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The Impact of the Digital Economy on the Efficiency of Healthcare Resource Allocation in China: Based on Panel Data 2012-2022

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Abstract

The main purpose of the article in to study the impact of the development of digital economy on the efficiency of healthcare resource allocation in China , and to explore the specific mechanism of action and regional heterogeneity of its efficiency enhancement. Based on the panel data of 30 provinces in China from 2012 to 2022, the article constructs a two-way fixed-effects model, taking the level of digital economy development as the core explanatory variable, the healthcare resource allocation efficiency measured by the Envelopment of Data Approach (EDA) as the explanatory variable, and gradually introduces control variables such as the level of urbanisation, the level of economic development, the level of education, and the fiscal expenditure. In addition, the article adopts three-level indicator substitution of explanatory variables and principal component analysis (PCA) instead of entropy weight method (EWM) accounting, Tobit regression and other methods to carry out the robustness test, and explores the heterogeneous impact of the digital economy in the eastern, central and western regions through group regression. The results of the study show that the digital economy significantly improves the efficiency of healthcare resource allocation, and this effect remains robust after introducing different control variables. The reliability of the model and the robustness of the results are further verified by robustness tests. Heterogeneity analysis shows that the digital economy has the most significant effect on healthcare resource allocation efficiency in the eastern region, while it is relatively weaker in the central and western regions. The findings of the article not only enrich the research on the digital economy and healthcare resource allocation efficiency, but also provide policy references for optimising healthcare resource allocation. It is recommended to strengthen the construction of digital infrastructure in the future and formulate policies according to local conditions to promote the balanced development of regional medical resources.

Keywords: Healthcare Resource Allocation Efficiency; Digital Economy; Fixed Effects Modelling; Regional Heterogeneity

1 | Introduction

With the advent of the digital era, all levels of the global economy and society are undergoing profound changes in the digital economy. With big data, cloud computing, and artificial intelligence as the core driving force, the digital economy has become an important factor in promoting social progress, economic growth, and industrial upgrading. Wang Yong and Hou Mengyao (2024)[1] found that in the medical field, the application of digital technology has significantly changed the traditional medical resource allocation model.

However, there are still many problems in the allocation of medical resources in China, especially the imbalance in the distribution of medical resources between urban and rural areas and regions. Weng Mengqing et al. (2024)[2] illustrated that the rise of the digital economy offers great potential for optimising the allocation of healthcare resources, and that the accessibility, quality and efficiency of healthcare services can be improved through technological means such as telemedicine and electronic medical records.

In this context, the impact of digital economy on healthcare resource allocation has become a research hotspot. Liang Binghua and Zhai Shaoguo (2024)[3] found that the digital economy can effectively enhance the utilisation efficiency of healthcare resources and improve the fairness and accessibility of healthcare services by, among other things, promoting technological progress.

2 | Literature Review

Digital economy is an economic activity based on the production, distribution, exchange and consumption of digitised knowledge and information. The research of Dong Kangyin and Liu Yang (2024)[5] illustrates that it covers a wide range of fields including e-commerce, digital payment, cloud computing and so on. In China, the development of digital economy has become an important part of the national strategy.

China's medical resource allocation has long been plagued by regional imbalance, large urban-rural gap, and unreasonable resource distribution. Xu Xiaodong (2024)[10] illustrates that this unbalanced resource allocation leads to problems of accessibility and fairness of medical services.

The digital economy provides new solution ideas and technical support for optimising the allocation of medical resources. Jiajia Liu (2024)[6] illustrates that telemedicine technology can break through geographic limitations so that patients are no longer confined to the nearest hospital, especially for patients in remote areas, providing a convenient way to seek medical treatment.

In summary, existing studies have shown that the digital economy has great potential to enhance the efficiency of medical resource allocation. By analysing existing studies, we can see that the application of the digital economy, especially in terms of information technology and intelligent management, can significantly improve the efficiency of healthcare resource utilization and reduce imbalance.

3 | Variable Design

3.1 Explanatory Variable

Based on the assumptions and theoretical analyses mentioned above, the explanatory variable chosen in this article is "healthcare resource allocation efficiency" (denoted by the symbol emra in the following). The indicators of healthcare resource allocation efficiency are shown in Table 1 with reference to the studies of Wang, Yong and Hou, Mengyao (2024)[1] and Zhu, Yaxin, Chen, Baoqi and Jin, Fulei (2023)[16] :

Table 1 Indicators for measuring the efficiency of healthcare resource allocation

Target	First indicators	Secondary indicators	Meaning of the indicator
Efficiency of medical resource allocation	Input indicators	Human and material inputs	Number of health personnel per 1,000 population (places per 1,000 population)
			Number of beds per 1,000 population (beds per 1,000 population)
		Organisational setup	Number of health-care institutions (units)
	Output indicators	Hospital visits	Number of hospital admissions (10,000)
			Number of consultations (10,000)
		Hospital consultation fees	Per capita health costs (yuan)
	environment variable	Demographic and environmental factors	Urban population density (persons/km2)

In the study of the article, the accounting of the efficiency of healthcare resource allocation uses the Data Envelopment Analysis (DEA, Data Envelopment Analysis) method. Cui, Xi-cheol and Kong, Xiangyu (2024)[11] The DEA method used is a non-parametric technique commonly used to evaluate the relative efficiency of decision-making units (e.g., hospitals, regions, etc.), which measures the efficiency of resource allocation by comparing the inputs and outputs of different units. Its calculation steps are shown below:

(1) Defining inputs and outputs

There are n decision cells, each with m inputs and s outputs. The input vector for decision cell i is $X_i = (x_{i1}, x_{i2}, \ldots, x_{im})$ and the output vector is $Y_i = (y_{i1}, y_{i2}, \ldots, y_{is})$, where x_{ij} is the j input and y_{ik} is the k output for decision cell i .

(2) The basic model of DEA

For the decision unit i , the efficiency value θ_i is calculated with the objective of maximising the ratio of inputs to outputs as follows:

$$\theta_i = \frac{\sum_{k=1}^{s} \lambda_k y_{ik}}{\sum_{j=1}^{m} \mu_j x_{ij}}, \tag{1}$$

Where, λ_k and μ_j are optimisation variables representing the weights of each output and input. The relative efficiency of each decision unit can be solved by linear programming method.

(3) Constraints

In order to ensure that the efficiency values of all decision-making units are compared under a uniform criterion, the DEA model sets the following constraints:

$$\text{s.t.}\begin{cases}\sum_{k=1}^{n} \lambda_k x_{jk} \le x_{jj} \text{ for all } j \\ \sum_{k=1}^{n} \lambda_k y_{ik} \ge y_{ii} \text{ for all } i\end{cases}, \quad (2)$$

Where $\lambda_k \ge 0$ is a weighting factor to indicate the relative importance of each decision unit in the calculation.

3.2 Core explanatory variables

The article chooses digital economy as the core explanatory variable (denoted by the symbol dig in the later section). The article mainly draws on the studies of Wang Jun (2021)[19] and Guo Feng (2020)[18] et al. The article chooses digital economy accounting indicators as shown in Table 2 below:

Table 2 Indicator system for the level of development of the digital economy

First indicators	Secondary indicators	Variant	Causality
Level of development of the digital economy	Digital economy infrastructure	Number of domain names	forward
		Number of IPV4	forward
		Number of Internet access ports	forward
		Mobile phone penetration rate	forward
		Length of long-distance fibre-optic cable per unit area	forward
	Digital economy industrial development	Number of information technology enterprises	forward
		Websites per 100 enterprises	forward
		E-commerce turnover ($ billion)	forward
		Share of enterprises with e-commerce trading activities	forward
		Revenue from software operations ($ million)	forward
	Digital Inclusive Finance	Digital Finance Breadth of Coverage Index	forward
		Depth of use index for digital finance	forward
		Degree of digital finance digitisation	forward

In order to accurately measure the impact of the digital economy on the efficiency of healthcare resource allocation, the article adopts the Entropy Weight Method to comprehensively assess the indicators of the digital economy. The calculation steps are shown below:

Step.1 Standardised processing. $z_{ij}=\frac{x_{ij}-min(x_j)}{max(x_j)-min(x_j)}$,

Step.2 Calculate the entropy value of each indicator. $e_j=-\frac{1}{ln\,n}\sum_{i=1}^{n}p_{ij}ln\left(p_{ij}\right)$

Step.3 Calculate the weights of the indicators. $w_j=\frac{1-e_j}{\sum_{j=1}^{m}(1-e_j)}$

Step.4 Calculation of the composite index$I=\sum_{j=1}^{m}w_jx_j$,

3.3 control variable

In the article, in addition to the core explanatory variable "digital economy", four control variables, namely, the level of urban development (lud), the level of economic development (GDP), the level of educational attainment (edu), and the financial expenditure (fin), are selected to comprehensively consider other key factors affecting the efficiency of healthcare resource allocation.

(1) Level of urban development

With the gradual improvement of urban infrastructure and healthcare networks, healthcare resource allocation in urban areas tends to show higher efficiency. Conversely, areas with a lower level of urban development are less efficient in their allocation of resources because of poor infrastructure and a lack of medical resources.

(2) Level of economic development

Economically developed regions tend to be able to provide more efficient healthcare services through higher financial expenditures, more healthcare investments, and so on. Regions with a higher level of economic development are able to attract more high-end medical resources, thus improving the efficiency of medical resource allocation.

(3) Educational attainment

Residents of more educated areas usually have better health awareness and higher demand for healthcare services, while areas with a higher concentration of highly qualified healthcare professionals tend to provide higher quality healthcare services.

(4) Financial expenditures

In regions with more adequate financial expenditure, the government is usually able to provide more healthcare resources, optimise the allocation of resources and improve the efficiency of healthcare services.

Specific variable definitions are shown in Table 3:

Table 3 Variable Definition Table

Notation	Variable Name	Define
emra	Efficiency of medical resource allocation	EDA-measured healthcare resource allocation efficiency
dig	Level of development of the digital economy	Level of development of the digital economy as measured by EWM
lud	Level of urban development	Share of regional urban population in total regional population
GDP	Level of economic development	gross regional product (GDP)
edu	educational attainment	Percentage of people in junior and senior high school and university
fin	and financial expenditures	Regional financial expenditures

3.4 Source of data

The article selects panel data for 30 provinces in China (excluding Tibet, Hong Kong, Macao and Taiwan) for the period from 2012 to 2022. The data sources include annual statistics released by the National Bureau of Statistics (NBS), data from the Digital Finance Research Centre of Peking University (DFRC), and official statistical annual reports such as China Industrial Statistical Yearbook (CISY), China Statistical Yearbook (CSY), China Information Yearbook (CINY), and China Health and Sanitation Statistical Yearbook (CHSYY) for all years. In addition, relevant data from the CNRDS database and provincial statistical yearbooks were used. Descriptive statistics of the variables are shown in Table 4 below:

Table 4 descriptive analysis

VARIABLES	N	max	min	mean	std
emra	330	1	0.336	0.693	0.18
dig	330	0.712	0.024	0.153	0.118
lud	330	0.896	0.363	0.607	0.117
GDP	330	129118.6	1528.48	28148.955	23441.312
edu	330	93.2	54	76.986	8.143
fin	330	185330800	8643600	56344147.17	31115849.475

4|Empirical results and analyses

4.1 modelling

In order to study the impact of the level of digital economy development on the efficiency of healthcare resource allocation, the article constructs the following two-way fixed effect model with reference to the study of Wang Yong and Hou Mengyao (2024)[1] :

$$Emra_{it} = \alpha + \beta Dig_{it} + \delta Z_{it} + \mu_i + \varepsilon_{it} \ ,$$

Where, $Emra_{it}$: Healthcare resource allocation efficiency of the i th province in the tth year, the explanatory variable. α: Constant term. Dig_{it}: The level of digital economy development in$i$ provinces in the year t , the core explanatory variable. Z_{it} : Vector of control variables, including lud, GDP, edu and fin. δ: Vector of coefficients of control variables. μ_i: Individual fixed effects, controlling for characteristics that do not vary across provinces over time. ε_{it} : Random error terms.

4.2 return to baseline

The article used Stata 26.0 software to calculate the results of the model with fixed effects, and the random effects model could not be chosen because the results of the Hausman test (test statistic of 57.19, p-value of 0.000) indicated that there was a significant difference between fixed effects and random effects. The results of the regression analysis of dig on the emra are demonstrated as shown in Table 5.

Table 5 base regression table

variant	(1) emra	(2) emra	(3) emra	(4) emra	(5) emra	(6) emra
dig	0.415*** (6.402)	0.159* (1.853)	0.876*** (6.323)	0.878*** (6.230)	0.987*** (6.806)	0.629*** (4.350)
lud		0.493*** (4.418)	0.690*** (6.309)	0.689*** (6.252)	0.855*** (6.853)	0.433*** (3.777)
GDP			-0.000*** (-6.361)	-0.000*** (-6.254)	-0.000*** (-3.011)	-9.42e-07 (-0.839)
edu				0.000 (0.096)	-0.000 (-0.500)	-8.59e-10 (-1.230)
fin					-0.000*** (-2.737)	-0.00107 (-1.088)
_cons	0.630*** (59.865)	0.370*** (6.186)	0.293*** (5.095)	0.287*** (3.369)	0.265*** (3.133)	0.492*** (5.827)
individually	be	be	be	be	be	individual randomisation
N	330	330	330	330	330	330
R2	0.121	0.175	0.274	0.274	0.292	0.231

Note: ***, ** and * indicate significant at the 1 per cent, 5 per cent and 10 per cent levels, respectively; t-values in parentheses; same table below.

All models in Table 5 show that dig has a significant positive effect on Emra, and the significance of this effect and the size of the coefficients change with the introduction of different control variables. The R^2 value of the model gradually increases from 0.121 to 0.292, indicating that the explanatory power of the model improves with the increase of control variables. Model (1) includes only dig as an explanatory variable, and the results show that it has a significant positive effect on the efficiency of healthcare resource allocation. Models (2) to (5) gradually include control variables. The results show that the level of urbanisation has a significant positive effect on the efficiency of medical resource allocation, while the level of economic development and fiscal expenditure show a negative effect. The effect of education level is not significant. The regression results show that the level of digital economic development has a significant positive effect on medical resource allocation efficiency, which is in line with the main hypothesis.

4.3 robustness regression

In order to test the robustness of the model, the article adopts three different methods for analysis. Firstly, for the core explanatory variable "digital economy", the third-level indicator of the degree of digital financial digitisation (denoted by ddfd later) is chosen to replace the indicator calculated by the entropy weight method. Second, Principal Component Analysis (PCA) is used to replace the calculation method of entropy weight method for the core explanatory variable, and the robustness of the model is examined by replacing the digital economy accounting method. Thirdly, Tobit regression model was used to replace the original multiple linear regression for analysis. The results are shown in Table 6 below:

Table 6 robustness regression

Regression method	(1) emra	(2) emra	(3) emra
ddfd	0.000*** (8.593)		
dig(PCA)		0.089*** (6.526)	
dig(Tobit)			1.025*** (16.469)
_cons	0.586*** (45.525)	0.690*** (196.669)	0.537*** (44.646)
var(e.Emra)			0.018*** (12.845)
individual effect	be	be	be
N	330	330	330
R2	0.198	0.125	

The results of the model robustness analysis are presented in Table 6. The first column recalculates ddfd using a three-level indicator, and the results show that the core explanatory variables have a significant effect on Emra. The second column replaces the core explanatory variables by PCA method and the results are also significant. The third column is tested for robustness by Tobit regression method, and the results show that the level of digital economy development has a significant and strong effect on healthcare resource allocation efficiency. Overall, the results of all three methods support the hypothesis that the digital economy has a positive effect on healthcare resource allocation efficiency.

4.4 (math.) Heterogeneity Regression

Since there are significant differences in the level of economic development, digital economy penetration, and healthcare resource allocation among the eastern, central, and western regions of China, the article adopts heterogeneity analysis to regress groupings of the eastern, central, and western regions, respectively, in order to explore the regional variability of the impact of the digital economy on the efficiency of healthcare resource allocation.

Table 7 (math.) Heterogeneity Regression

Variant	Eastern Region Emra	Central Region Emra	Western Region Emra

dig	0.330*** (4.889)	0.662*** (3.449)	0.717*** (3.544)
_cons	0.681*** (41.514)	0.589*** (27.151)	0.574*** (28.504)
individual effect	be	be	be
N	132	99	99
R2	0.167	0.118	0.124

The results of the heterogeneity analysis of Dig on Emra in the eastern, central and western regions are presented in Table 7. The results show that the digital economy exhibits a significant positive impact on healthcare resource allocation efficiency in all three regions, but there are differences in the degree of impact. As can be seen from the R^2 value, the explanatory power of the model is relatively high for the eastern region ($R^2 = 0.167$), indicating that the improvement of the digital economy on medical resource allocation efficiency is more significant in the eastern region. In contrast, the R^2 values for the central and western regions are lower, at 0.118 and 0.124, respectively, possibly reflecting the fact that the digital economy's enhancement of healthcare resource allocation efficiency in these regions is still constrained by other factors.

5|Findings

5.1 Main Findings

Based on the panel data of 30 provinces in China from 2011 to 2022, the article investigates the impact of the level of development of the digital economy on the efficiency of healthcare resource allocation, and draws the following main conclusions through the two-way fixed effect model and the robustness test method: firstly, the digital economy significantly improves the efficiency of healthcare resource allocation. This effect is reflected in optimising the allocation of medical resources, improving the efficiency of resource utilisation and reducing regional differences. Second, the robustness test, further confirms the importance of the digital economy in enhancing healthcare resource allocation efficiency. Third, the heterogeneity analysis reveals the regional differences of the digital economy. In the eastern region, the digital economy has the most significant impact on healthcare resource allocation efficiency, while the impact is weaker in the central and western regions.

In summary, the digital economy plays a key role in promoting the optimal allocation of healthcare resources and improving the efficiency of healthcare services.

5.2 Policy recommendations

Based on the above conclusions, the following policy recommendations are made to further improve the effectiveness of the digital economy in influencing the efficiency of healthcare resource allocation:

Promoting digital infrastructure. In the central and western regions, accelerating Internet penetration and improving broadband coverage will provide support for the application of digital technology in the medical field and bridge the infrastructure gap between regions.

Strengthening the digital transformation of healthcare, promoting the in-depth application of technologies such as artificial intelligence, big data and cloud computing in the allocation of healthcare resources, such as promoting telemedicine services and electronic health records, and upgrading the digital service capacity of primary healthcare institutions.

Establishing a multi-sectoral collaboration mechanism. Encourage cooperation among governments, medical institutions and enterprises to promote the coordinated development of digital economy platforms for medical resource sharing, service innovation and health management.

Strengthening digital education and promotion. Targeting medical personnel and the general public, relevant training and publicity will be carried out to enhance the acceptance and ability to use digital technology, so as to lay the foundation of human resources for the full-scale promotion of digital health care.

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