISI) on the efficiency of the hub economy.

H3: education expenditure has a significant positive impact on the efficiency of the hub economy.

Strengthening investment in education is the key to the transformation and growth of the economy at the present stage [32], and economic benefits are an essential output indicator of the hub economy. Therefore, the education expenditure is used to represent the impact of education (EdI) on the efficiency of the hub economy.

H4: the number of legal entities has a significant positive impact on the efficiency of the hub economy.

Urban hub economy, enterprise agglomeration, and regional development affect each other and are inseparable [33]. Therefore, the number of legal entities is used to represent the enterprise impact (EnI) on the efficiency of the hub economy.

H5: the grant volume of domestic patent applications has a significant positive impact on the efficiency of the hub economy.

The grant volume of domestic patent applications can reflect the innovation ability of research and experiments to a certain extent [8]. Strengthening the innovation elements in the operation of the hub economy can help integrate the resource elements in the hub system [1]. Therefore, the grant volume of domestic patent applications is used to represent the innovation impact (InI) on the efficiency of the hub economy.

H6: technology market turnover has a significant positive impact on the efficiency of the hub economy.

The economy driven by transportation factors is an economic development mode caused by the technological progress of offline connectivity [34]. In addition, technological innovation promotes the transformation of economic development mode and indirectly promotes economic growth by improving factor productivity and optimizing resource allocation [35]. Technological progress has significantly improved the construction of hub economy platforms in the context of "Internet+" [1]. Therefore, the technology market turnover is used to represent the technological impact (TeI) on the efficiency of the hub economy.

4.4. Data Sources and Descriptive Statistics. The data on the hub economy's input, output, and influencing factors required in this study are mainly from the China Statistical Yearbook from 2012 to 2023 (https://www.stats.gov.cn/sj/ndsj/). The period is 2012–2021. There are a total of 300 data for each indicator. The DMUs refer to 30 of China's 34 provincial-level administrative regions. They are Beijing, Tianjin, Shanghai, Chongqing, Hebei, Shanxi, Liaoning,

Jilin, Heilongjiang, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Hainan, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Inner Mongolia Autonomous Region (Inner Mongolia) and Guangxi Zhuang Autonomous Region (Guangxi), Ningxia Hui Autonomous Region (Ningxia), and Xinjiang Uygur Autonomous Region (Xinjiang). Taiwan, Tibet Autonomous Region (Tibet), Hong Kong Special Administrative Region (Hong Kong), and Macao Special Administrative Region (Macao) are excluded because the data are difficult to obtain. The descriptive statistical results, such as mean, maximum, minimum, and standard deviation, are shown in Table 2. Due to the large geographical span and time span, the standard deviation is significant. However, the data source is trustworthy and reliable, so it does not affect the adoption and application of data.

5. Empirical Analysis

5.1. Static Efficiency Analysis of China's Hub Economy. This paper uses the nonangle and nonradial Super SBM models (CRS and VRS) in DEA Solver 13 software to measure the TE, PTE, and SE of hub economies in 30 provinces and cities from 2012 to 2021.

5.1.1. Analysis of the Efficiency of China's Overall Hub Economy. Figure 2 shows that from 2012 to 2017, China's hub economy's TE remained unchanged, the PTE gradually increased, and the SE gradually decreased. From 2017 to 2019, China's hub economy's TE, PTE, and SE increased significantly. From 2019 to 2021, the TE, PTE, and SE of China's hub economy first declined significantly, and then the degree of decline eased. The reasons for such a volatile trend are as follows. 2017 and 2019 are two critical nodes in developing China's hub economy. Before 2017, China's transportation and logistics economy construction was normalized, and people paid insufficient attention to the construction of the hub economy. The construction of the hub economy has not been formally proposed, and the TE of the hub economy has remained basically unchanged. By 2017, many provinces and cities in China focused on constructing the hub economy and its weak points and made precise efforts to improve the three kinds of efficiency. Gansu, Henan, Hubei, Shaanxi, Sichuan, Yunnan, Jiangsu, Xinjiang, Zhejiang, and Chongqing mainly proposed the construction of hub economies in 2017 [8]. By 2019, due to the sudden outbreak of the global COVID-19 epidemic, the construction of the hub economy of all provinces and cities in China has been negatively affected to varying degrees. The management level and scale production remuneration of the hub economy all decline, which ultimately leads to the decline of the TE of the hub economy. By 2020, under the normalizable prevention and control of the epidemic, all walks of life in China have gradually resumed production, the construction of the hub economy has gradually returned to the right track, and the downward trend of TE has eased. It can be seen that China's hub economy is in a state of fluctuation and instability. The results that fit the actual situation confirm that the input-output evaluation system of the hub economy constructed in this study is reasonable and accurate.

Overall, the mean values of TE, PTE, and SE of China's overall hub economy from 2012 to 2021 are 0.5853, 0.7402, and 0.8201, respectively. Among them, TE is the lowest, PTE is the second, and SE is the highest, which does not reach the efficient state. It shows that the management level in the development of China's hub economy is not high, the return to production scale is not high, and the resource allocation ability and resource use level are deficient. Low PTE and low SE cause the low TE of the hub economy. Low PTE is the main factor, and low SE is the secondary factor. The reason is that China's hub economy is still in the initial stage of formation [8]. Management means, system, investment scale, and other experience are insufficient. Therefore, it is urgent to carry out institutional reform, improve the management level, and increase the return to scale of production.

In terms of the efficiency of each region in each year, the gap of TE in 2014 is the largest. The difference between Shanghai, with the highest efficiency, and Qinghai, with the lowest efficiency, is 1.6194. In terms of PTE, the gap in 2014 is the largest. The difference between Shanghai, with the highest efficiency, and Shanxi, with the lowest efficiency, is 1.6640. In terms of SE, the gap in 2012 is the largest. The difference between Hubei, with the highest efficiency, and Qinghai, with the lowest efficiency, is 0.9938. It can be seen that there is a sizeable inter-regional gap in the development of the hub economy, and the problems of imbalance and incoordination are prominent. The reason is that there are significant gaps in geographical location, economic level, transportation foundation, management level, and other aspects among different regions. In this regard, all regions should consider the local basic status quo, find the weak points, make precise efforts, and realize the catch-up of the hub economy.

5.1.2. Analysis of TE, PTE, and SE of Hub Economy

(1) *The Analysis of TE.* By analyzing the average TE of the hub economy from 2012 to 2021 of all provinces and cities, it is found that nine provinces and cities have reached an efficient state and frontier, as shown in Table 3. They are Beijing, Tianjin, Liaoning, Shanghai, Jiangsu, Zhejiang, Anhui, Hunan, and Guangdong. The remaining provinces and cities have not reached an efficient state. In the production frontier, 7/9 provinces and cities are located in the eastern region and 2/9 in the central region. The ability of resource allocation and the efficiency of resource use in the central and western regions are not high. The hub economy in the central and western regions rarely reaches the production frontier. There are 15 provinces and cities with an average TE level higher than the national average. By comparing the TE of the hub economy in each region each year, it is found that Beijing, Shanghai, Jiangsu, Anhui, Hunan, and Guangdong have fully achieved

Table 2: Descriptive statistics.

Type	Variables (unit)	Mean	Std. dev	Min	Max
Input	Input of transportation (100 million CNY)	1675.927	1222.375	113.28	5957.633
	Input of logistics (person)	265436.9	168493	32920	907794.5
	Input of information (ten thousand units)	2295.277	1804.853	105.6	9333.7
Output	Degree of connectivity (the goods) (100 million ton-km)	5962.963	6028.176	398.43	34074.6
	Degree of connectivity (the passenger) (100 million person-km)	719.7241	512.7666	52.51	2998.23
	Degree of informatization (100 million CNY)	$1.83E+07$	$3.02E+07$	2680.7	$2.04E+08$
	Degree of openness to the outside world (thousand dollars)	$1.47E+08$	$2.52E+08$	310856	$1.47E+09$
	Economic benefits (100 million CNY)	27005.38	22319.91	1528.5	124719.5
Impact	Impact of policy (100 million CNY)	320.1766	178.0773	51.02	1982.63
	Impact of industrial structure	0.501239	0.0870958	0.3446413	0.837316
	Impact of education (ten thousand CNY)	$1.25E+07$	8431663	1446399	$5.86E+07$
	Impact of enterprises (unit)	673919.6	639044.5	33425	3634156
	Impact of innovation (item)	70552.81	109730.1	502	872209
	Impact of technology (100 million CNY)	521.2936	962.3252	0.57	7005.65

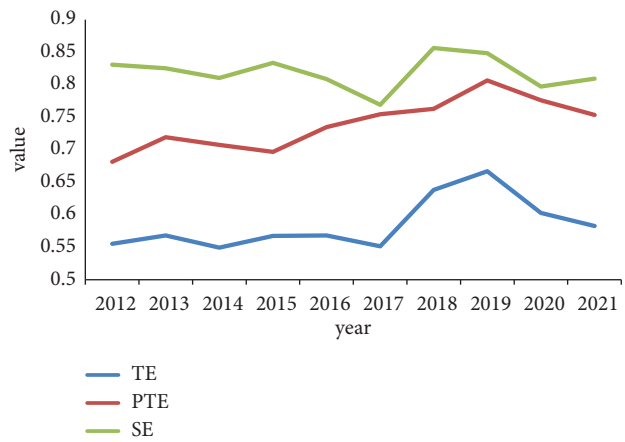

Figure 2: Static efficiency of China's overall hub economy from 2012 to 2021.

Table 3: Mean values and rankings of the TE, PTE, and SE of the hub economy in each region from 2012 to 2021.

Regions	*TE*				*PTE*				*SE*			
	2020	2021	Mean	Ranking	2020	2021	Mean	Ranking	2020	2021	Mean	Ranking
Beijing	1.164	1.209	1.130	4	1.172	1.224	1.137	7	0.993	0.988	0.994	3
Tianjin	0.659	0.694	1.002	9	1.041	1.030	1.161	5	0.633	0.674	0.859	20
Hebei	1.003	0.396	0.605	14	1.009	1.019	0.790	16	0.994	0.389	0.816	22
Shanxi	0.061	0.049	0.052	29	0.070	0.051	0.151	26	0.869	0.965	0.810	23
Inner Mongolia	0.015	0.152	0.054	28	0.017	0.161	0.057	30	0.842	0.942	0.952	13
Liaoning	1.243	1.184	1.106	5	1.269	1.238	1.131	8	0.979	0.956	0.979	7
Jilin	0.220	0.220	0.248	21	0.275	0.277	0.299	23	0.799	0.795	0.829	21
Heilongjiang	0.029	0.027	0.099	26	0.033	0.030	0.109	28	0.889	0.898	0.911	15
Shanghai	1.603	1.478	1.487	1	1.635	1.524	1.529	1	0.980	0.970	0.972	8
Jiangsu	1.258	1.314	1.207	2	1.265	1.318	1.211	4	0.994	0.997	0.997	2
Zhejiang	1.043	1.024	1.003	8	1.045	1.030	1.006	11	0.999	0.995	0.997	1
Anhui	1.139	1.108	1.131	3	1.140	1.130	1.138	6	0.999	0.980	0.994	4
Fujian	1.005	1.017	0.701	11	1.010	1.017	0.727	18	0.994	1.000	0.959	11
Jiangxi	1.068	1.062	0.980	10	1.072	1.067	1.000	12	0.996	0.995	0.969	10
Shandong	0.564	0.669	0.661	13	0.569	0.672	0.668	19	0.991	0.995	0.989	6
Henan	0.223	0.230	0.378	17	1.000	1.020	1.019	10	0.223	0.226	0.370	28
Hubei	0.397	0.448	0.594	15	0.428	0.458	0.728	17	0.926	0.978	0.862	19
Hunan	1.036	1.041	1.051	7	1.052	1.045	1.057	9	0.985	0.997	0.993	5
Guangdong	1.060	1.055	1.088	6	1.437	1.361	1.367	2	0.738	0.775	0.800	24
Guangxi	0.403	0.344	0.214	23	0.434	0.386	0.236	25	0.930	0.893	0.910	16

Table 3: Continued.

Regions	TE				PTE				SE			
	2020	2021	Mean	Ranking	2020	2021	Mean	Ranking	2020	2021	Mean	Ranking
Hainan	0.256	1.125	0.315	20	1.024	1.151	0.665	20	0.250	0.978	0.489	27
Chongqing	0.398	0.415	0.366	18	0.435	0.442	0.390	21	0.916	0.940	0.940	14
Sichuan	0.296	0.286	0.247	22	0.304	0.292	0.255	24	0.971	0.978	0.970	9
Guizhou	1.031	0.260	0.505	16	1.043	0.380	0.806	15	0.988	0.684	0.627	26
Yunnan	0.072	0.056	0.080	27	0.085	0.069	0.089	29	0.848	0.817	0.907	17
Shaanxi	0.377	0.370	0.334	19	0.390	0.386	0.347	22	0.967	0.958	0.957	12
Gansu	0.307	0.097	0.691	12	1.005	0.146	0.879	14	0.306	0.666	0.758	25
Qinghai	0.020	0.008	0.012	30	0.999	0.999	0.908	13	0.020	0.008	0.026	30
Ningxia	0.091	0.103	0.102	25	1.000	1.651	1.215	3	0.091	0.062	0.085	29
Xinjiang	0.047	0.051	0.114	24	0.056	0.062	0.130	27	0.841	0.822	0.882	18
Mean	0.603	0.583	0.585	—	0.777	0.755	0.740	—	0.798	0.811	0.820	—

Note. The mean values and rankings in the table are based on all data from 2012 to 2021, and only the specific efficiency values of 2020 and 2021 are listed due to space limitations.

efficiency. The TE values of these regions in all years during the observation period are more significant than 1. Tianjin, Hebei, Liaoning, Zhejiang, Fujian, Jiangxi, Shandong, Henan, Hubei, Hainan, Guizhou, and Gansu have achieved relatively whole effect. The TE values of these regions are more significant than 1 in some years of the observation period. The TE values of the hub economy in the other provinces and cities each year are all nonefficient.

(2) *The Analysis of PTE*. By analyzing the mean value of PTE of the hub economy from 2012 to 2021 in all provinces and cities, it is found that the mean values of PTE of the hub economy in 11 regions have reached the effective state, as shown in Table 3. They are Beijing, Tianjin, Liaoning, Shanghai, Jiangsu, Zhejiang, Anhui, Henan, Hunan, Guangdong, and Ningxia. The mean values of PTE of the hub economy in the other provinces and cities are less than 1. Moreover, the mean values of PTE of 16 provinces and cities are higher than the national average level. By observing the PTE values of the hub economy in each region each year, it is found that the PTE of the hub economy in Beijing, Tianjin, Shanghai, Jiangsu, Anhui, Henan, Hunan, and Guangdong is entirely effective. The PTE of the hub economy in Hebei, Liaoning, Zhejiang, Fujian, Jiangxi, Shandong, Hubei, Hainan, Guizhou, Gansu, and Ningxia is relatively wholly effective. The other provinces and cities are not effective. For the regions where the PTE of the hub economy is not effective, they should improve the management level and optimize the institutional arrangement of the construction of the hub economy.

(3) *The Analysis of SE*. It can be found that from 2012 to 2021, the mean values of SE of the hub economy in 13 regions are more significant than 0.95, as shown in Table 3. They are Beijing, Inner Mongolia, Liaoning, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Hunan, Sichuan, and Shaanxi. There are 21 provinces and cities with higher than average scale efficiency. It is worth noting that the mean values of SE in Qinghai and Ningxia are 0.0259 and 0.0853, respectively, which are far lower than the annual mean values of SE in other regions. This leads to the fact that the mean TE of these two regions is also lower than that of other provinces and cities. The ranking of the TE mean is 30 and 25, respectively. For provinces and cities with low SE of hub economies, such as Qinghai and Ningxia, it is necessary to increase the return to scale of production.

5.1.3. Quadrant Analysis of Static Efficiency of Hub Economy. Taking the mean value of PTE and SE as the standard [36], 30 provinces and cities are divided into four types of regions distributed in four quadrants, respectively, as shown in Figure 3. In general, most regions are distributed in the first, second, and fourth quadrants, indicating that the development of the hub economy in most regions in China is in these three states. This result is related to many factors, such as unbalanced regional development, uneven construction teams of the hub economy, and different emphasis on the construction of the hub economy. The following conclusions are drawn from the zoning observations. The PTE and SE of the hub economy in the regions in the first quadrant are above their respective means. The development of the hub economy in these regions has taken the lead in China. These regions should take foreign developed regions as a comparison and further improve the corresponding efficiency according to their shortcomings. The PTE of the hub economy in the regions in the second quadrant is below the mean, while the SE is above the mean. Such regions should focus on improving the management level and optimizing the institutional arrangement when developing the hub economy. The PTE of the hub economy in the regions in the fourth quadrant is above the mean, while the SE is below the mean. Such regions should pay attention to improving the returns to scale of production when developing the hub economy. The PTE and SE of the hub economy in the regions in the third quadrant are below their respective mean values. Such regions should focus on improving their management level and increasing the return to scale of production.

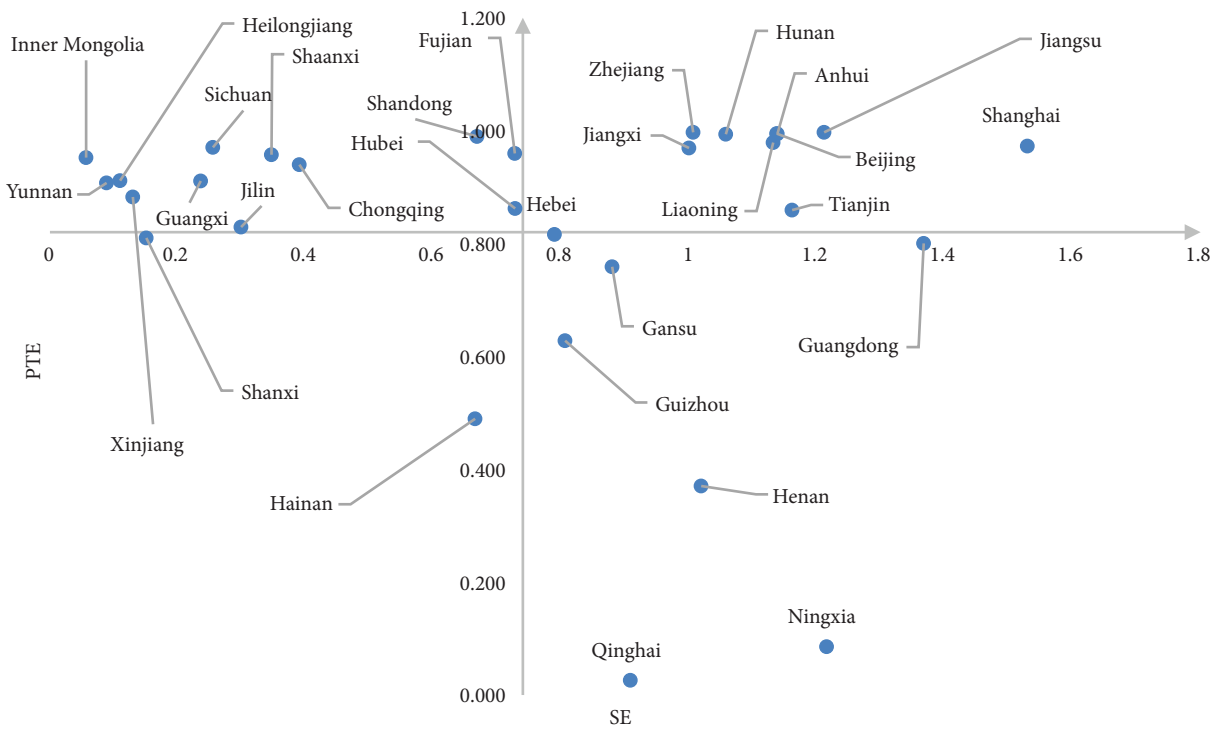

Figure 3: Quadrant diagram of static efficiency of hub economy based on PTE and SE.

5.2. Analysis of the Dynamic Change Trend of China's Hub Economy. This paper uses the Malmquist model under the assumption of VRS from the input perspective in DEAP 2.1 software to calculate the Tfpch and its decomposition items of the hub economy of 30 provinces and cities from 2012 to 2021. The dynamic evolution trend of the hub economy is analyzed as follows.

5.2.1. Intertemporal Analysis of Dynamic Changes of Hub Economy. Figure 4 shows that the Tfpch of the hub economy in 2016-2017, 2017-2018, and 2018-2019 is 1.037, 1.016, and 1.009, respectively, indicating that the utilization degree of total factor input is on the rise. The Tfpch of the hub economy in 2019-2020 is 0.821, the most drastic decline in the nine periods. From 2020 to 2021, the utilization rate of total factor input in the hub economy increased again, and the Tfpch was 1.044. The reasons for such fluctuations are as follows: many provinces and cities in China started to build hub economies in 2017, which led to an increase in the utilization rate of total factor inputs in the hub economy. However, by 2019, the outbreak of COVID-19 in the world severely hindered the construction of the hub economy and even the overall economic development. It has led to a sharp decline in the utilization of total factor inputs. By 2020, under the normalizable prevention and control of COVID-19, China has gradually resumed the orderly development of all walks of life, including the construction of the hub economy. It can be seen that the development of China's hub economy has fluctuated dramatically in recent years, and the data results, which are consistent with the actual situation, confirm the accuracy and rationality of the constructed index system.

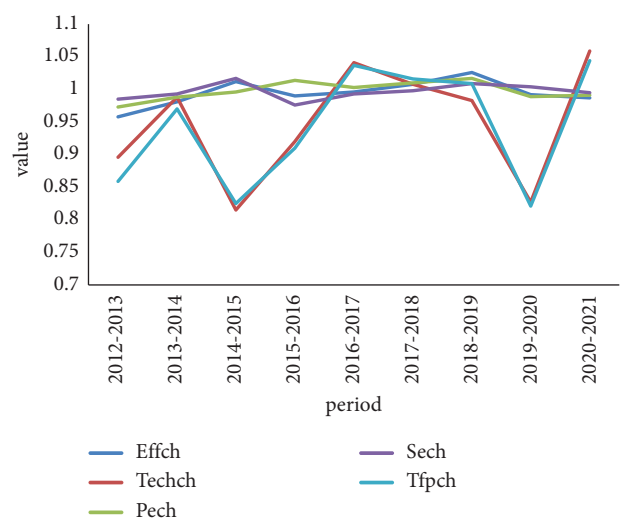

Figure 4: Tfpch and its decomposition items of hub economy from 2012 to 2021.

From the average data, the average value of the Tfpch from 2012 to 2021 is 0.939. It shows that the total factor productivity of China's hub economy has been declining for many years, and the hub economy as a whole has not developed in a good direction. Furthermore, observing the decomposition terms of Tfpch, the Effch is 0.994 and the Techch is 0.945. It shows that the main reason for the decline in total factor productivity is the deterioration of technological innovation and introduction. The secondary reason is the decline of technical efficiency. In other words, the overall resource allocation, resource use, and technology

application are not ideal. According to the decomposition terms of the Effch, the decline in technical efficiency is jointly caused by the decline in scale efficiency and pure technical efficiency. The scale efficiency decreases by 0.3%, and the pure technical efficiency decreases by 0.2%.

Overall, from period 1 (2012-2013) to period 9 (2020-2021), the Effch, Sech, and Pech fluctuate little, while the Techch and Tfpch fluctuate considerably. The total factor productivity of the hub economy in period 9 has the most significant increase of 4.4%, mainly due to technological progress of 5.9%. The total factor productivity of the hub economy in period 8 has the most significant decline of 17.9%, mainly due to technological regression of 17.3%. In addition, compared with Effch, Sech, and Pech, the fluctuation of Tfpch and Techch tend to be the same. The fluctuation of Tfpch in the hub economy is mainly due to the change in Techch. By 2020-2021, the Techch has exceeded one and reached the maximum value of historical change. It shows that the production technology level of China's hub economy is constantly improving in the fluctuation. From the data of each period, the Tfpch and its decomposition items of the hub economy fluctuate to varying degrees. It shows great instability factors in the development of China's hub economy at the present stage. It is urgent to stabilize technological progress and realize the innovation and transformation of knowledge and technology. In general, to improve the total factor productivity of the hub economy, we must pay attention to technological innovation, rational allocation of resources, and effective use of technology.

5.2.2. Regional Analysis of Dynamic Changes in Hub Economy. In Table 4, from the perspective of the eastern, central, and western regions, the mean value of Tfpch in the eastern region is the largest, followed by the central and western regions. Only the mean value of Tfpch in the eastern region is above the overall mean value. It shows that the total factor utilization level of the hub economy in the eastern region is higher than that in the central and western regions and the nation. The Techch in the eastern region is the largest, followed by the central and western regions. The Techch in the eastern region is higher than the national average level. However, the Techch and Tfpch of the eastern, central, and western regions and the national average level do not exceed 1. It indicates that the corresponding efficiency shows a decreasing trend. The mean value of Effch in the eastern region is the largest, followed by the central and western regions, which are 1.006, 0.989, and 0.987, respectively. Among them, only the average technical efficiency in the eastern region shows an increasing trend, while the average technical efficiency in the central and western regions still shows a decreasing trend.

According to Figure 5, from the perspective of specific provinces and cities, only four regions in the eastern region show an increasing trend in the total factor productivity of the hub economy. They are Beijing, Zhejiang, Fujian, and Hainan. The other provinces and cities show varying degrees of decline. Observing the Tfpch and its decomposition items in all regions in China, it is found that only Beijing and Fujian show an increasing trend of technological progress change. Other provinces and cities show a decreasing trend to varying degrees, which is also the main reason for the decline in total factor productivity in most regions. Among them, the total factor productivity of the hub economy in Beijing increases the most, which is 9.5%. The total factor productivity of the hub economy in Gansu decreased the most, which is 18%. It can be seen that the development of the hub economy in most regions of China is not optimistic at the current stage. The problem of unbalanced regional development is serious. In this regard, all regions should pay attention to the balanced and coordinated development of the hub economy.

5.2.3. Quadrant Analysis of Dynamic Changes of Hub Economy. The respective mean values of the Effch and Techch are used as criteria to draw quadrant plots, as shown in Figure 6. In general, most provinces and cities in China are located in the first, second, and fourth quadrants. Five provinces and cities are located in the third quadrant. From the perspective of zoning, the following conclusions can be drawn. The Effch and Techch of the regions located in the first quadrant are above their respective means. In the process of building a hub economy, these regions are already at the head of China. Therefore, they should target foreign developed regions to improve the efficiency of the hub economy. The Effch of the hub economy in the regions in the second quadrant is below the mean, while the Techch is above the mean. These regions should focus on improving technology utilization, resource allocation capacity, and resource use efficiency. The Techch of the hub economy in the regions in the fourth quadrant is below the mean, while the Effch is above the mean. These regions should be committed to upgrading the level of technological progress, focusing on the innovation and progress of technology and knowledge. The Effch and Techch of the hub economy in the third quadrant are below their respective mean values. These regions should improve the efficiency of technology applications and the level of technological progress. In this regard, different regions should combine their conditions to overcome the shortcomings and then move forward to the first quadrant to realize the balanced and coordinated development of the hub economy among regions.

5.3. Analysis of the Influencing Factors of the Efficiency of China's Hub Economy

5.3.1. Variable Selection and Model Setting. This paper uses Stata SE 12 statistical analysis software to analyze the influencing factors of the efficiency of the hub economy. The super efficiency values of TE of the hub economy of 30 provinces and cities from 2012 to 2021 are used as the explained variable. The six environmental impact indicators are used as explanatory variables. They are policy impact, industrial structure impact, education impact, enterprise impact, innovation impact, and technology impact. The rationale and justification for selecting the six explanatory variables are given in Section 4. In order to eliminate the

Table 4: Tfpch and its decomposition items of hub economy in eastern, central, and western regions from 2012 to 2021.

Regions	Effch	Techch	Pech	Sech	Tfpch
The eastern region	1.006	0.990	1.005	1.000	0.995
The central region	0.989	0.927	0.995	0.994	0.917
The western region	0.987	0.917	0.992	0.995	0.905
Overall mean	0.994	0.945	0.998	0.997	0.939

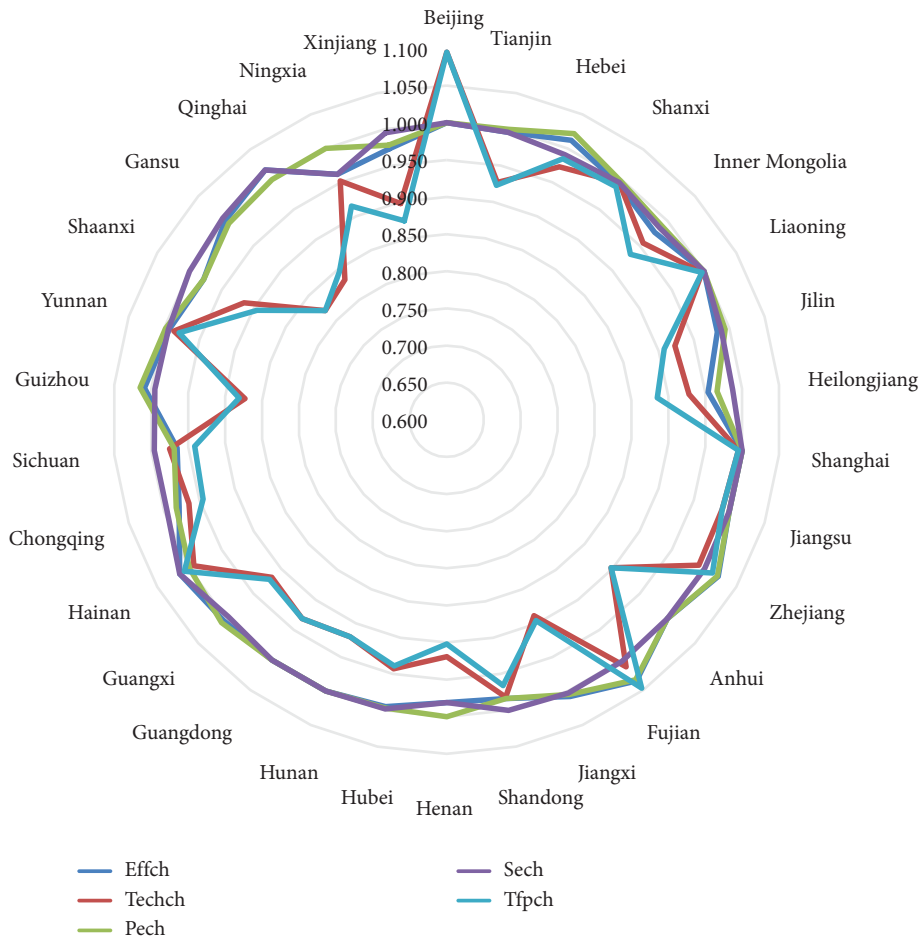

Figure 5: Tfpch and its decomposition items of hub economy in each region from 2012 to 2021.

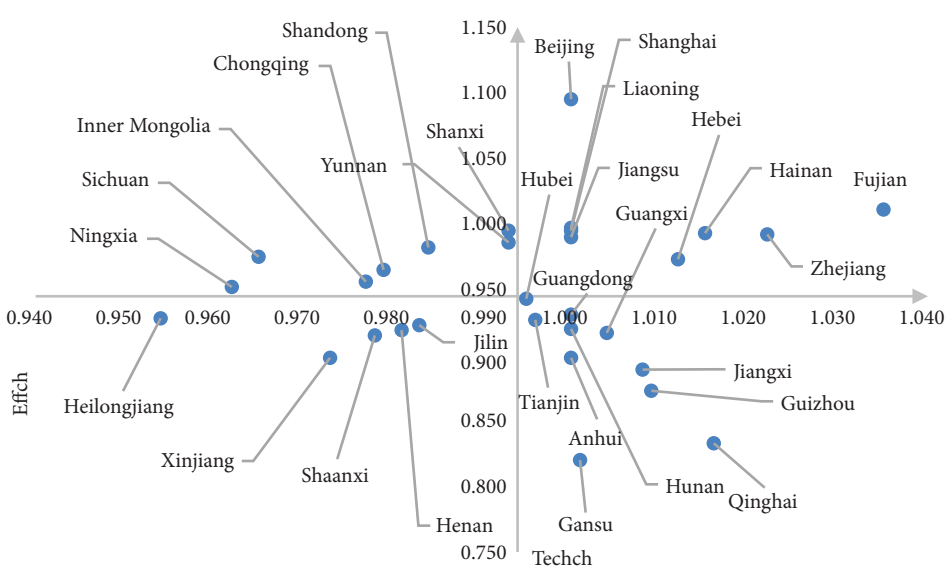

Figure 6: Quadrant diagram of dynamic efficiency of hub economy based on Effch and Techch.

heteroscedasticity in the regression model, this study logarithmizes some influencing factor indicators [37]. The Tobit regression model of the TE of the hub economy is shown in the following equation:

$$Y_{ij} = \alpha + \beta_1 \ln \mathrm{PoI}_{ij} + \beta_2 \mathrm{ISI}_{ij} + \beta_3 \ln \mathrm{EdI}_{ij} + \beta_4 \ln \mathrm{EnI}_{ij} + \beta_5 \ln \mathrm{InI}_{ij} + \beta_6 \ln \mathrm{TeI}_{ij} + \mu, \quad (7)$$

where i represents the ith province or city; j represents the jth year; Y_{ij} is the explained variable, namely, the super efficiency value of the TE of the hub economy of the ith province or city in the jth year; α is the constant term; β_1, β_2, β_3, β_4, β_5, and β_6 are the regression coefficients of the six independent variables; PoI_{ij} represents the policy impact; ISI_{ij} represents the industrial structure impact; EdI_{ij} represents the education impact; EnI_{ij} is the enterprises' impact; InI_{ij} represents the innovation impact; TeI_{ij} represents the technology impact; and μ is the disturbance term. The final Tobit regression analysis results are shown in Table 5.

5.3.2. Result Analysis of Influencing Factors. Table 5 shows that industrial structure, innovation, and technology significantly positively impact the TE of the hub economy. Policy and enterprises significantly negatively affect the TE of the hub economy. However, education has no significant correlation with the TE of the hub economy. Therefore, H2, H5, and H6 are all valid. H1, H3, and H4 are not valid.

(1) The negative impact of local transportation fiscal expenditure on the efficiency of the hub economy passes the test at the significance level of 1%.

Improving local transportation fiscal expenditure will reduce the efficiency of the hub economy. The prerequisite for realizing the transportation organization effect and the maximization of the value of the transportation chain is the matching of the transportation hub and the transportation mode with the development of the hub economy [38]. After the infrastructure construction of the port industry reaches a certain level, the continued expansion of the construction will lead to a decline in the scale efficiency of the port [37]. At present, the key to China's logistics and transportation operation is to improve operational efficiency, which is no longer a matter of the scale and coverage of facilities [2]. The possible reason is that the local transportation fiscal expenditure that does not match the construction of the hub economy will restrict the development of the hub economy. Therefore, the government should play an effective guiding role by rationalizing local transportation financial expenditure. Local governments should carry out transportation construction based on local basic conditions. It is necessary to promote transportation construction moderately, optimize the structure of transportation investment, and promote the optimization of transportation structure.

(2) The positive impact of the proportion of the tertiary industry's added value in the gross regional product on the efficiency of the hub economy passes the test at the significance level of 1%.

Increasing the proportion of the added value of the tertiary industry in the gross regional product will improve the efficiency of the hub economy. The hub economy is very dependent on the tertiary industry. The transportation, logistics, and information industries are the supporting and leading industries of the hub economy. However, on the whole, the development of the tertiary industry in China is not good. The proportion of the added value of the tertiary industry in gross regional product in most regions has not reached the level of the developed countries, and there is a big gap between regions. Take 2021 as an example. The added value of China's tertiary industry accounted for 53% of gross domestic product. Beijing and Shanghai reached 82% and 74%, respectively. Hebei, Shanxi, Inner Mongolia, and other provinces did not even exceed 50%. Guangdong (55%) and Jiangsu (51%), China's largest and second-largest provinces, did not reach 60%. Therefore, China urgently needs to promote the construction of the tertiary industry, especially the transportation, logistics, and information industries.

(3) The negative impact of the number of legal entities on the efficiency of the hub economy passes the test at the significance level of 5%.

Increasing the number of legal entities will reduce the efficiency of the hub economy. The possible reason is that the increase in the number of relevant enterprises does not represent the construction of excellent vital enterprises. Cultivating market players that do not match the hub economy cannot build the hub industry, and it is not easy to promote the development of the hub economy. According to the Fortune Global 500 data for 2022, 145 companies from China (including Taiwan) are on the list, while 124 companies from the United States are on the list. However, the strength in numbers has not yet opened up the revenue gap. Chinese companies account for 31% of the total revenue of the top 500 companies, while American companies account for 30% of the total revenue of the top 500 companies. There is not much difference between the two sides. Therefore, China should focus on cultivating excellent enterprises, leading enterprises and headquarters enterprises, developing hub industries, and then developing hub economies.

(4) The positive impact of the grant volume of domestic patent applications on the efficiency of the hub economy passes the test at the significance level of 1%.

Increasing the grant volume of domestic patent applications can improve the efficiency of the hub economy. The grant volume of domestic patent

Table 5: Tobit regression analysis results.

Variable	The coefficient estimates	Standard error	T value	Level of significance
ln PoI	−0.228***	0.065	−3.500	0.001
ISI	0.792***	0.257	3.080	0.002
ln EdI	0.147	0.122	1.210	0.228
ln EnI	−0.215**	0.086	−2.500	0.013
ln InI	0.276***	0.043	6.410	0.000
ln TeI	0.035*	0.019	1.880	0.061
Constant α	−1.114	0.997	−1.120	0.265

Note. *, **, and *** indicate significance at the levels of 10%, 5%, and 1%, respectively.

applications reflects innovation ability to a certain extent. However, to achieve real effective innovation, it is necessary to transform patent achievements into commercial value and benefits. According to the 2022 World Intellectual Property Indicators, China's State Intellectual Property Office received 1.59 million patent applications, while the United States received 0.59 million patent applications. According to the 2022 Global Innovation Index Report, China ranks 11th, while the United States ranks second. It can be seen that the number of patent applications does not match the situation of innovation in China. Therefore, in addition to encouraging talents to convert their research results into patents, attention should also be paid to the commercial value transformation of patents to achieve genuinely effective innovation.

(5) The positive impact of technology market turnover on the efficiency of the hub economy passes the test at the significance level of 10%.

The increase in technology market turnover can improve the efficiency of the hub economy. The elements of science and technology play an essential role in all walks of life, and the construction of the hub economy is no exception. Taking information technology as an example, the German Association for Information Technology, Telecommunications, and New Media (BITKOM) released data. According to the data, global sales of information technology and telecommunications are expected to grow by 4.8% in 2023 to reach 4.33 trillion euros. The United States continues to dominate the global market with a 35.7% market share, while China ranks second with an 11.7% market share. It can be seen that there is a large gap between China and the United States in terms of global information technology and telecom sales. Therefore, the development of the hub economy should earnestly develop and master the core technology, improve the technical level, and strengthen the protection of technology and intellectual property.

6. Conclusions

6.1. Findings Based on Static Efficiency Evaluation. The efficiency of China's hub economy is fluctuating, and the overall efficiency change is consistent with the actual situation of the construction of the hub economy. The TE, PTE, and SE of China's hub economy from 2012 to 2021 did not achieve effectiveness. In the development process of the hub economy, the management level is not high, and the return to scale of production is not ideal. These two points lead to comprehensive technical inefficiency in the hub economy. In terms of static efficiency, the development of the hub economy in most parts of China is in three states: (1) only PTE is above the average level; (2) only SE is above the average level; and (3) both PTE and SE are above average. The construction of the hub economy has the problem of unbalanced regional development.

6.2. Findings Based on Dynamic Efficiency Evaluation. The low utilization degree of total factor input in China's hub economy is mainly due to technological deterioration, while technology utilization efficiency maintains a high and stable level. The Effch has little effect on the Tfpch. Total factor productivity, technical efficiency, technical progress, pure technical efficiency, and scale efficiency all declined. The utilization degree of total factor input in the hub economy of all provinces and cities in China is not ideal. The Tfpch, Techch, and Effch of the eastern region are all higher than those of the central and western regions and higher than the national average. The change rates of technological progress and technology utilization in most provinces are above the national average. In terms of dynamic efficiency, the hub economy development in most parts of China is in the following three states of change: (1) only Effch is higher than the average change level; (2) only Techch is higher than the average change level; and (3) both Effch and Techch are above the average change level. The problem of unbalanced development between regions is serious.

6.3. Findings Based on the Analysis of Influencing Factors. Increasing the proportion of the added value of the tertiary industry in the gross regional product, the grant volume of domestic patent applications, and the technology market turnover will increase the technical efficiency of the hub economy. Increasing the financial expenditure of local transportation and the number of legal entities will reduce the technical efficiency of the hub economy.

7. Implications

7.1. Theoretical Implications. This study has the following theoretical implications. First, based on the Super SBM, Malmquist, and Tobit models, this paper proposes a two-

stage analysis framework. This two-stage analysis framework can quantitatively evaluate the efficiency of the hub economy and explore the influencing mechanism. Among them, the Super SBM and Malmquist models are used to measure the efficiency of the hub economy and its degree of change. The quadrant analysis method is used to measure the development status of the hub economy in different regions. These enrich the relevant literature on the evaluation system of the hub economy [2]. Second, this paper uses the Tobit model to measure the effects of industrial structure, technology, innovation, education, enterprises, and policies on the input-output efficiency of the hub economy. It enriches the relevant literature on the impact of the hub economy [8].

7.2. Practical Implications. This paper has practical significance for policymakers and government department managers in developing the hub economy. First, the research results of this paper provide valuable reference information for the central and provincial governments to formulate policies on the development of the hub economy [1, 13]. The static and dynamic research results of the efficiency of the hub economy can help national and local decision-makers better grasp the status quo and pain points of the input and output of the hub economy. The research results on the impact of hub economy efficiency can help national and local decision-makers better use environmental factors' impact on the construction of the hub economy. Second, when formulating development policies for hub economies, the government should (1) focus on research and innovation of key technologies and reduce the dependence on technology import, (2) focus on optimizing institutional arrangements, setting up an excellent team, and improving management level, and (3) focus on increasing returns to scale production, expanding effectual output, and avoiding waste of construction resources. Third, in developing the hub economy, the government should optimize the regional industrial structure and improve regional talent innovation and the activity of the technology market. In addition, local transportation fiscal expenditure should be rationally used, and hub characteristic industry subjects should be cultivated.

7.3. Limitations and Research Directions. This paper has the following two limitations. First, due to the difficulty in obtaining data, this paper carries out research at the provincial scale but fails to carry out more detailed research at the city level. Second, due to the large number of provincial administrative regions involved, data are missing for some years in some provinces. Although this paper makes up for the missing data, the research results may still be affected.

This paper has the following two future research directions: first, this paper only focuses on the desirable outputs of the hub economy. The hub economy, closely related to the transportation and logistics infrastructure, also has undesirable outputs such as traffic congestion and carbon emissions. The development process of the hub economy should consider both the expansion of desirable output and the reduction of undesirable output. Future research on the efficiency of hub economy involving undesirable outputs should be carried out. Second, this paper focuses on the static and dynamic evaluation of the efficiency of the hub economy. Dynamic efficiency evaluation is also a characteristic of time evolution. The efficiency of China's hub economy varies significantly among regions. So, it is necessary to analyze the spatial evolution characteristics of the hub economy and strengthen the exploration of the influencing factors of spatial heterogeneity in the future.

Data Availability

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

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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References

[1] J. Ran and G. Li, "Theory, reality and path: the construction of the unified national market boosted by hub economy," *Reform of Economic System*, vol. 5, pp. 5–12, 2023b.

[2] R. Wen, "Practice and reflection on the development of China's hub economy," *Regional Economic Review*, vol. 6, pp. 120–126, 2023.

[3] G. Li, "Hub economy: connotative property, operating mechanism and promoting path," *Southwest Finance*, vol. 479, no. 6, pp. 26–35, 2021a.

[4] H. Tian and Y. Huang, "Research on innovative development model for supply China hub cities," *China Business And Market*, vol. 34, no. 11, pp. 44–56, 2020.

[5] C. Rikap and D. Flacher, "Who collects intellectual rents from knowledge and innovation hubs? Questioning the sustainability of the singapore model," *Structural Change and Economic Dynamics*, vol. 55, pp. 59–73, 2020.

[6] V. Y. Atiase, O. Kolade, and T. A. Liedong, "The emergence and strategy of tech hubs in Africa: implications for knowledge production and value creation," *Technological Forecasting and Social Change*, vol. 161, p. 13, 2020.

[7] C. V. Trappey, G. Y. P. Lin, A. J. C. Trappey, C. S. Liu, and W. T. Lee, "Deriving industrial logistics hub reference models for manufacturing based economies," *Expert Systems with Applications*, vol. 38, no. 2, pp. 1223–1232, 2011.

[8] W. Zhao, "Hub economy and its development mechanism: an empirical study taking transportation hub as an example," *Human Geography*, vol. 35, no. 3, pp. 115–122, 2020.

[9] C. Gao, "Discussion on improving the competitiveness of China's hub economy," *Regional Economic Review*, vol. 40, no. 4, pp. 78–83, 2019b.

[10] G. Li, "Evolution mechanism and promoting path of hub economy in the view of comprehensive transportation," *Railway Transport and Economy*, vol. 43, no. 8, pp. 37–42, 2021b.

[11] J. Ran and Z. Qiao, "Theoretical logic, practical problems and realization path of hub economy boosting the construction of a unified national market: from the perspective of regional commodity factor agglomeration," *Academic Journal of Zhongzhou*, vol. 316, no. 4, pp. 37–45, 2023a.

[12] Y. Gong, "Multidimensional thinking on the development of China's hub economy," *Academic Journal of Zhongzhou*, vol. 281, no. 5, pp. 39–45, 2020.

[13] G. Ruan, Y. Shao, and Y. Yu, "Construction of inland open hub central city: international experience and enlightenment," *Foreign Investment in China*, vol. 23, pp. 70–75, 2022.

[14] G. Yao, X. Fan, L. Liu, and X. Bian, "Research on simulation and optimization of logistics hub service and comprehensive transportation integrated development from the perspective of hub economy," *Systems Engineering*, vol. 39, no. 2, pp. 101–110, 2021.

[15] M. Cattaneo, P. Malighetti, and M. Percoco, "The impact of intercontinental air accessibility on local economies: evidence from the de-hubbing of malpensa airport," *Transport Policy*, vol. 61, pp. 96–105, 2018.

[16] A. Thierstein and S. Conventz, "Hub Airports, the knowledge economy and how close is close? Evidence from Europe," in *Proceedings of the 54th Congress of the European Regional Science Association: Regional Development & Globalisation: Best Practices*, pp. 1–32, European Regional Science Association (ERSA), St. Petersburg, Russia, August 2014.

[17] C. Gao, "Research on the formation and future development trend of hub economy: exploration based on the theory of factor agglomeration and resource integration," *Price: Theory and Practice*, vol. 415, no. 1, pp. 157–160, 2019a.

[18] M. Li, X. Lin, H. Li, and D. Li, "Research on the mechanism of high-speed railway hub economy: introducing the 'communication value' into the 'node-place' model," *Advances in Transportation Studies*, vol. 58, pp. 261–276, 2022.

[19] D. Chu, "Deepen the theoretical cognition of hub economy in practice," *Journal of Party School of Nanjing Municipal Committee of CPC*, vol. 86, no. 6, pp. 52–57, 2016.

[20] W. Li, "Experience and enlightenment of German transportation in promoting coordinated urban development," *Macroeconomic Management*, vol. 9, pp. 86–92, 2023.

[21] S. Zhang, H. Zheng, Y. Chen, and F. Witlox, "Factors influencing the hub connectivity of Beijing Capital Airport in its international markets," *Journal of Air Transport Management*, vol. 88, Article ID 101873, 2020.

[22] T. Song, T. Chahine, M. Sun, and C. Ruili, "The China-Myanmar nexus hub at the crossroads," *Cities*, vol. 104, 2020.

[23] H. Li and D. Wu, "Online investor attention and firm restructuring performance: insights from an event-based DEA-Tobit model," *Omega*, vol. 122, p. 14, 2024.

[24] D. Wu, H. Li, Q. Huang, C. Li, and S. Liang, "Measurement and determinants of smart destinations' sustainable performance: a two-stage analysis using DEA-Tobit model," *Current Issues in Tourism*, vol. 18, 2023.

[25] G. Cheng, *Data Envelopment Analysis: Methods and MaxDEA Software*, Intellectual Property Publishing House, Beijing, China, 2014.

[26] Q. Chen, *Advanced Econometrics and Stata Applications*, Higher Education Press, Beijing, China, 2014.

[27] R. Davidson and J. G. Mackinnon, *Econometric Theory and Methods*, Oxford University Press, New York, NY, USA, 2003.

[28] J. Tobin, "Estimation of relationships for limited dependent variables," *Econometrica*, vol. 26, no. 1, pp. 24–36, 1958.

[29] L. Zhao and Y. Jia, "Cluster coordination between high-speed rail transportation hub construction and regional economy based on big data," *Complexity*, vol. 2021, Article ID 6610882, 18 pages, 2021.

[30] X. Chen, C. Xuan, and R. Qiu, "Understanding spatial spillover effects of airports on economic development: new evidence from China's hub airports," *Transportation Research Part A: Policy and Practice*, vol. 143, pp. 48–60, 2021.

[31] C. Ducruet, "Hub dependence in constrained economies: the case of North Korea," *Maritime Policy & Management*, vol. 35, no. 4, pp. 377–394, 2008.

[32] Y. Liu, C. Wang, and W. Ying, "Research on the regional difference of the influence of education fund input on economic development," *Statistics & Decisions*, vol. 36, no. 2, pp. 121–124, 2020.

[33] S. Yao and C. Yu, "New development of urban hinge economic," *Urban Planning Forum*, vol. 79, no. 5, pp. 17–19+24, 2002.

[34] M. Li, "The study of transportation factor driven economy," *Macroeconomic Management*, vol. 445, no. 11, pp. 78–84, 2020.

[35] Z. Sun, T. Wang, H. Guo, and X. Li, "Technological innovation, industrial agglomeration and economic development," *On Economic Problems*, vol. 527, no. 7, pp. 77–86, 2023.

[36] Y. Chu and J. Chu, "Calculation and analysis of the influencing factors on 211 Project university libraries efficiency," *Library Tribune*, vol. 36, no. 8, pp. 107–118, 2016.

[37] B. Zheng and H. Yang, "Evaluation of port efficiency of China's coastal cities in 'The Belt and Road' – based on DEA game crossover efficiency–Tobit model," *Journal of Applied Sport Management*, vol. 40, no. 3, pp. 502–514, 2021.

[38] H. Peng and G. Zhang, "Intelligent logistics mode of highway, railway and waterway transportation after the 19th National Congress of the Communist Party of China," *Journal of Transportation Systems Engineering and Information Technology*, vol. 18, no. 1, pp. 2–5+245, 2018.