Measurement and Evaluation of Provincial Digital Economy Development Efficiency

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Abstract. In this paper, an evaluation index system of digital economy is constructed from the perspective of input-output, and the entropy weight TOPSIS method is used to comprehensively calculate the development level of digital economy in China's provinces from 2015 to 2019. On this basis, BCC-DEA model and Malmquist index model are used to calculate the output efficiency of China's digital economy from static and dynamic aspects, respectively. It is found that the digital economic development level of the eastern region led by Guangdong province is far ahead. From the perspective of static efficiency, the development of digital economy in most provinces in China has been in a state of inefficiency for a long time. From the perspective of dynamic efficiency, the total factor productivity of China's digital economy generally shows an upward trend, and from the data, the overall average annual growth rate of 0.14 percent. This study enriches and updates the digital economy evaluation index system, which provides practical significance and policy reference for improving the level and output efficiency of provincial digital economy, making better use of digital economy to reduce the imbalance of national digital economy development, and promoting common prosperity.

Keywords: digital economy · the level of development of the digital economy · DEA-Malmquist index method · Total factor productivity

1 Introduction

As the "stabilizer" and "accelerator" of the national economy, the scope, development speed and impact of the digital economy are unprecedented. The digital economy is not only the key to China's sustainable development, but also an important force leading the national innovation strategy. Therefore, studying the level of digital economy development and its output efficiency is an indispensable part of the road to the development of China's digital economy.

In the relevant research on the definition of digital economy, the concept of digital economy can be traced back to the end of the 20th century and has not yet been unified, but with the development of digital economy, relevant definitions are constantly being supplemented and improved: Don Tapscott (1996) defines it in terms of the characteristics of the digital economy, including globalization, digitization, virtualization, knowledge driven, etc. [2]. In the 2016 G20 Initiative for the Development and Cooperation of the

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Digital Economy, the digital economy is defined as a series of economic activities that use digital knowledge and information as key production factors, modern information networks as important carriers, and effective use of information and communication technologies as an important driving force for efficiency improvement and economic structure optimization [5]; Han Fengqin et al. (2022) believe that compared with the traditional economic era, the digital economy is more digital and information from a technical point of view [3]. From the perspective of industrial development, the digital economy mainly includes industrial digitalization and digital industrialization, the digital economy is more networked and intelligent in scenario application, and the governance perspective is mainly the government's digital governance and governance digitalization. In summary, although there is no unified definition, combined with the definition of digital economy by various organizations and scholars, it can be concluded that data is the core element of the digital economy, and the digital economy itself is also an economic means of innovation based on statistics, an economic form developed based on statistics, and an economic technology based on innovation based on statistics (Dong Bangjun et al., 2022 [1]). Therefore, this paper conducts objective research on the digital economy based on data.

In the research on the level of digital economy development, the research team of Digital China Research Institute, China Academy of Information and Communications Technology and Tencent Research Institute constructed a digital economy measurement system to measure the level of digital economy development from different perspectives, and different scholars also constructed an index system to measure the level of digital economy from different levels. Zhang Xueling et al. (2017) construct an index system from five levels: ICT infrastructure, ICT primary applications, ICT advanced applications, enterprise digital development, and ICT industry development [8]; Wang Jun et al. (2021) incorporated the development environment of the digital economy into the index system [6]. On this basis, some scholars have begun to study the output efficiency of the digital economy from different levels. From the perspective of the industry, Li Yan et al. (2021) used the relevant indicators of information transmission, software and information technology service industries as the proxy variables of the digital economy, and explored the regional differences and dynamic evolution of the output efficiency of the digital economy in various provinces and eight major economic zones in China [4]. In summary, the relevant measurement of the digital economy is mainly from the two aspects of development level and its output efficiency, and the digital economy measurement index system constructed by different scholars is different. Therefore, on the basis of the research of these scholars, this paper constructs an evaluation index system for the development of the digital economy with reference to the latest definition of digital economy released by the National Bureau of Statistics and conducts research.

It can be seen that most of the existing research focuses on the qualitative research of the digital economy and the research on the development level of the digital economy, while there are few related studies on the output efficiency of the digital economy. Based on this, this paper takes the province as the research unit and the latest Statistical Classification of Digital Economy and Its Core Industries (2021) released by the National Bureau of Statistics as the classification basis to measure the development level of the digital economy in various provinces in China. On this basis, the output efficiency of the digital economy is measured and reasonably analyzed, which provides reference and empirical basis for narrowing the regional digital development gap, solving digital development obstacles, improving the level of digital economy development, improving the output efficiency of the digital economy, and promoting the development level of digital economy in various regions.

2 Provincial Digital Economy Development Level Measurement

2.1 Construction of Indicator System

This paper refers to the existing research to construct a digital economy evaluation index system from the two perspectives of input and output. The definition and classification of the digital economy is based on the White Paper on the Development of China's Digital Economy (2021) and the Statistical Classification of Digital Economy and Its Core Industries issued by the National Bureau of Statistics in 2021. The input index of this paper refers to the research on the evaluation index system of Wan Xiaoyu et al. (2019) on the development of digital economy [7]. The selection of output indicators mainly refers to the "White Paper of China's Digital Economy Development (2021)". The indicator system is shown in Table 1.

2.2 Data Sources

The research object of this paper is the output efficiency of the digital economy in 30 provinces of China (Tibet was excluded due to lack of data), the sample year is from 2015 to 2019, and the data involved is mainly derived from the selected sample years of "China Information Yearbook", "Statistical Report on China's Internet Development", "White Paper on China's Digital Economy Development and Employment", etc.

Since the indicators selected in this paper are objective statistical data, and the objectivity of the entropy weight TOPSIS method is relatively strong, the entropy weight TOPSIS method is used to measure the development level of the digital economy in various provinces in China, and the weight is objectively determined based on this method, and then the Euclidean distance is used to obtain the relative proximity of each evaluation object to the positive ideal scheme, and this paste progress is used as the basis for evaluation ranking.

The calculation process is as follows:

Assuming that there are m evaluation objects and n evaluation indicators for each evaluated object, a judgment matrix is constructed:

$$X = (x_{ij})m \times n(i = 1, 2, ..., m; j = 1, 2, ..., n) \tag{1}$$

Step 1: Data standardization processing

$$x'_{ij} = \frac{x_{ij} - \min\{x_{1j}, ..., x_{mj}\}}{\max\{x_{ij}, ..., x_{mj}\} - \min\{x_{1j}, ..., x_{mj}\}}) \tag{2}$$

In Eq. (2): xij is the original value of the indicator; min(x1j,…,xmj) and max(x1j,…,xmj) are the minimum and maximum values of the group in which the indicator belongs; x'ij is the normalized value of an indicator.

Table 1. Digital economy development level evaluation index system

Target layer	First-order index	Secondary index	Three-level index	weight
Digital economy input index (0.384)	Digital factors of production (0.384)	Labor input (0.150)	R&D Personnel are equivalent to full time (Person/year)	0.086
			Number of employees in information service industry (10^4 people)	0.047
			Number of degrees awarded in higher education (person)	0.017
		Capital input (0.125)	R&D Project funds (10^4 CNY)	0.057
			Investment in fixed assets in information transmission, software and information technology services (10^8 CNY)	0.068
		Technological input (0.108)	Number of cell phone base stations (10^4 CNY)	0.022
			Number of broadband Internet access ports (10^4 CNY)	0.025
			The number of Internet domain names (10^4 CNY)	0.038
			Long distance cable line length (KM)	0.025
Digital economy output index (0.616)	Digital industrialization (0.378)	Electronic information manufacturing industry (0.175)	The number of electronic information manufacturing enterprises above designated size (pcs)	0.086
			The main business income of the electronic information manufacturing industry above designated size (10^8 CNY)	0.089
		Telecommunication industry (0.026)	Total volume of telecommunications services (10^8 CNY)	0.026
		Software and information technology services (0.150)	Software business revenue (10^8 CNY)	0.075
			Information Technology Services Revenue (10^8 CNY)	0.076
		Internet industry (0.026)	Mobile Internet access traffic (10^4GB)	0.026
	Industry digitization (0.239)	Digitalization of traditional industries (0.195)	Proportion of enterprises with e-commerce activities (%)	0.022
			E-commerce sales (10^8 CNY)	0.057
			Number of valid invention patents (pcs)	0.117
		Digitization of government environment (0.043)	Number of government websites (pcs)	0.024
			The number of microblogs of government agencies (pcs)	0.019

Step 2: The entropy weight method calculates the index weight.

This paper constructs the index system from the perspectives of input and output, and the first, second and third level indicators are weighted by the entropy weight method, and the steps are as follows:

Find the information entropy e_j of the jth indicator:

$$ej = -\frac{\sum_{i=1}^{m} (p_{ij} \times \ln p_{ij})}{\ln m} \tag{3}$$

In Eq. (3), ln is the natural logarithm, and when studying the spatial differences of 30 provinces, m is 30, ej $\geq$ 0, and pij indicates the proportion of the ith scheme under the jth indicator:

$$p_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{n} x'_{ij}} \tag{4}$$

wj represents the weight of the jth indicator:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \tag{5}$$

Step 3: Calculate the weighted decision matrix

$$R = (r_{ij})m \times n, r_{ij} = w_j \times x'_{ij} \quad (\mathrm{i} = 1, 2, ..., \mathrm{m}; \mathrm{j} = 1, 2, .., \mathrm{n}) \tag{6}$$

In Eq. (6), rij is the weighted decision score of the ith programme under indicator j; R is a weighted decision matrix consisting of all weighted decision scores.

Step 4: Determine the positive ideal solution S_j+ and negative ideal solution S_j−

$$S_j^+ = \begin{cases} \max(r_{ij}), j \in j^+ \\ \min(r_{ij}), j \in j^- \end{cases} \quad \mathrm{j} = 1, 2, ..., \mathrm{n};$$

$$S_j^- = \begin{cases} \min(r_{ij}), j \in j^+ \\ \max(r_{ij}), j \in j^- \end{cases} \quad \mathrm{j} = 1, 2, ..., \mathrm{n}; \tag{7}$$

where j + stands for positive and j- stands for negative.

Step 5: Calculate the Euclidean distances sep + j and sep-j between each scheme and the positive ideal solution Sj + and the negative ideal solution Sj-.

$$sep_i^+ = \sqrt{\sum_{j=1}^{n} (S_j^+ - r_{ij})^2}$$

$$sep_i^- = \sqrt{\sum_{j=1}^{n} (S_j^- - r_{ij})^2} \tag{8}$$

Step 6: Calculate the comprehensive evaluation index Ci

$$Ci = \frac{sep^-}{sep^+ + sep^-} \tag{9}$$

In Eq. (9), the larger the Ci value, the closer the scheme is to the ideal sample solution.

2.3 Analysis of Results

Based on the digital economy development level system constructed above, this paper calculates the comprehensive index of digital economy development, digital economy input index, digital economy output index and subsystem index of 30 provinces in China from 2015 to 2019.

1) **Overall characteristics and regional differences of China's digital economy development.**

From the perspective of the comprehensive index of the development of the digital economy. Referring to the National Bureau of Statistics' regional division method, China's 30 provinces (except Tibet) are divided into four major regions, namely the eastern region: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; Central region: Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan; Western region: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang; Northeast China: Liaoning, Jilin, Heilongjiang. Table 2 shows the development level of the digital economy in the four major regions.

As shown in Fig. 1, the level of digital economy development is eastern, central, western, and northeastern, and the eastern region is far ahead, of which the province with the highest level of digital economy development is Guangdong Province, the central region is slightly behind, and the western region is close to the digital economy level in the northeast region. Overall, among the four major regions, the digital economy level in the central region is relatively stable, while the other three regions have shown varying degrees of decline.

3 Analysis of Provincial Digital Economy Output Efficiency

The above measures the level of digital economy development in each province, and the level of digital economy development is closely related to the output efficiency of the digital economy, so the output efficiency of the digital economy is studied and measured from the perspective of input and output, and the DEA-BCC model and the Malmquist index model are used to measure the output efficiency of the digital economy in each province, and the problems and causes of the input and output of the digital economy are analyzed by decomposing various efficiency indicators, in order to continuously improve

Table 2. Digital economy development index of China's four major regions from 2015 to 2019

Region	2015	2016	2017	2018	2019	mean
Eastern region	0.367	0.370	0.357	0.318	0.335	0.349
Central region	0.197	0.192	0.194	0.186	0.200	0.194
Western region	0.148	0.145	0.145	0.124	0.144	0.141
Northeast	0.161	0.144	0.151	0.112	0.117	0.137

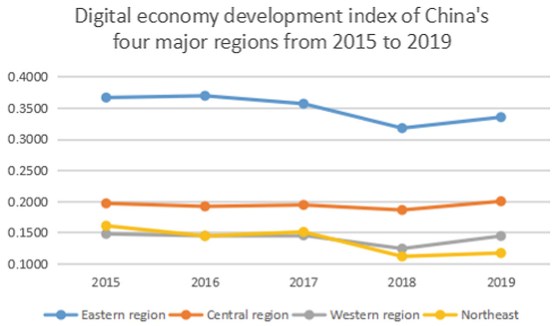

Fig. 1. Economic development trend map of China's four major regions from 2015 to 2019

the output efficiency of China's digital economy. In turn, it provides theoretical support for promoting the development level of digital economy.

3.1 Research Models

1) **DEA-BCC model.**
Given that the DEA method can study the relative effectiveness of the same type of decision unit (DEA), the BCC-DEA model considers the scale benefit and determines the relative efficiency value in the decision unit within each time section. Therefore, this paper takes the cross-sectional data of 30 provinces in China in each year from 2015 to 2019 as an independent DMU decision-making unit, uses the BCC-DEA model to measure the comprehensive efficiency of each province, and decomposes it into pure technical efficiency and scale efficiency.
According to the above research results, the digital economy production factor index of each province in China is taken as the input variable of efficiency analysis, and the digital industrialization index and industrial digitalization index are used as the output variables of efficiency analysis, and the data envelopment analysis method is used to evaluate the production efficiency of China's provincial digital economy. Among them, the overall efficiency can reflect the number of products produced per unit of input consumed in each province, that is, the technical level of the production unit. When each efficiency value is equal to 1, it means that the decision unit is at the forefront of production in terms of efficiency, and the DEAP2.1 software is used for analysis, and the results are shown in Table 3.
2) **The Malmquist productivity index method based on the DEA.**
Since BCC-DEA can only measure the relative efficiency value of each decision unit in the same time section, it cannot accurately reflect the change trend of the decision unit in different periods. Therefore, based on the digital economy index system constructed above, this study will use the digital economy production factor index of each province calculated by the TOPSIS entropy weight method as the input index, the digital industrialization index and the industrial digitalization index as the output index, and use the Malmquist total factor productivity (TFP) calculated based on DEA to characterize the dynamic changes of output efficiency in 30 provinces in

China from 2015 to 2019. And decompose the Malmquist index into the Technology Efficiency Change Index (EC) and the Technology Change Index (TC).

The Malmquist index essentially represents the change in productivity by the ratio of two different time distance functions, which can be expressed in the following form according to the definition of Fare et al.:

$$M\left(x^{t+1}, y^{t+1}, x^{t}, y^{t}\right) = \sqrt{\frac{Et\left(x^{t+1}, y^{t+1}\right)}{E^{t}\left(x^{t}, y^{t}\right)} \times \frac{E^{t+1}\left(x^{t+1}, y^{t+1}\right)}{E^{t+1}\left(x^{t}, y^{t}\right)}}$$

Among them, Et(xt + 1, yt + 1) and Et(xt,yt) represent the technical efficiency values of the decision-making unit in the t + 1 and t periods, respectively, so the technical efficiency change index of the two periods is:

$$EC = \frac{E^{t+1}\left(x^{t+1}, y^{t+1}\right)}{E^{t}\left(x^{t}, y^{t}\right)}$$

Compared with the production front surface in the t + 1 period and the production front surface in the T period, the movement situation can be determined by $\frac{E^{t}(x^{t},y^{t})}{E^{t+1}(x^{t},y^{t})}$ and $\frac{E^{t}(x^{t+1},y^{t+1})}{E^{t+1}(x^{t+1},y^{t+1})}$ reflected. This paper considers the movement of the production front as a technological change, so the technical change index for the two periods is:

$$TC = \sqrt{\frac{E^{t}\left(x^{t}, y^{t}\right)}{E^{t+1}\left(x^{t}, y^{t}\right)} \times \frac{E^{t}\left(x^{t+1}, y^{t+1}\right)}{E^{t+1}\left(x^{t+1}, y^{t+1}\right)}}$$

By breaking down EC into PTEC and SEC, the Malmquist index can be expressed as:

$$\begin{aligned} M_{c}^{t,t+1} &= \frac{E_{c}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{E_{c}^{t}\left(x^{t}, y^{t}\right)} \\ &\times \left(\frac{E_{v}^{t}\left(x^{t}, y^{t}\right)}{E_{c}^{t}\left(x^{t}, y^{t}\right)} \Big/ \frac{E_{v}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{E_{c}^{t+1}\left(x^{t+1}, y^{t+1}\right)}\right) \\ &\times \left(\frac{E_{c}^{t}\left(x^{t}, y^{t}\right)}{E_{c}^{t+1}\left(x^{t}, y^{t}\right)} \times \frac{E_{c}^{t}\left(x^{t+1}, y^{t+1}\right)}{E_{c}^{t+1}\left(x^{t+1}, y^{t+1}\right)}\right)^{1/2} \\ &= PTEC \times SEC \times TC \\ &= EC \times TC \end{aligned}$$

3.2 Empirical Results and Analysis

1) **Static Efficiency Analysis.**

Using DEAP2.1 software, the results are shown in Table 3 to compare the output efficiency of each province during the sample period.

Table 3 reflects the combined technical efficiency values for each province from 2015 to 2019. The national column is the arithmetic average of the comprehensive technical

Table 3. Digital economy development index of China's four major regions from 2015 to 2019

Region	mean	Rank
Beijing	0.751	5
Tianjin	0.696	7
Hebei	0.376	23
Shanxi	0.331	25
Inner Mongolia	0.279	27
Liaoning	0.556	11
Jilin	0.313	26
Heilongjiang	0.214	29
Shanghai	0.898	3
Jiangsu	0.727	6
Zhejiang	0.605	9
Anhui	0.507	16
Fujian	0.367	24
Jiangxi	0.498	19
Shandong	0.568	10
Henan	0.499	18
Hubei	0.438	22
Hunan	0.441	21
Guangdong	1.000	1
Guangxi	0.505	17
Hainan	0.781	4
Chongqing	0.688	8
Sichuan	0.531	13
Guizhou	0.555	12
Yunnan	0.521	15
Shaanxi	0.528	14
Gansu	0.463	20
Qinghai	0.212	30
Ningxia	0.927	2
Xinjiang	0.263	28
China	0.534	

efficiency of each province in each year, the average column is the arithmetic average of the comprehensive technical efficiency of each province in the sample period, and the regional ranking order is the average size of the comprehensive technical efficiency of each province in the sample interval. From Table 3, it can be observed that the top five annual average comprehensive technical efficiency are Guangdong, Ningxia, Shanghai, Hainan and Beijing, of which Guangdong is in the state of optimal efficiency all year round (comprehensive technical efficiency = 1), which is at the forefront of production, which shows that the above five provinces are in a relatively leading position in the country in terms of digital economy output efficiency, and the vast majority of enterprises have been in an inefficient state for a long time from the national point of view.

Taking Guangdong as an example, we will further analyze the reasons why its digital economy output efficiency ranks first in the country: First, Guangdong Province is a major province in the national information and communication industry, providing a solid backing for the development of the digital economy, while Guangdong Province has relatively complete digital-related infrastructure, a solid information industry foundation, and huge data reserves; Secondly, Guangdong Province has a large number of digital economy backbone enterprises, of which 25 of China's top 100 electronic information enterprises in 2017 are from Guangdong Province, accounting for a quarter of the country; In addition, Guangdong Province is a major manufacturing province in China, and the digital transformation of the manufacturing industry is not only fast but also of high quality; Finally, Guangdong Province has an excellent top-level design for the development of the digital economy, and plans the overall "128" development strategy, that is, one main line of development and two directions to focus on promoting the innovative development of Guangdong's digital economy with eight major priorities.

2) **Dynamic efficiency analysis.**

a) *Malmquist Index and Breakdown of China's Digital Economy.*

In order to better grasp the output efficiency of China's digital economy, it is analyzed from the perspective of time series. Therefore, the efficiency indices for the relevant years in the results are compiled in Table 4.

From the data in Table 4, it can be seen that the average value of China's digital economy output efficiency M index from 2015 to 2019 is 1.027. Therefore, on the whole, China's digital economy output efficiency is getting higher and higher, that is, the average annual growth rate is 0.27%.

Table 4. 2015–2019 China Digital Economy Output Efficiency M Index and its breakdown

Year	EFFC	TC	PTEC	SEC	M
2015–2016	0.985	1.032	0.912	1.050	0.988
2016–2017	1.039	0.879	1.049	0.990	0.913
2017–2018	0.927	1.200	0.912	1.017	1.113
2018–2019	1.131	0.968	1.207	0.937	1.095
mean	1.021	1.020	1.020	0.999	1.027

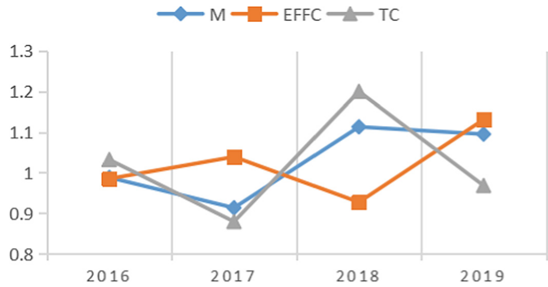

Fig. 2. Economic development trend map of China's four major regions from 2015 to 2019

In order to study the changes of the M index and its decomposition terms more clearly and intuitively, the change of the M index is plotted according to Table 4, as shown in Fig. 2.

As can be seen from Fig. 2, from 2016 to 2019, the M index rose dynamically, but there was a certain decline in 2016–2017. Through the decomposition and analysis of the M-index, it is found that from 2016 to 2019, the technological progress index and the technological efficiency index fluctuated significantly, indicating that the impact of both on the M-index is not small. The decline in the M index in 2017 was mainly due to the sharp decline in the technological progress index, indicating that the level of technology limited the improvement of output efficiency in the digital economy to a certain extent.

b) *Malmquist index and decomposition of digital economy in each province.*

After analyzing the overall digital economy output efficiency in China from the perspective of time series, this paper will further analyze the changes in digital economy output efficiency in various provinces across the country, and the evaluation data compiled are shown in Table 5.

According to the size of the M value, the provinces are divided into three intervals, and the critical points of the division are M index = 1 and M index = 1.1

a) First interval: M $\in [1.1 + \infty]$

The provinces in this range are Tianjin, Guizhou and Inner Mongolia, and 3 of the 30 provinces in the country are located in this range, accounting for 10% of the country, indicating that the digital economy output efficiency of a very small number of provinces in the sample range of all regions of the country has maintained a growth trend, and has an average annual growth rate of 10%. Through the decomposition and analysis of the M-index, it is found that the M-index of these provinces is mainly contributed by technological progress, which shows that the technological level is closely related to the output efficiency of the digital economy and is a positive promotion relationship. Further decomposition of technical efficiency shows that the scale efficiency index of the above three provinces is around 1, and the scale efficiency index of Guizhou and Inner Mongolia is lower than 1, so in the next stage, in order to improve the output efficiency of the digital economy, it is necessary to continuously improve and optimize the scale of the digital industry to adapt it to the technical level.

Table 5. 2015–2019 China Digital Economy Output Efficiency M Index and its breakdown

Province	EFFC	TC	PTEC	SEC	M
Beijing	1.025	1.022	1.016	1.009	1.048
Tianjin	1.107	1.020	1.080	1.024	1.129
Hebei	1.090	1.006	1.105	0.986	1.096
Shanxi	1.092	1.007	1.109	0.985	1.099
Inner Mongolia	1.136	0.999	1.203	0.944	1.135
Liaoning	0.847	1.024	0.907	0.965	0.895
Jilin	1.002	1.021	0.919	1.090	1.023
Heilongjiang	1.019	1.014	0.975	1.046	1.033
Shanghai	1.009	1.015	1.013	0.996	1.024
Jiangsu	0.912	1.029	0.911	1.001	0.938
Zhejiang	0.993	1.023	0.987	1.006	1.016
Anhui	1.054	1.010	1.077	0.979	1.064
Fujian	0.913	1.018	0.899	1.015	0.929
Jiangxi	1.021	1.015	1.084	0.942	1.036
Shandong	1.002	1.019	1.052	0.952	1.021
Henan	1.015	1.008	1.048	0.969	1.023
Hubei	0.992	1.009	1.034	0.959	1.001
Hunan	1.028	1.041	1.003	1.025	1.070
Guangdong	1.000	1.026	1.000	1.000	1.026
Guangxi	1.085	1.005	1.160	0.935	1.090
Hainan	0.955	0.990	0.897	1.065	0.946
Chongqing	0.992	1.018	0.963	1.030	1.009
Sichuan	0.974	1.011	1.002	0.972	0.985
Guizhou	1.115	0.997	1.117	0.998	1.111
Yunnan	1.000	1.009	0.903	1.107	1.009
Shaanxi	0.965	1.010	0.980	0.985	0.975
Gansu	1.096	1.000	1.174	0.933	1.095
Qinghai	0.929	0.998	0.887	1.047	0.927
Ningxia	1.000	1.007	1.000	1.000	1.007
Xinjiang	0.985	1.025	0.995	0.990	1.010
mean	1.012	1.013	1.017	0.999	1.026

Inner Mongolia is located in the western region with an underdeveloped level of digital economy development, but its digital economy output efficiency ranks among the top three in the country, mainly because of Inner Mongolia's high technological efficiency index. It was found that Inner Mongolia is rich in energy and mineral resources, and its pillar industries are rare earths, steel and coal as the core, and the "IDC Development Guidelines of Inner Mongolia Autonomous Region" has been formulated in line with the wave of new infrastructure construction to promote the construction of Inner Mongolia's modern economic system. As early as 2016, Inner Mongolia reached a strategic cooperation with Huawei, and cooperated in urban industrial cloud centers, software development cloud innovation centers, and cloud computing centers in the northern region. In 2019, the two sides signed another strategic cooperation agreement to further strengthen cooperation and lay a solid foundation for improving Inner Mongolia's technological progress. So Inner Mongolia's digital economy output efficiency ranked high nationwide.

b) Second interval: $M \in [1\ 1.1]$

The provinces in this range include Beijing, Hebei, Shanxi, Jilin, Heilongjiang, Shanghai, Zhejiang, Anhui, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Chongqing, Yunnan, Gansu, Ningxia and Xinjiang, accounting for 66.7% of the country, although the M index of these 20 regions is greater than 1, but less than 1.1, it can be seen that in the sample interval, the growth of digital economy output efficiency in these 20 regions is not significant. Through the decomposition analysis of the M-index, it is found that the technological progress of these 20 provinces is in the [1 1.1) range, and the scale efficiency value and technical efficiency index are around 1. Therefore, in order to improve the output efficiency of the digital economy, these regions should not only increase investment in digital economy technology to improve the level of technology, but also continuously expand and optimize the scale of the digital industry.

c) Third interval: $M \in [0,1]$

Located in this range, there are 7 provinces of Liaoning, Jiangsu, Fujian, Hainan, Sichuan, Shaanxi and Qinghai. The analysis of the M-index decomposition shows that the scale efficiency index of these seven regions is around 1, which is effective in the preproduction edge, while the technical efficiency index is less than 1, indicating that these seven provinces have encountered obstacles in digital-related technologies in the process of digital economy development. Therefore, for these seven regions, in order to improve the output efficiency of the digital economy, we should first pay attention to technological upgrading, increase the introduction of digital talents and digital management talents, increase investment in digital technology research and development, and continuously improve the level of technology, so as to improve the overall level of digital economy development.

4 Conclusions and Recommendations

4.1 Conclusions

In this study, the entropy weight TOPSIS method was used to comprehensively measure the digital development level of various provinces in China from 2015 to 2019, and on this basis, the BCC-DEA model and the Malmquist index model were used to measure the output efficiency of China's digital economy from the perspectives of static and dynamic, respectively, and the following conclusions were summarized and concluded: The development level of China's digital economy presents a spatial pattern of eastern > central & gt; western > Northeastern, and the digital economy in the east is highly developed. From the perspective of dynamic efficiency, the total factor productivity of China's digital economy shows a trend of first rising, then falling and then rising, but from the data, the average annual growth rate is 0.27%. In addition, although the level of development of Inner Mongolia's digital economy is not high, the output efficiency of the digital economy is high at the current level, which is attributed to the emphasis on new infrastructure and cooperation with Huawei, which has greatly improved Inner Mongolia's digital technology, thereby promoting the improvement of digital economy output efficiency.

4.2 Research Recommendations

1) **The two sides will increase input in factors of production in the digital economy and build a new system of digital infrastructure.**

The production factors of the digital economy are the basis of the development of the digital economy, and since most provinces in China are still in the low-developed stage of the digital economy, the main reason for the constraint is the input of production factors. According to the digital economy level evaluation index system established above, digital input is digital production factors, including labor input, capital input and technology input. First of all, increasing labor investment refers to increasing investment in digital talents and accelerating the introduction and training of digital talents. Second, increase capital investment, including fixed asset investment in digital industries, as well as investment in scientific and technological research and development; Finally, technology investment is to clarify the focus of the fields involved in "digital infrastructure", accelerate the implementation of "digital infrastructure" and the digital transformation of traditional infrastructure, fully stimulate the initiative and enthusiasm of market players to participate in "digital infrastructure", and accelerate the process of industrial digitalization.

2) **The two sides will raise the level of technology and promote the application of digital economy technology.**

It is known from the above that for the output efficiency of China's digital economy, whether static or dynamic, for the vast majority of provinces in China, the improvement of their digital economy total factor productivity is mainly contributed by technological progress, so the improvement of digital technology should be promoted from multiple angles and in all directions. First, improve the digital technology level of local enterprises, guide the real economy to accelerate the upgrading and transformation of machinery and production processes, and deepen the digital application of all production links; Second, strengthen digital research, provide solid economic backing for improving innovation capabilities, and enhance the modernization level of the industrial chain; Finally, seize the historical opportunity of a new round of scientific and technological revolution, and strive to achieve global leadership in some fields of disruptive scientific and technological innovation, strategic emerging industries and future industries, and obtain new industrial advantages.

3) **The two sides will strengthen policy guidance and strengthen institutional safeguards.**

Under the background of the new trend of digital economy development during the 14th Five-Year Plan period, the government and the market go hand in hand, relying on national policies to improve the design and planning capabilities of the development of the digital economy according to their own economic and digital resource conditions. Carry out overall planning and construction of the development of the digital economy at the provincial or municipal level. Regions with developed digital economy should learn advanced industrial policies and measures related to the development of the digital economy like regions with a high level of digital economy, improve the design of relevant systems, clarify the boundaries of rights and responsibilities of various social subjects, improve the level of digitalization of government affairs, improve communication efficiency, and continuously narrow the "digital divide" between provinces in China.

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