ISSN 2616-5902 Vol. 7, Issue 8: 25-31, DOI: 10.25236/AJBM.2025.070804

Analysis on the Resource Allocation Efficiency of Rural Medical in Hubei Province Based on DEA Model

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Abstract: *This paper examines the allocation situation and efficiency of such resources from 2010 to 2023, aiming to explore the rationality of the allocation of rural medical resources in Hubei Province, and provide references for improving the allocation efficiency of rural medical resources. Based on the data from the China Health Statistics Yearbook from 2011 to 2022 and the statistical data released by the Health Commission of Hubei Province from 2022 to 2023, the year - on - year growth rate and the average annual growth rate were used to describe the general situation of rural medical resources and medical services in Hubei Province from 2010 to 2023. The BCC model of the Data Envelopment Analysis (DEA) method was adopted for a static analysis of the allocation efficiency of rural medical resources in Hubei Province from 2010 to 2023, and the Malmquist index was applied for a dynamic analysis of the data during the same period. The total amount of resources in rural health centers in Hubei Province showed an upward trend, but the problem of insufficient scale efficiency was prominent. The scale efficiency reached its lowest point in 2020, with only 0.942. Technological progress was the main reason for the improvement of the allocation efficiency of rural medical resources in Hubei, while scale efficiency was the main factor restricting the growth of such efficiency. While increasing the input of resources for rural health centers, the government should also actively explore a development scale suitable for the local area, optimize the scale allocation, strengthen technological innovation and talent cultivation, and improve the organizational management system. Multiple measures should be taken to enhance the allocation of rural medical resources in Hubei Province.*

Keywords: *Rural Medical Resources; DEA Model; Efficiency*

1. Introduction

The allocation of medical resources is a core issue in the development of the health sector, and focusing on the primary level is the top priority of the health work policy in the new era. Rural health centers are at the fundamental position of the primary medical and health service system and serve as the key link connecting county - level medical and health institutions with village clinics[1]. They provide basic medical security for the majority of rural residents, and the efficiency of their resource allocation directly affects the health level of rural residents and the accessibility of medical services. As an important province in central China, the allocation status of rural medical and health resources in Hubei Province is representative to a certain extent. In recent years, with the rapid economic and social development and changes in the population structure of Hubei Province, the demand for medical and health services among rural residents has been increasing, which puts forward higher requirements for the service capacity and efficiency of rural health centers.

2. Materials and Methods

2.1 Data Sources

The research data are the statistical data on the input and output of health services of rural health centers in Hubei Province from 2010 to 2023. The data are sourced from the China Health Statistics Yearbook and the official website of the Health Commission of Hubei Province, mainly including the number of rural health centers, the number of rural health technical personnel, the number of beds in rural health centers, the number of patient visits, the bed utilization rate, and the average length of stay.

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2.2 Indicator Selection

The key to evaluating the efficiency of medical resource allocation lies in the reasonable selection of input and output indicators. The selection of input and output indicators should meet three conditions: disposability, negative input and positive output, and dimension irrelevance[2]. By reviewing and drawing on relevant existing research literatures[3], it is found that the input - output indicator system for measuring the allocation of medical resources in China is relatively mature. Combined with the actual situation of this study, 3 input indicators and 3 output indicators are selected respectively.

2.2.1 Input Indicators

Number of health centers (unit: piece): It reflects the scale of infrastructure for rural medical and health services and represents the number of basic units providing medical services.

Number of health technical personnel (unit: person): It represents the input of human resources, which is a key factor in providing medical services. The quantity and quality of these personnel directly affect the quality and efficiency of services.

Number of beds in health centers (unit: bed): It reflects the scale of hardware facilities in rural health centers and is related to the number of inpatients that can be accommodated.

2.2.2 Output Indicators

Number of patient visits (unit: person - time): It measures the total number of outpatient services in rural health centers and is an important reflection of service output.

Average length of stay (unit: day): It reflects the efficiency of medical services. A shorter average length of stay usually indicates more sufficient utilization of medical resources and a higher level of management.

Bed utilization rate (unit: %): It reflects the utilization degree of bed resources. A higher bed utilization rate indicates a higher efficiency of resource utilization, but an excessively high rate may lead to problems such as excessive pressure on medical services.

2.3 Research Methods

2.3.1 Descriptive Statistical Method

The year - on - year growth rate and average annual growth rate are used to describe the general situation of rural medical and health resources and medical services in Hubei Province from 2010 to 2023.

2.3.2 DEA - BCC Model

The BCC model is used to measure and analyze the efficiency level in the same period (static state), and decomposes technical efficiency (i.e., comprehensive efficiency) into pure technical efficiency and scale efficiency[4]. When both the pure technical efficiency value and the scale efficiency value are 1, it indicates that the unit is DEA - effective; when only one of the pure technical efficiency or scale efficiency is 1, it indicates that the unit is DEA - weakly effective; when both are less than 1, it indicates that the unit is DEA - ineffective. In this paper, the DEA - BCC model is used for the static analysis of the allocation efficiency of rural medical and health resources in Hubei Province from 2010 to 2023.

2.3.3 Malmquist Index Method

It mainly reflects the dynamic changes in the productivity of decision - making units in different periods, specifically reflected by total factor productivity. The total factor productivity change index (TFP) is decomposed into the technical efficiency change index (EC) and the technical level change index (TC). Among them, the technical efficiency change index is composed of the pure technical efficiency change index (PEC) and the scale efficiency change index (SEC)[5]. When TFP > 1, it indicates that the total factor productivity has improved compared with the previous period; when TFP = 1, it indicates that the total factor productivity remains unchanged; when TFP < 1, it indicates that the total factor productivity has decreased. In this paper, the Malmquist index method is used for the dynamic analysis of the allocation efficiency of rural medical and health resources in Hubei Province from 2010 to 2023.

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3. Results

3.1 Basic Situation of Input and Output of Rural Medical and Health Resources in Hubei Province from 2010 to 2023

3.1.1 Input Situation

From 2010 to 2023, the input of rural medical and health resources in Hubei Province generally showed an increasing trend. Among them, the number of health technical personnel increased from 56,898 to 74,660, with a year - on - year growth rate of 31.22% and an average annual growth rate of 2.11%; the number of beds increased from 46,382 to 93,683, with a year - on - year growth rate of 101.98% and an average annual growth rate of 5.56%; however, the number of health center institutions showed a slow downward trend, decreasing from 1,149 to 1,107, with a year - on - year growth rate of - 3.66% and an average annual growth rate of - 0.29%. See Table 1 and Figure 1.

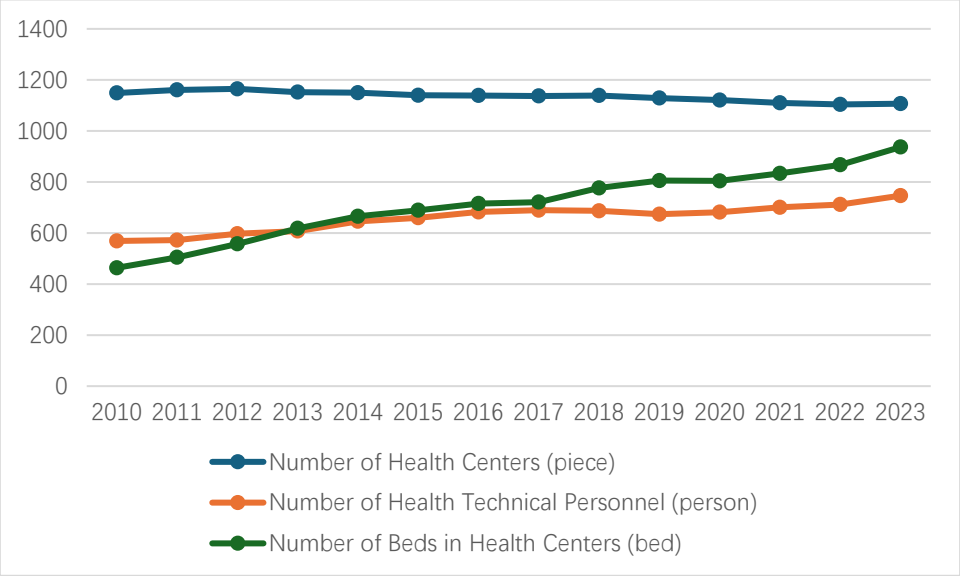

Figure 1: Input of Rural Medical and Health Resources in Hubei Province from 2010 to 2023

Table 1: Input and Output of Rural Medical and Health Resources in Hubei Province from 2010 to 2023

Time	Number of Health Centers (piece)	Number of Health Technical Personnel (person)	Number of Beds in Health Centers (bed)	Number of Patient Visits (person - time)	Bed Utilization Rate (%)	Average Length of Stay (day)
2010	1149	56898	46382	41919374	69.1	6.5
2011	1161	57207	50467	46420616	68.5	6.7
2012	1165	59719	55753	55769174	74.9	6.7
2013	1152	60761	61845	56149388	75.7	7
2014	1150	64583	66557	59075221	73.7	7.2
2015	1140	65980	68933	59141649	73.6	7.1
2016	1139	68270	71546	57558456	76.7	7
2017	1137	68946	72127	56112471	81.1	6.9
2018	1139	68705	77677	54379337	76.5	6.9
2019	1129	67382	80549	55507918	72.9	6.8
2020	1121	68176	80429	48829760	61.3	6.6
2021	1110	70085	83365	51148596	59.8	6.9
2022	1104	71190	86741	53410738	59.65	6.8
2023	1107	74660	93683	54630973	66.08	6.6
Year-on-year Growth Rate	-3.66%	31.22%	101.98%	30.32%	-4.37%	1.54%
Average Annual Growth Rate	-0.29%	2.11%	5.56%	2.06%	-0.34%	0.12%

3.1.2 Output Situation

From 2010 to 2023, the output of rural medical and health resources in Hubei Province generally showed an increasing trend. Among them, the number of patient visits increased from 41,919,374 to 54,630,973, with a year - on - year growth rate of 30.32% and an average annual growth rate of 2.06%;

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the average length of stay fluctuated and increased from 6.5 days to 6.6 days, with a year - on - year growth rate of 1.54% and an average annual growth rate of 0.12%; however, the bed utilization rate showed a slow downward trend, fluctuating and decreasing from 69.1% to 66.08%, with a year - on - year growth rate of - 4.37% and an average annual growth rate of - 0.34%. See Table 1 and Figure 2.

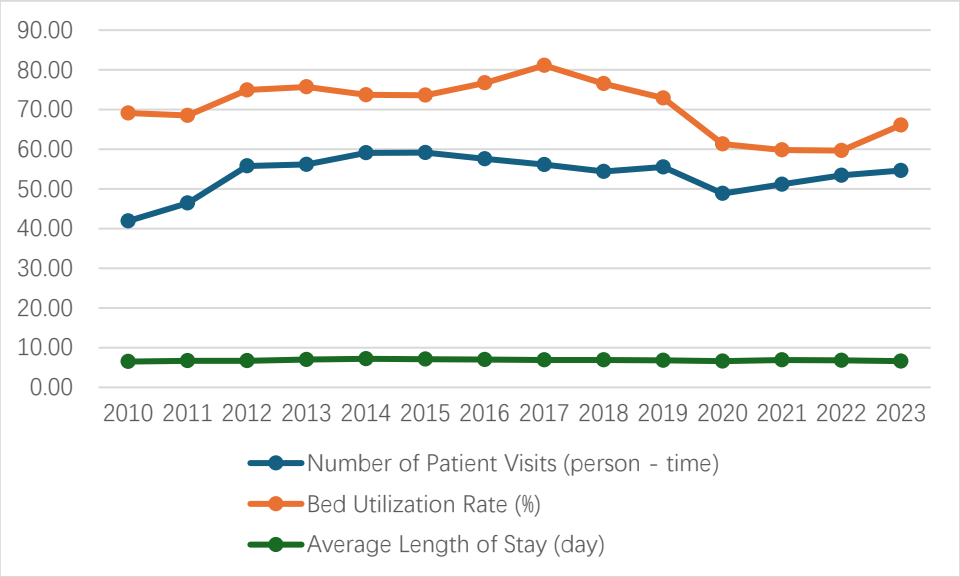

Figure 2: Output of Rural Medical and Health Resources in Hubei Province from 2010 to 2023

3.2 DEA Result Analysis of Allocation Efficiency of Rural Medical and Health Resources in Hubei Province from 2010 to 2023

It can be seen from Table 2 that DEA relative efficiency was achieved in 2010 - 2015 and 2017, while the other years were DEA - ineffective with increasing returns to scale. The years 2019 and 2021 - 2023 were weakly effective, and both technical efficiency and scale efficiency were less than 1, indicating that the existing technical level has not yet reached the optimal state. The increasing returns to scale indicate that the current region needs to reasonably expand the production scale and increase the input ratio of various factors to achieve a more reasonable output.

Table 2: Input - Output Efficiency of Rural Medical and Health Resources in Hubei Province from 2010 to 2023

Time	Technical Efficiency	Pure Technical Efficiency	Scale Efficiency	Analysis of Returns to Scale	DEA Effectiveness
2010	1.000	1.000	1.000	Constant	Effective
2011	1.000	1.000	1.000	Constant	Effective
2012	1.000	1.000	1.000	Constant	Effective
2013	1.000	1.000	1.000	Constant	Effective
2014	1.000	1.000	1.000	Constant	Effective
2015	1.000	1.000	1.000	Constant	Effective
2016	0.997	0.999	0.999	Increasing	Ineffective
2017	1.000	1.000	1.000	Constant	Effective
2018	0.985	0.995	0.990	Increasing	Ineffective
2019	0.972	1.000	0.972	Increasing	Weakly Effective
2020	0.940	0.994	0.946	Increasing	Ineffective
2021	0.993	1.000	0.993	Increasing	Weakly Effective
2022	0.984	1.000	0.984	Increasing	Weakly Effective
2023	0.955	1.000	0.955	Increasing	Weakly Effective
Average Value	0.988	0.999	0.988		

Overall, from 2010 to 2023, the allocation efficiency of rural health resources in Hubei Province was relatively high, reaching 0.988, which means that 98.8% of the invested medical and health resources were effectively used, and the remaining 1.2% of the resources were wasted and did not contribute to the output. On the whole, the order is pure technical efficiency > scale efficiency > technical efficiency, indicating that the overall allocation efficiency of medical and health resources still needs to be optimized. By decomposing each part of the comprehensive efficiency, it is found that the pure technical efficiency and scale efficiency are relatively high, at 0.999 and 0.988 respectively, but the important factor that reduces the comprehensive efficiency level is still the scale efficiency.

ISSN 2616-5902 Vol. 7, Issue 8: 25-31, DOI: 10.25236/AJBM.2025.070804

Technical efficiency and pure technical efficiency respectively reflect the comprehensive level, management level and service capacity of medical and health resource allocation. Among them, the technical efficiency in 2016 and 2018 - 2023 did not reach 1, indicating that in these years, the optimal output level was not achieved under the given input. In the above 7 years, except for 2018 and 2020, the pure technical efficiency was lower than the average value, which indicates that the reason affecting these years is the relatively low management level of medical and health resources. Scale efficiency is the key factor affecting the allocation efficiency of medical and health resources, which reflects the gap between the actual scale and the optimal production scale. Since 2018, the scale efficiency has gradually decreased, and in 2023, it has been far lower than the average value, indicating that the government of Hubei Province should increase the scale investment to reduce the gap with the optimal production scale.

3.3 Dynamic Analysis of Malmquist Index in Hubei Province from 2010 to 2023

The DEA - Malmquist index analysis method was used for the dynamic analysis of the allocation efficiency of medical resources in rural health centers in Hubei Province, and the main factors affecting the allocation efficiency of medical resources in rural health centers in Hubei were further analyzed through index decomposition. As shown in Table 3, the average value of total factor productivity of health resource allocation from 2010 to 2023 was 0.983, and the proportion of years with total factor productivity less than the average value was 46.00%, which to a certain extent indicates that the overall efficiency of health resource allocation showed a downward trend during this period. The total factor productivity index was less than 1 from 2012 to 2016 and 2017 to 2023, indicating that during these periods, the total factor productivity of rural medical resources in Hubei Province showed a downward trend. The total factor productivity index was greater than 1 from 2010 to 2012 and 2016 to 2017, indicating that compared with 2010, the total factor productivity of rural medical resources in Hubei Province increased in 2012, and compared with 2016, it increased in 2017. From the perspective of the decomposed Malmquist index, the technological progress index is the same as the total factor productivity index, and the technical efficiency change index was 1 from 2010 to 2023, indicating that the technical efficiency of rural medical resources in Hubei Province remained stable during this period. The change in total factor productivity was mainly due to the change in the technical level, which suggests that the key to improving total factor productivity is to improve the technical level.

Table 3: Malmquist Index and Its Decomposition of Allocation Efficiency of Rural Medical Resources in Hubei Province from 2010 to 2023

Time	EC	TC	PEC	SEC	TFP
2010-2011	1.000	1.002	1.000	1.000	1.002
2011-2012	1.000	1.041	1.000	1.000	1.041
2012-2013	1.000	0.979	1.000	1.000	0.979
2013-2014	1.000	0.976	1.000	1.000	0.976
2014-2015	1.000	0.981	1.000	1.000	0.981
2015-2016	1.000	0.989	1.000	1.000	0.989
2016-2017	1.000	1.011	1.000	1.000	1.011
2017-2018	1.000	0.938	1.000	1.000	0.938
2018-2019	1.000	0.978	1.000	1.000	0.978
2019-2020	1.000	0.901	1.000	1.000	0.901
2020-2021	1.000	0.998	1.000	1.000	0.998
2021-2022	1.000	0.997	1.000	1.000	0.997
2022-2023	1.000	0.996	1.000	1.000	0.996
Average Value	1.000	0.983	1.000	1.000	0.983

4. Discussion and Suggestions

4.1 Mismatch between Resource Input and Output, and the Need to Optimize Scale Efficiency

From 2010 to 2023, the number of rural health technical personnel and beds in Hubei Province increased significantly, but the number of health centers decreased and the bed utilization rate dropped, showing a contradiction between input expansion and inefficient output. This phenomenon reflects that the resource input does not match the actual demand, and some resources are underutilized. The scale efficiency is lower than the pure technical efficiency, and the scale efficiency was as low as 0.946 in 2020, which has become a key factor restricting the overall efficiency.

Therefore, Hubei Province should accurately adjust the input based on resource utilization data. For

ISSN 2616-5902 Vol. 7, Issue 8: 25-31, DOI: 10.25236/AJBM.2025.070804

rural health centers with a high bed vacancy rate, the bed scale should be reduced through mergers, transformations, and other methods[6]; for areas with a shortage of health technical personnel, targeted human resource supplementation should be carried out to avoid the situation of "emphasizing hardware over human resources". A "population - resource" matching mechanism should be established to dynamically adjust the resource input according to the number of permanent residents in towns and townships and disease demands, so as to avoid blind expansion. At the same time, a dynamic adjustment mechanism of "input - output" should be established to regularly evaluate the rationality of the scale. For areas with increasing returns to scale, the input should be appropriately expanded, and for areas with decreasing returns to scale, redundant resources should be reduced.

4.2 Fluctuations in Technological Progress Affect the Stability of Efficiency, and There Is a Need to Strengthen Technical and Talent Support

Technological progress is the main driving force for improving the efficiency of rural medical care in Hubei Province, but the total factor productivity fluctuates and continued to decline from 2012 to 2016 and 2017 to 2023; the average annual growth rate of health technical personnel was only 2.11%, and the problem of talent shortage is prominent.

Therefore, Hubei Province should promote the technical linkage between county - level and rural medical institutions, promote appropriate technologies such as telemedicine and standardized management of chronic diseases, and establish a mechanism for experts to be dispatched to the grassroots and rural health personnel to receive further education; expand the scale of training of targeted medical students[7], improve the salary and benefits to retain talents, and at the same time introduce external technical talents to make up for the shortcomings.

4.3 The Impact of the COVID - 19 Pandemic on Allocation Efficiency, and the Need to Optimize the Organizational Management System

COVID - 19 broke out in Wuhan in December 2019, and the allocation efficiency of rural medical resources in Hubei Province decreased significantly in 2020. In the following years, it was still in the stage of increasing returns to scale. With the increase in input, due to the interference of the pandemic, the input could not be fully converted into effective medical service output, and the actual medical demand after the pandemic was not fully considered. As a result, the bed utilization rate decreased, the patient flow was imbalanced, the growth of the number of patient visits lagged behind the growth of beds, and the resources were underutilized.

Therefore, Hubei Province should guide patients to seek initial medical treatment at township health centers by implementing policies such as increasing the medical insurance reimbursement rate for primary-level medical visits and expanding the scope of outpatient overall planning[8][9], thereby improving the efficiency of resource utilization. Meanwhile, it should introduce information-based management tools: for instance, adopting electronic medical record systems to optimize diagnosis and treatment processes and shorten the average length of hospital stay; and establishing dynamic monitoring platforms to regularly evaluate the efficiency of resource utilization and promptly rectify inefficient links[10].

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