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Research on the Efficiency of Medical and Health Resource Allocation in China from the Perspective of Digital Economy

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Abstract: This study is based on the input-output model of 31 provinces and cities (districts) in China from 2011 to 2020 in terms of the efficiency of healthcare resource allocation to construct an efficiency level evaluation index system, uses the super efficiency DEA model to conduct a static analysis of the efficiency of medical and health resource allocation of each province and city (district), and uses the Malmquist index model to conduct a dynamic analysis of the development of the efficiency of medical and health resource allocation of each province and city (district). The research conclusion indicates that there are currently problems such as imbalanced and unstable allocation of medical and health resources among provinces, cities, and districts. The integration of digital economy and medical and health fields is expected to achieve reasonable and optimized allocation of medical and health resources through the inclusion of new concepts and technologies in the traditional medical and health industry.

1. Introduction

With the integration of emerging technologies such as the Internet, cloud computing, and 5G communication with the traditional economy, a new form of economic development - the digital economy - has emerged and has rapidly had a profound impact on various industries such as traditional manufacturing and knowledge intensive industries[1]. The digital economy is an economy based on digital technology, and healthcare is one of the important targets of the digital economy[2]. China Internet Network Information Center (CNNIC) pointed out in the 51st Statistical Report on the Development of Internet in China released on March 2, 2023 that "as of December 2022, the number of Internet medical users in China will reach 363 million, an increase of 64.66 million over December 2021, accounting for 34.0% of the total Internet users."[3] The cross-border empowerment of the digital economy in the healthcare sector is an opportunity to promote the transformation and upgrading of China's healthcare industry, which is conducive to promoting high-quality development in the healthcare sector. As early as the 1980s and 1990s, China introduced medical information technology. At that time, a few large hospitals with conditions purchased computer software and hardware, established IT systems and databases to improve hospital

management workflow and promote efficiency improvement. Medical informatization achieved initial results in China. With the iterative updating of science and technology, "Internet plus+medical care" has gradually developed, and new models of information interconnection such as Internet hospitals, telemedicine, resident health file management, "120" emergency network, and "one-stop" settlement have gradually been used and promoted, which has played an important role in promoting the efficiency of China's medical and health resource allocation. In the context of the "digital economy" strategy, China's medical and health sector will also achieve Digital transformation, and the efficiency of China's medical and health resource allocation will be significantly improved. With the outbreak of COVID-19, although the Chinese government has taken a series of decisive measures to effectively control the spread of the epidemic and avoid large-scale casualties and social unrest[4], it has also exposed China's long-term problems such as low correspondence between supply and demand of medical and health resources, biased localized supply of medical resources, and unreasonable health structure[5]. Optimizing the efficiency of China's healthcare resource allocation remains a key issue of concern in the healthcare sector. The advent of the digital economy era has provided development opportunities for promoting high-quality development of China's healthcare services and resource structure adjustment.

Therefore, this paper, based on the perspective of digital economy, combined with the super efficiency DEA model and Malmquist index model, conducts research on the efficiency of China's medical and health resource allocation from the perspective of both static and Dynamic efficiency analysis, with a view to providing theoretical support for China's relevant departments to improve the mechanism of medical and health resource allocation and optimize the path construction of policies and measures, and promoting the coordinated development of China's medical and health resources.

2. Model Establishment and Indicator Selection

2.1. Model Establishment

2.1.1. Super Efficient DEA Model

The super efficient DEA model is a functional improvement based on the traditional DEA model, which adjusts and refines the functions based on two variants of the CCA model, the CCR model and the BBC model. CCR model is a Data envelopment analysis model proposed by Charnes, Cooper and Rhodes. The BBC model is named after three scholars, Banker, Charnes, and Cooper. The CCR model assumes constant returns to scale and evaluates technical efficiency (TE), which is also known as the CRS model; The BBC model assumes variable returns to scale and evaluates pure technological efficiency, also known as the VRS model[6]. The meaning of the super efficiency DEA model is to not constrain the decision-making unit (DMU), and by not constraining the DMU, the final efficiency value can break through the traditional limit of "1" to make its efficiency value higher than 1, without making assumptions about constant or variable returns to scale. The specific calculation formula is shown in equation (1):

$$\min\theta \text{ :s.t. } \begin{cases} \sum_{j=1}^{n} x_j + s^- = \theta x_k \\ \sum_{j=k}^{n} y_j + s^- = y_k \\ j \neq k \\ j \geqslant 0, j = 1, 2, \cdots, n \\ s^- \geqslant 0, s^+ \geqslant 0 \end{cases} \tag{1}$$

Among them, x_j and y_j respectively represent the input and output of the jth province, city

(district); k represents the DMU for evaluation; j represents the planning decision variable; θ Represents the effective value of DMU; S+and S - represent relaxation variables.

2.1.2. Malmquist Index Model

Malmquist index model is a Data envelopment analysis model proposed by Malmquist in the 1980s. Malmquist index model can evaluate the efficiency change of decision making units (DMUs) at different time points, which is called time Dynamic efficiency evaluation. The Malmquist index model obtains a comprehensive efficiency indicator by comparing the efficiency of two time points, and decomposes it into two parts: technical change efficiency and technical efficiency change rate. This can help analysts better understand the reasons for the efficiency changes of DMUs[7]. The specific calculation formula for the Malmquist index model is shown in equation (2):

$$M(x^t, y^t, x^{t+1}, y^{t+1}) = [\frac{D^t(x^{t+1},y^{t+1})}{D^t(x^t,y^t)} \times \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^t,y^t)}]^{\frac{1}{2}} \quad (2)$$

In equation (2), x^t and y^t represent the specific indicators of healthcare resource input and output in period t, while D^t represents the distance function in period t. When M>1, the production efficiency of medical and health resource allocation increases; When M<1, the production efficiency of healthcare resource allocation decreases.

2.2. Indicator Selection

Table 1: A comprehensive evaluation system for the efficiency of healthcare resource allocation in China based on the perspective of digital economy.

Primary indicators	Secondary indicators	Third level indicators	Unit	Code
Input indicators	Digital health human resources	Number of health technical personnel	Person	X11
	Digital healthcare infrastructure	Number of beds	10000 sheets	X21
		Ipv4 ratio	%	X22
		Number of 'CN' domain names	Piece	X23
		Number of pages	Piece	X24
	Scale of investment in medical and health resources	Number of medical and health institutions	Piece	X31
	Medical and health expenditure level	Total per capita health expenses	Yuan	X41
		Proportion of total health expenditure to GDP	%	X42
Output indicators	Service capacity of medical and health institutions	Number of patients diagnosed and treated	Person-time	Y11
	Carrying capacity of medical and health institutions	Bed utilization rate	%	Y21
		Number of admissions	Person-time	Y22

This study is based on the input-output models of 31 provinces and cities (districts) in China from 2011 to 2020 in terms of the efficiency of healthcare resource allocation, to construct an efficiency level evaluation index system and measure the efficiency level. The selection of input and output indicators in the measurement and empirical analysis of the efficiency level of healthcare resource allocation by Chinese scholars is relatively mature. This study constructs an input-output model based on the research results of relevant scholars and the integration of the digital economy in the healthcare field. This paper selects the panel data of 31 provinces and cities (districts) in

China from 2011 to 2020 as the decision-making unit, and the relevant data mainly comes from the relevant data such as China Health Statistics Yearbook, China Statistical Yearbook and China Internet Development Statistical Report from 2012 to 2021. The final efficiency comprehensive evaluation system is shown in Table 1.

3. Results and Analysis

3.1. Static analysis results

This study relies on the super efficiency DEA model and uses DEA-SOLVER software to input input-output data on the efficiency of medical and health resource allocation from the perspective of digital economy in 31 provinces and cities (districts) in China from 2011 to 2020, and calculates the static efficiency level. Obtain the super efficiency DEA values of China from 2011 to 2020 through software operation, and then calculate the average efficiency and ranking. The specific ranking is shown in Table 2.

Table 2: The average efficiency of healthcare resource allocation from the perspective of digital economy in 31 provinces, cities, and districts in China from 2011 to 2020.

Serial Number	Province	Average efficiency value	Serial Number	Province	Average efficiency value
1	Guizhou	1.804	17	Inner Mongolia	1.065
2	Tibet	1.801	18	Gansu	1.050
3	Qinghai	1.455	19	Jiangxi	1.049
4	Tianjin	1.411	20	Chongqing	1.049
5	Ningxia	1.331	21	Hubei	1.042
6	Shanghai	1.327	22	Anhui	1.033
7	Jiangsu	1.260	23	Guangdong	1.000
8	Sichuan	1.256	24	Beijing	0.960
9	Xinjiang	1.241	25	Hebei	0.930
10	Yunnan	1.221	26	Hainan	0.885
11	Zhejiang	1.106	27	Liaoning	0.874
12	Shandong	1.104	28	Heilongjiang	0.825
13	Fujian	1.090	29	Shaanxi	0.806
14	Hunan	1.087	30	Jilin	0.788
15	Guangxi	1.084	31	Shanxi	0.683
16	Henan	1.081	——	——	——

Overall, from 2011 to 2020, there were significant differences in the average efficiency of healthcare resource allocation from the perspective of digital economy in 31 provinces, cities, and districts in China. There are a total of 22 provinces, cities (districts) with an average efficiency greater than 1, and 8 provinces, cities (districts) with an average efficiency less than 1. By comparing the number of provinces, cities (districts) with an average greater than 1 and less than 1, it can be concluded that from the perspective of the digital economy, there are more provinces in China with relatively effective allocation efficiency of healthcare resources. Taking Jiangsu Province as an example, the average efficiency value of Jiangsu Province is 1.260. This indicates that Jiangsu Province has a certain elastic range in equal proportion, and even if the investment in medical and health resources can be proportionally adjusted within a range of 26%, its relative effectiveness can still be guaranteed among the 31 evaluated provinces, cities, and districts. Therefore, it can be concluded that 22 provinces and cities (districts) in China can achieve optimal allocation of medical and health resources from the perspective of the digital economy. However, the average super efficiency DEA of 8 provinces and cities (districts), including Hebei, Hainan, and Liaoning, is lower than 1, indicating that these provinces and cities (districts) have problems with

redundant and insufficient utilization of medical and health resources that exceed their effective investment range. From the overall data situation, the 31 provinces and cities (districts) included in the evaluation have problems of imbalanced allocation of medical and health resources and low efficiency.

3.2. Dynamic analysis results

This study is based on the Malmquist index model and uses Deap3.0 software to measure the allocation efficiency of medical and health resources in various provinces and cities (districts) in China. From the perspective of annual changes, the dynamic changes in the allocation efficiency of medical and health resources in China from 2011 to 2020 are examined. The total factor productivity index and specific sub index efficiency of medical and health resource allocation in 31 provinces and cities (districts) in China are obtained by year (as shown in Table 3).

Table 3: Measurement results of total factor productivity of healthcare resource allocation in China from 2011 to 2020.

Year interval	Effch	Tech	Pech	Sech	TEP
2011-2012	0.998	0.969	0.999	0.999	0.966
2012-2013	1.006	1.226	1.001	1.005	1.234
2013-2014	1.007	0.815	1.003	1.004	0.820
2014-2015	0.999	0.774	0.999	1.000	0.773
2015-2016	1.002	1.019	1.002	1.000	1.021
2016-2017	0.999	1.007	1.002	0.998	1.006
2017-2018	0.992	0.924	0.995	0.997	0.916
2018-2019	0.997	0.955	1.001	0.996	0.952
2019-2020	0.979	0.845	0.989	0.990	0.828
Average value	0.998	0.940	0.999	0.999	0.938

Based on the data evolution trend of China's total factor productivity measurement results from 2011 to 2020, the average TFP index of China's healthcare resource allocation is 0.938. The TFP index showed varying degrees of decline from 2013 to 2015, 2016 to 2018, and 2018 to 2019, indicating that the decline in the TFP index was mainly caused by the decline in the Tech index. Specifically, from the decomposition index of the TEP index, the Tech index has a significant impact on the TFP index, as both its evolution trend and data variation range are relatively similar. Technological progress is an important factor in the several increases in the efficiency of China's healthcare resource allocation between 2011 and 2020. In addition, the growth and decline trends of Effch, Pech, and Sech index values tend to be consistent, mainly playing a positive role in the growth of TEP index.

4. Conclusion and Countermeasures

At present, there are significant differences in the average efficiency of healthcare resource allocation from the perspective of digital economy in 31 provinces, cities, and districts in China. There is an imbalance in the allocation of medical and health resources among provinces, cities, and districts. Although the investment indicator data selected in this study shows a relatively good trend of increasing year by year, the efficiency of resource allocation is still one of the key issues that need continuous attention and improvement in China's healthcare industry. In addition, the average annual TFP index of China's medical and health resource allocation is 0.938, which is still a certain gap from the effective state. There have been multiple efficiency fluctuations in the past 10 years, and the unstable efficiency allocation is still an urgent problem to be solved. Among them, the Tech index plays a leading role in the fluctuation of the TEP index, indicating that policies, funding, and

other measures should be implemented to optimize the efficiency of the Tech index and improve the TEP index of China's healthcare resource allocation. Based on this, relevant policy recommendations are proposed as follows:

Firstly, establish and improve digital infrastructure in the field of healthcare, providing hardware support for safeguarding the health of the entire population. The country should strengthen the application level of digital technology and improve the efficiency of the digital economy in the field of healthcare. The government should increase its investment in digital infrastructure construction. Medical institutions should enhance their digital capabilities and enhance their staff's understanding and application of digital technology and equipment.

Secondly, leverage the radiation effect of industrial digitization on the healthcare sector and promote efficient allocation of healthcare resources. The digitization of industries has now penetrated into the field of healthcare and is playing an increasingly important role. First, we will continue to promote the improvement of digital technology in the healthcare sector. Improving the level of digitalization in the medical and health field is the prerequisite and foundation for the radiation effect of industrial digitalization on the medical and health field. Second, optimizing the allocation and scheduling of medical and health resources through digital technology. Third, build an industrial digital ecosystem and create an advantageous environment for the development of information technology in the field of healthcare. Governments, healthcare institutions, enterprises, universities, and research institutes should jointly build a digital ecosystem to achieve comprehensive sharing, collaborative innovation, and enhancement of healthcare resources.

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