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Study on the efficiency of health resource allocation in the western region of China–based on three-stage DEA and Tobit regression analysis

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Abstract

Objective To analyze the allocation efficiency of health resources in the western region of China, and to explore the influence of external environmental factors on the allocation efficiency, to provide reference for optimizing the allocation of resources.

Methods In this study, we employed a three-stage Data Envelopment Analysis (DEA) model alongside Tobit regression analysis to evaluate the efficiency of health resource allocation and explore the factors that influence it across western China. This analysis focused on data from 2021, covering ten provinces. Through this combined approach, the study aimed to uncover key insights into the determinants and variations in resource allocation efficiency within western China.

Results Following the three-stage DEA analysis, the results showed that health resource allocation in western China achieved a comprehensive efficiency of 0.979, a pure technical efficiency of 0.980, and scale efficiency of 0.999. Notably, six provinces, specifically Chongqing, Guizhou, Yunnan, Tibet, Qinghai, and Ningxia, maintained efficient performance both before and after adjustment. The extensive efficiency of 3 provinces, including Sichuan, Shaanxi, and Gansu decreased. Xinjiang's comprehensive efficiency improved. The comprehensive efficiency of the southwest area was higher than that of the northwest area. The Tobit regression analysis revealed that factors such as per capita disposable income, the share of government spending in total healthcare expenditure, and the medical service price index significantly influenced the efficiency of health resource allocation in Western China.

Conclusion Environmental factors appeared to inflate the efficiency estimates of health resource allocation in China's western region, with considerable disparities across different areas. To address these issues, the government should advance reforms in medical resource distribution, enhance management practices and technology, optimize resource allocation structures, and minimize resource wastage. At the same time, strategies should be formulated according to provincial characteristics, and interregional cooperation and resource sharing should be strengthened to achieve complementary advantages and common development.

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Keywords Three-stage DEA model, Tobit regression, Health resource allocation efficiency

Introduction

The health status of the global population has improved significantly since 2000. However, the expansion of basic healthcare coverage has slowed globally since 2015, and inequalities persist [1]. There are large differences in healthcare resources between countries. For example, most low- and middle-income countries have yet to achieve universal coverage of essential healthcare services [2]. Efficient healthcare resource allocation is a global challenge, with organizations such as the World Health Organization (WHO) and the Organization for Economic Co-operation and Development (OECD) emphasizing equitable distribution, universal healthcare coverage, and the provision of cost-effective services. To promote equitable distribution of medical resources, the Third Plenary Session of the Twentieth Central Committee of the Communist Party of China (CPC) adopted a resolution stressing the need for comprehensive reforms to promote Chinese-style modernization. This resolution highlighted the importance of advancing reforms in the medical and healthcare system as a critical task for further deepening these reforms and fostering modernization with Chinese characteristics. The allocation of health resources was fundamental to the success of these reforms. As a result, optimizing the distribution of health resources and improving service efficiency became key priorities within China's healthcare sector. As a key region of China's economic development, the study of health resource allocation efficiency in the Western region will help to understand the status quo of inter-regional development imbalance, provide a scientific basis for the government to formulate and adjust the health policy, and provide decision-making support for narrowing the development gap between the east and the west.

For the evaluation of health resource allocation efficiency, existing studies have been carried out mainly at the regional and national levels. In terms of regional studies, Yao et al. used the Malmquist index to evaluate the resource allocation efficiency of primary healthcare organizations in Urumqi from 2007–2015 [3]; Liang et al. evaluated the efficiency of basic public health services in Tianjin jurisdictions [4]; Lin et al. used a combination of descriptive and Health Resource Agglomeration Degree (HARD) analyses to assess the current situation and equity of health resource allocation in Guangdong Province from 2013 –2019 to assess the current status and equity of health resource allocation in Guangdong Province [5]; Wang et al. used three-stage data envelopment analysis and Malmquist productivity index to analyze the equity and effectiveness of health resource allocation in the Chengdu-Chongqing Provincial Economic Circle from both static and dynamic perspectives [6]. For national studies, Hao et al. used the Gini coefficient and Terrell index to analyze the fairness of national healthcare resource allocation [7]; Zhao et al. used DEA to evaluate the efficiency of primary healthcare resource allocation in each region of the country [8]; Ruan et al. used the agglomeration index, entropy weighting method, and DEA to analyze the efficiency of China's public healthcare resource use [9]; and Fang et al. used a three-stage data envelopment analysis model based on the directional relaxation measure and the global Malmquist-luenberger index to measure healthcare efficiency and its changes, and found that the total factor productivity of China's healthcare services declined from 2012 to 2021, and that the excessive number of healthcare institutions and insufficient volume of healthcare services were the main reasons for the inefficiency of healthcare services [10]; González-de-Julián et al. pointed out that DEA allowed analyzing inefficiencies in primary health care and clearly distinguished between efficient and inefficient, and assessments could be based on health care activities, health outcomes, or both [11]. In summary, the existing studies mainly used the traditional DEA model to analyze the allocation efficiency of public health resources, however, due to the existence of the agglomeration effect of public health resources, the configuration had significant regional variability, and was greatly influenced by environmental factors such as resource endowment and economic level within the region, while the traditional DEA model was unable to identify the environmental factors in the efficiency measurement, which would result in the bias of the results [12]. Therefore, taking Western China as the scope of the study, this study further investigated the main determinants of health resource allocation efficiency and their degree of influence in Western China by adopting a three-stage DEA model to eliminate the influence of external factors and random errors, and by combining it with the Tobit regression model. These insights were crucial for enhancing the efficiency of health resource distribution in the region.

Data and methods

Data

This study compiled and analyzed data on health resource allocation across ten provinces in the western region of China. The dataset included inputs, outputs, and environmental variables, all sourced from the 2022 edition of the China Health and Wellness Statistical Yearbook. Based on China's seven geographic divisions, the western region was divided into the southwest area (Sichuan,

Guizhou, Yunnan, Chongqing, and Tibet Autonomous Region) and the northwest area (Shaanxi, Gansu, Qinghai, Ningxia Hui Autonomous Region, and Xinjiang Uygur Autonomous Region). It should be noted that in China, provinces, and municipalities directly under the central government and autonomous regions are all provincial level.

Methods

In this study, we used the DEA model to measure the efficiency of healthcare resource allocation. DEA is a nonparametric method that can effectively assess the relative efficiency of decision-making units and is widely used in the study of the efficiency of healthcare resource allocation [13]. There are two main types of DEA models: input-oriented and output-oriented, and their selection depends mainly on the research objectives. Input-oriented DEA models focus on how to reduce inputs while keeping the output level constant, optimize the use of resources, reduce unnecessary waste of resources, and improve the efficiency of input use. The output-oriented DEA model, on the other hand, focuses on how to maximize outputs while keeping existing inputs constant, and is suitable for situations where research is conducted on how to improve the supply capacity of healthcare services. Since medical equipment, infrastructure, and training of healthcare professionals required long-term investment, it was difficult to rapidly expand the total amount of medical resources in the short term. In contrast, it was more realistic to optimize the use efficiency of existing resources, so input-oriented DEA was more suitable for the study of healthcare resource allocation efficiency. At the same time, compared with the traditional DEA method, the three-stage DEA method could eliminate the influence of environmental factors and random errors on the decision-making unit, so that the efficiency values obtained reflect the efficiency level of health resource allocation in each province more realistically and accurately. Therefore, this study adopted the three-stage DEA model to evaluate the allocation efficiency of health resources in western China. The first stage uses a DEA model to measure the initial efficiency of each region based on input–output data. The second stage uses a Stochastic Frontier Analysis (SFA) regression to adjust the input slack variables, taking into account external environmental factors (such as population density and Gross Domestic Product [GDP] per capita) as well as random errors. This adjustment allows for a more accurate estimation of efficiency values. The third stage recalculates the efficiency scores using the adjusted inputs, reflecting true managerial efficiency rather than the effects of external factors. After adjusting for external circumstances and random disturbances, the combined efficiencies of the Southwest and Northwest regions changed, providing a more reliable measure of the efficiency of healthcare resource allocation.

The comprehensive technical efficiency value from the three-stage DEA analysis lies between (0, 1], which was restricted data, and Tobit regression was applied [14]. To further explore the factors affecting the efficiency of health resource allocation in the western region, this study employed Tobit regression analysis to identify and assess the extent of their impact.

Selection indicators

Selection of three-stage DEA indicators

To ensure a sound assessment, the selection of appropriate input–output indicators is crucial. Input indicators should include all necessary resources, while output indicators need to describe the management objectives of the decision-making unit (DMU) [15]. This study was mainly based on the relevant theories and established research on the evaluation of the efficiency of medical resource allocation, and combined the actual situation of medical services in the western region to determine the three human resource, financial, and material aspects. The selection and analysis of each indicator are shown in Table 1.

Input indicator selection and rationale Input indicators mainly measured the input of medical resources. Based on the existing studies by Xu Xiaofang [16], Sun Jiaying [17], and other scholars, and taking into account the principles of importance and availability of data, we selected the number of medical institutions, the number of health technicians, and the number of beds as input

Table 1 Key indicators for assessing health resource distribution efficiency in Western China

Indicator Type		Indicator name	Unit
Input indicators	X_1	Number of medical and health institutions	ten thousand
	X_2	Number of beds in health facilities	lit. ten thousand sheets
	X_3	Number of medical and health personnel	all the people
Output indicators	Y_1	Annual number of consultations in health-care institutions	ten thousand people
	Y_2	Annual discharges	ten thousand people
	Y_3	Hospital bed occupancy rate	%
environment variable	E_1	population density	Persons per square kilometer
	E_2	GDP per capita	CNY

indicators. The number of medical institutions represented the basic supply capacity of health resources in the region and could measure the overall allocation level of medical resources. The number of health technicians was a key factor in measuring the capacity of medical service provision, which directly affected the utilization efficiency of medical resources. The number of beds, as an important resource of medical institutions, affected the service capacity and efficiency of hospitals. These variables have been widely used in several healthcare efficiency studies and have been shown to have a significant impact on healthcare service efficiency [3, 5, 7, 12].

Selection and basis of output indicators Output indicators mainly measured the utilization of medical resources and service output. Combined with the mainstream methods of medical efficiency evaluation [18, 19], this study selected outpatient visits, hospitalization visits, and surgical cases as output indicators. Outpatient visits reflected the medical service capacity of hospitals and were usually used to measure the utilization efficiency of medical institutions. The number of inpatient visits, as the main indicator of inpatient medical services, could measure the utilization of inpatient resources. The number of surgical cases represented the output level of hospitals in surgical medical services and was an important indicator of medical efficiency. These variables have been applied in relevant studies of medical resource allocation efficiency at home and abroad and could reflect the service capacity and resource utilization of medical institutions in a more comprehensive way [13, 15, 17, 19].

Selection of indicators of environmental variables and their basis Following the principle of "separation assumption" and taking into account the development characteristics of each province, "GDP per capita" and "population density" were selected as environmental variables to reflect the level of provincial economic development and people's living conditions [20].

Reasonableness test for the selection of input–output indicators In order to further validate the rationality of variable selection, we referred to the way of data categorization in the China Health Statistical Yearbook and combined the evaluation standards of health resource allocation in existing studies to ensure that the selected input and output indicators could objectively and comprehensively measure the efficiency of medical resource allocation in the western region. In addition, we conducted a Pearson correlation analysis of the variables to ensure the logical consistency between the variables. As shown in Fig. 1, the results of the analysis indicated that the correlation coefficients of the input–output indicators were ≥ 0.702, and all of them were strongly positively correlated at the 1% significance level, which indicated that the selected input–output indicators had good rationality and representativeness in measuring the efficiency of healthcare resource allocation, which met the requirements of the DEA model [21].

Tobit regression analysis indicators

Based on previous studies and data availability [22–24], this study selected three indicators, namely, per capita disposable income, government health expenditure as a proportion of total health costs, and medical service price index, from three aspects, namely, residents' living standards, the degree of government health service investment, and changes in the level of medical service prices, to conduct Tobit regression analysis.

Statistical methods

The panel data of health resources in 10 provinces in 2021 were statistically analyzed using Excel 2010. The DEA-BCC (Banker, Charnes, and Cooper) model data of the first stage and the third stage were computed and analyzed by the software DEAP 2.1, and the SFA regression results of the second stage were computed using the Frontier 4.1 software [17]. Tobit regression analyses were performed by the SPSS software.

Analysis of empirical results

First-stage DEA health resource allocation efficiency analysis

From the results of the first-stage DEA analysis, the traditional DEA model measured the comprehensive

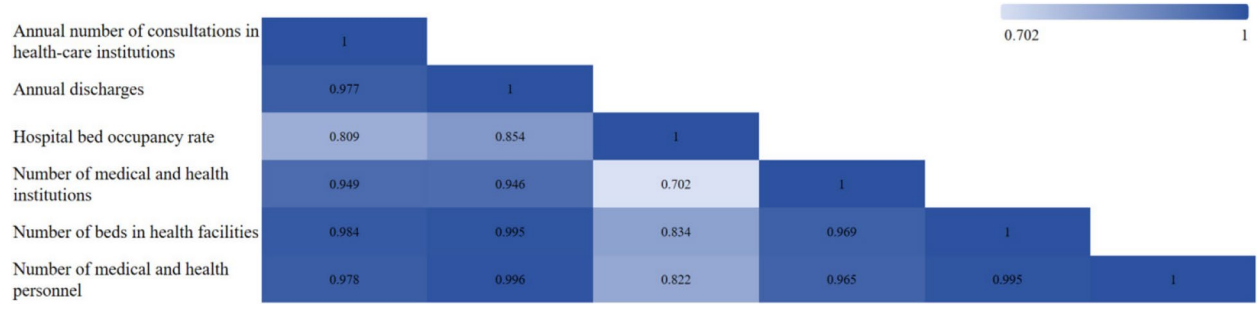

Fig. 1 Heat map of correlation coefficients of input–output indicators

Table 2 Comparison of health resource allocation efficiency in the western region before and after adjusting environmental variables in the SFA model

Serial number	Province	Pre-adjustment				Adjusted			
		crste	vrste	Scale efficiency	Scale gains	crste	vrste	Scale efficiency	Scale gains
1	Chongqing	1	1	1	-	1	1	1	-
2	Sichuan	1	1	1	-	0.997	1	0.997	drs
3	Guizhou	1	1	1	-	1	1	1	-
4	Yunnan	1	1	1	-	1	1	1	-
5	Tibet	1	1	1	-	1	1	1	-
6	Shaanxi	0.951	0.952	1	-	0.942	0.943	0.999	irs
7	Gansu	0.88	0.882	0.998	irs	0.867	0.869	0.998	irs
8	Qinghai	1	1	1	-	1	1	1	-
9	Ningxia	1	1	1	-	1	1	1	-
10	Xinjiang	0.979	0.991	0.988	drs	0.988	0.992	0.996	drs
	average	0.981	0.982	0.999	-	0.979	0.980	0.999	-

irs is increasing returns to scale; drs is decreasing returns to scale; - is constant returns to scale

Table 3 Results of second-stage SFA analysis

variant	Number of medical and health institutions	Number of beds in health facilities	Number of medical and health personnel
constant term (math.)	−2066.3026	8813.1466	−24327.134
population density	−1.4343536	−1.9274238	−6.4422969
GDP per capita	0.029934263	−0.16596217	0.30764592
σ^2	54086827	162191990	820737260
γ	1.000	1.000	1.000
log-likelihood function value	−94.120	−99.932	−108.457
LR one-sided test	8.916	8.274	7.439

efficiency of China's western region as 0.981, pure technical efficiency as 0.982, and scale efficiency as 0.999. However, the comprehensive efficiency of Shaanxi (0.951), Gansu (0.88), and Xinjiang (0.979) were below 1, indicating inefficiencies in their healthcare resource allocation. The scale reward in Gansu was increasing, while in Xinjiang, it was decreasing, and the scale reward of the remaining eight provinces remained unchanged. The details are shown in Table 2.

Second-stage SFA regression analysis

SFA regression analysis model was introduced in the second stage to regress the slack variables of the input indicators in the first stage. The results showed that all three input slack variables pass the LR likelihood ratio judgment test at a 1% significance level, indicating that it is reasonable to use the SFA regression test and strip the environmental variables. The γ value of the three input variables was 1, indicating that it was more reasonable to choose population density and GDP per capita as the environmental variables and that inefficiency was mainly caused by managerial inefficiency, and the random error has less impact on it [25], and the details were shown in Table 3.

(1) The regression coefficients for population density were consistently negative and statistically significant at the 1% level. It indicated that with the decrease of population density, the input redundancy of medical and health institutions, beds, and medical and health personnel showed an increasing trend, and the utilization efficiency of health resources decreased accordingly. On behalf of China's western region, the lower the population density, the more redundant the inputs of medical and health institutions, health institution beds, and medical and health personnel, the lower the efficiency of health resource utilization, in which the redundancy of the number of personnel increased more significantly, indicating that there might be a problem of over-allocation of resources in sparsely populated areas.

(2) The regression coefficients of GDP per capita on the number of health care institutions slack variable and the number of health care personnel slack variable passed the 1% significance test and were positive, indicating that the high level of provincial economic development instead resulted in the redundancy of inputs for health care institutions and health care personnel.

Third-stage DEA health resource allocation efficiency analysis

Comparative analysis of the efficiency of health resource allocation in the western region

The efficiency of health resource allocation in the western region in 2021 was assessed using SFA regression, which accounted for environmental factors and random disturbances (refer to Table 1). After incorporating these external influences, the average comprehensive technical efficiency, pure technical efficiency, and scale efficiency in the western region were found to be 0.979, 0.980, and 0.999, respectively. This represented a decline in both comprehensive and pure technical efficiency compared to the results from the first stage.

(1) The combined technical efficiency before adjustment was 0.981, and after adjustment, it dropped to 0.979. This suggested that the overall technical efficiency in the western region decreased once the influence of environmental factors and random disturbances was removed. It meant that after controlling for other factors, the efficiency of healthcare resource allocation in the western region was overestimated, and there might be some efficiency losses that had not been taken into account.
(2) The pure technical efficiency before adjustment was 0.982, and after adjustment, it dropped to 0.980. The modest decline in pure technical efficiency suggested that when environmental factors and random disturbances were excluded, the role of management and technical capabilities in determining the efficiency of health resource allocation in the western region was diminished. This reflected some shortcomings in management and technical efficiency that required further improvement.
(3) Scale efficiency, both before and after the adjustment, remained at 0.999, which was very close to 1. This suggested that the allocation of health resources in the western region was nearly optimal in terms of scale. It further indicated that scale-related inefficiencies were not significant, and that the scale factor was not a major determinant affecting the overall efficiency of resource allocation.

Analysis of the efficiency of health resource allocation in Southwest and Northwest China

The integrated efficiency of the Southwest and Northwest areas both changed after adjusting for the effects of the external environment and random disturbances. The Southwest area's combined and scale efficiencies both decreased slightly after the adjustment, but remained very close to 1, indicating that the adjustment did not have much of an impact on the Southwest area and that the efficiency of resource and scale use remained high. Pure technical efficiency remained unchanged, indicating no improvement or regression in the use of technology. In the Northwest, both combined and pure technical efficiencies declined after the adjustment, yet scale efficiency remained very high, close to 1, indicating that the adjustment of the scale of production had a relatively small impact on the Northwest, and the details are shown in Table 4.

Comprehensive efficiency analysis of health resource allocation by province

Following adjustments for environmental factors and random disturbances, the overall efficiency of health resource allocation shifted in certain provinces (refer to Table 2). The comprehensive efficiency of 6 provinces, including Chongqing, Guizhou, Yunnan, Tibet, Qinghai, and Ningxia, remained at 1, indicating that their resource allocation and technical management levels were in a better state. The comprehensive efficiency of 3 provinces, including Sichuan, Shaanxi, and Gansu declined. Xinjiang's comprehensive efficiency improved, and the details are shown in Fig. 2.

Distribution of remuneration status of health resource allocation scale by province

There was only one province with increasing and decreasing returns to scale in the first stage, both accounting for 10% and eight provinces with constant returns to scale, accounting for 80%. After an increase in the external environment and random interference, the proportion of provinces with increasing and decreasing returns to scale in the first stage increased, as shown in Table 5 below.

Empirical analysis of impact factors—Tobit regression

In this study, the Tobit regression model was used to analyze the influencing factors of healthcare resource allocation efficiency. To verify the reasonableness of the application of the Tobit model, a likelihood ratio test was conducted. The test results showed that the likelihood ratio statistic was 17.4, df = 3, $P < 0.001$, and this result rejected the original hypothesis at a 1% significance level, indicating that the Tobit model has a significant

Table 4 Efficiency of health resource allocation in Southwest and Northwest areas

Area	Pre-adjustment				Adjusted			
	crste	vrste	Scale efficiency	Scale gains	crste	vrste	Scale efficiency	Scale gains
Southwest China	1	1	1	-	0.9994	1	0.9994	-
Northwest China	0.962	0.965	0.9972	-	0.9594	0.9608	0.9986	-

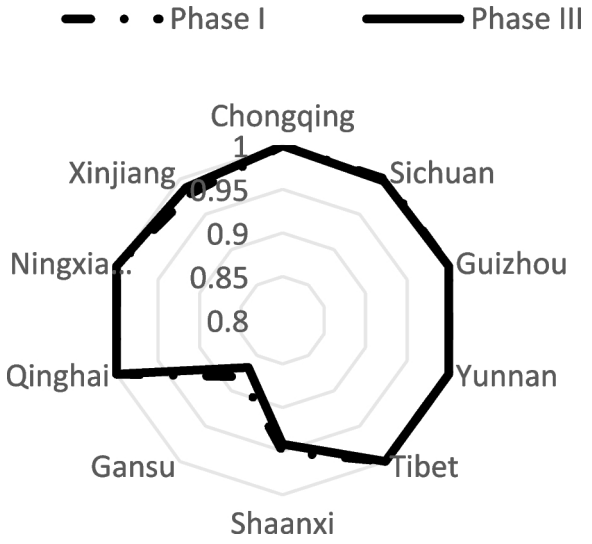

Fig. 2 Comparison of comprehensive efficiency before and after adjustment in the western areas of China

advantage over the linear regression model. Tobit regression analysis revealed that factors such as per capita disposable income, the proportion of government health expenditure relative to total health costs, and the medical service price index significantly influence the efficiency of health resource allocation in the Western region (see Table 6 below).

(1) Per capita disposable income was positively correlated with the comprehensive efficiency of health resource allocation. This indicated that as income levels rise, residents' demand for health services and their ability to pay for them increase, thus promoting the effective allocation and utilization of health resources. At the same time, high-income levels were usually accompanied by better health awareness, higher quality of life, and a preference for high-quality medical services, which prompted medical institutions to improve the quality of their services, thereby increasing the efficiency of resource allocation.

(2) There was a positive correlation between the ratio of government health expenditure to total health costs and the overall efficiency of health resource allocation. It showed that government financial investment in health had a positive effect on enhancing the quality and efficiency of medical services and improving resource allocation. With the increase in government health expenditure, medical institutions were able to obtain more funds for upgrading service quality, improving facilities, and increasing human resources, thus improving the comprehensive efficiency of health resource utilization. Emphasizing the critical importance of the Government in promoting efficiency and equity in the health system, it also suggested that policymakers, while increasing health expenditure, needed to consider how best to allocate and utilize these resources to achieve optimal public health benefits.

(3) The medical service price index was positively correlated with the overall efficiency of health resource allocation. The price of medical services reflected the value of medical services, the value of the technical labor of medical personnel, and the quality of medical services. The increase in medical service prices was of great significance to the optimization of the income structure of medical institutions, and had a strong incentive effect on the optimization of resource allocation and improvement of service quality of medical institutions, thus enhancing the efficiency of health resource allocation. In addition, the government could also support the innovative development of medical services and promote the progress of medical technology through the price adjustment of

Table 5 Distribution of remuneration status of health resource allocation scale by province

Return to scale status	Pre-adjustment size status		Adjusted size status	
	Quantities	Percentage	Quantities	Percentage
Increasing returns to scale	1	10%	2	20%
Constant returns to scale	8	80%	6	60%
Diminishing returns to scale	1	10%	2	20%

Table 6 Results of Tobit regression analysis of factors affecting comprehensive efficiency

Term (in a mathematical formula)	Ratio	*t*	*P*	Coefficient 95% confidence interval	
				limit	lower limit
A constant (math.)	−11.629	−3.007	0.003***	−4.049	−19.209
Per capita disposable income	0.418	6.366	0.000***	0.547	0.29
Government health expenditure as a proportion of total health costs	0.022	5.287	0.000***	0.03	0.014
Price index for medical services	0.107	2.891	0.004***	0.179	0.034

medical services, which also helped to control the unreasonable growth of medical costs. The reform of medical service prices was a complex systematic project, which related not only to the quality and efficiency of medical services but also to the fairness and sustainability of the medical security system. Through scientific and reasonable price adjustment, it could promote the healthy development of the medical service industry and improve the health of the people.

Discussion

Overestimation of health resource allocation efficiency

This study analyzed the three-stage DEA model and found that the comprehensive and pure technical efficiency of health resource allocation in the western region of China declined after removing environmental factors and random errors, which suggested that the previous assessment that did not take environmental factors into account might have overestimated the actual efficiency of health resource allocation in the western region [26]. This result further highlighted the importance of environmental factors in assessing the efficiency of health resource allocation. Therefore, it was recommended that the three-stage DEA model be widely used in future efficiency assessments to more accurately reflect the true level of resource allocation.

After adjusting for the external environment and stochastic disturbances, the state of the returns to scale in health resource allocation changed in the western provinces. Some provinces changed from constant returns to scale to increasing or decreasing returns to scale. In 2022, six provinces, including Chongqing, Guizhou, Yunnan, Tibet, Qinghai, and Ningxia, had high comprehensive efficiency and optimal scale efficiency, suggesting that their resource allocation and technical management levels were in a better state. In contrast, Shaanxi, Gansu, Xinjiang, and other provinces should focus on strengthening the management level of health resources and technological innovation capacity, optimizing the structure of resource allocation, reducing resource waste, and improving service efficiency. For provinces with increasing returns to scale, such as Shaanxi and Gansu, they could appropriately increase inputs and expand the scale of services according to the actual situation of development; while for provinces with decreasing returns to scale, such as Sichuan and Xinjiang, they should focus on optimizing the existing resources, improving the efficiency of resource utilization, and avoiding the waste of resources. To sum up, the resource allocation strategy should be flexibly adjusted according to the actual situation, to realize the optimal allocation and efficient use of resources and promote the sustainable and healthy development of health undertakings in the western region [27].

Significant impact of external environmental factors on resource allocation efficiency

The results of the second-stage SFA regression showed that external environmental variables such as population density and GDP per capita had a significant impact on the efficiency of health resource allocation in the western region. The lower the population density, the more redundant the inputs of health institutions and personnel, which might be attributed to the uneven distribution and inefficient utilization of health resources in sparsely populated provinces [28]. Provinces with high per capita GDP might also lead to redundancy in resource allocation despite better economic development, which might be related to the high demand and high-quality requirements for healthcare services of residents in high-income provinces. Therefore, the government should rationally plan and adjust the allocation of health resources according to provincial population distribution and economic development, avoid excessive concentration and waste of resources, and improve the efficiency of resource utilization [29]. Additionally, the government should enhance its support and guidance for primary healthcare institutions, facilitate the distribution of high-quality medical resources to grassroots levels, strengthen the capacity and quality of primary healthcare services, and reduce the disparities between urban and rural areas, as well as across different provinces [30].

Analysis of key factors affecting health resource allocation efficiency

The Tobit regression analysis revealed that factors such as per capita disposable income, the share of government health spending relative to total healthcare costs, and the medical service price index significantly influenced the efficiency of health resource allocation in the Western region. With the improvement of residents' living standards, residents' demand for health services and ability to pay increased, which promoted the effective allocation and utilization of health resources. The increase in government health expenditure had a positive effect on improving the quality and efficiency of medical services [31]. The Government should increase its investment in the healthcare sector, in particular strengthening its support for primary healthcare organizations and rural areas, to improve the accessibility and equity of healthcare services. At the same time, the government should focus on improving the efficiency and effectiveness of the use of funds, and strengthen the supervision and evaluation of healthcare programs to ensure the effective use of funds [32]. Increasing the price of medical services could provide incentives for medical institutions to optimize

resource allocation and improve service quality. As the price of medical services rose, hospitals were able to generate more revenue, which could be used to upgrade and improve medical equipment, facilities, and technology, thereby improving service quality [33]. It should be noted, however, that higher prices for medical services might also trigger overmedication and waste of resources, and there was a need to balance the positive and possible negative effects of price increases [34]. However, the reform of medical pricing was a complex and systematic undertaking that demanded collaborative efforts from the government, healthcare institutions, and all sectors of society. The government should strengthen its supervision and regulation of medical service prices to ensure that they are reasonable and fair. At the same time, medical institutions should strengthen their own management, improve service quality, and reduce operating costs to meet the challenges and opportunities brought about by the price reform [35]. Consequently, the government should continue to increase financial investments in the healthcare sector, refine the expenditure structure, and enhance fund utilization efficiency. Additionally, medical service prices should be adjusted reasonably to reflect the value of healthcare workers' labor and service quality, thereby encouraging medical institutions to optimize resource allocation and improve service levels [36].

Analysis of area differences in health resource allocation efficiency

This study found that there were differences in health resource allocation efficiency between the Southwest and Northwest areas. The Southwest area's comprehensive and scale efficiencies declined slightly after adjustment, but remained close to the optimal level, indicating that its resource allocation and scale utilization were already relatively mature. On the other hand, the Northwest area saw a decline in comprehensive efficiency and pure technical efficiency after adjustment, but scale efficiency was still high, indicating that its production scale was already close to the optimal level, but there was still room for improvement in management and technical level. Therefore, health resource allocation strategies should be tailored to the characteristics of different areas. The Southwest area can continue to maintain and optimize the existing resource allocation model while strengthening technological innovation and management level improvement. The Northwest area should focus on strengthening management and technological innovation to improve the efficiency of resource allocation and service level, and at the same time reasonably adjust the scale of production to avoid waste of resources. In addition, cooperation and exchanges should be strengthened among the provinces in the western region to form a mechanism for the synergistic development of provincial health [37]. Through cross-provincial cooperation and resource sharing, complementary advantages and common development can be realized [38]. In particular, the radiation-driven role of Chongqing and other provinces should be brought into play to promote the development of medical and health care in the surrounding provinces.

Limitations of the study

This study examined the efficiency of health resource allocation and its influencing factors in the western region of China based on a three-stage DEA model and Tobit regression analysis. Although the study provides valuable insights, there are still limitations in the following areas:

Limitations in the selection of external environmental factors

Although the Tobit regression analysis considered a variety of external environmental factors (e.g., per capita disposable income, percentage of government health expenditure, and price index of medical services), there are still some potential influencing factors that could not be included in the study, such as the mobility of health care resources and the variability of climate. Future studies could further expand the scope of influencing factors and consider the role of more variables on health resource allocation efficiency.

Complexity of regional differences

Studies have shown that there are obvious differences in the allocation efficiency of health resources in the western regions of China, especially in the southwestern and northwestern areas. However, the complexity and diversity between areas means that a single analytical approach may be difficult to fully reveal all levels of the problem. Factors such as cultural background and the age structure of the population in different areas may affect the efficiency of health resource allocation, and future studies may combine qualitative analytical methods to further delve into the reasons behind these differences.

Applicability of policy recommendations

The optimization recommendations made in this study are based on the current policy context and data situation, but with changes in national policies and further economic and social development, certain recommendations may be affected by different policy environments. With the continuous adjustment of national policy support and resource allocation in the Western region, future studies need to assess the long-term impact of policy changes on the efficiency of health resource allocation.

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Authors' contributions
Dongxue Zhao: Conceptualization, methodology, formal analysis, writing – original draft, writing – review and editing, supervision. Shuanghang Li: Data curation, methodology, formal analysis, writing – review and editing. Hua Huang: Investigation, resources, writing – review and editing. Yu Zhang: Visualization, writing – review and editing, project administration.

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Data availability
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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