Evaluation of Health Resource Allocation Efficiency in Chinese Medicine Hospitals Based on DEA

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Abstract: Based on the 2020 China Health and Hygiene Statistical Yearbook published by the National Health and Hygiene Commission, Chinese medicine hospitals in 30 provinces (autonomous regions and municipalities directly under the central government) of China were taken as the research object, and the data envelopment analysis method was applied to analyze the health resource allocation of Chinese medicine hospitals in China in 2019. The results show that the mean values of comprehensive efficiency, pure technical efficiency and scale efficiency of health resource allocation in Chinese medicine hospitals in 30 provinces and cities in 2019 are 0.990, 0.998 and 0.992, respectively, of which 25 provinces and cities (accounting for 83.33%) have reached the DEA effective provinces and cities, 4 provinces and cities with weak DEA effective provinces and cities (accounting for 13.33%), and 1 province and city with non-DEA effective provinces and cities (accounting for 3.33%). From this, it can be introduced that the overall level of health resource allocation efficiency in Chinese medicine hospitals in China in 2019 is very high, and only a small number of provinces and cities have irrational health resource allocation, which needs to optimize the structure of inputs and outputs in order to enhance the capacity of Chinese medicine services.

1. Introduction

The "14th Five-Year Plan" period is a critical period for the high-quality development of China's health care industry. Optimising the allocation of health resources, reasonably determining the number of health care institutions, beds, and health technicians in the region, revitalising the stock, and controlling the incremental increase can effectively avoid the phenomena of wastefulness of resources, and low resource utilisation rate. Health resource allocation refers to how the government or the market can make health resources fairly and efficiently distributed in different areas, regions, sectors, projects, and populations, so as to maximise the social and economic benefits of health resources[1]. As the process of reforming the national healthcare system continues to advance, the functional positioning of Chinese medicine hospitals has been further clarified. As a unique health resource and economic resource with great potential in China, Chinese medicine plays an important role in economic and social development, and its allocation will directly affect the development of Chinese medicine[2]. In this paper, we use the factor analysis method (data reduction factor, DRF) to screen the input and output indicators of health resources, and then use the data envelopment analysis (DEA) to assess the health resource allocation efficiency of Chinese medicine hospitals in 30 provinces and municipalities in China in 2019, in order to further optimise the Chinese medicine hospital input scale and improve the health resource allocation efficiency of Chinese medicine hospitals as a reference.

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2. Information and Methodology

2.1 Sources of Data

The research data in this article are from the 2020 China Health and Health Statistics Yearbook published by the National Health and Health Commission, with data as of the end of 2019. As there are no TCM hospitals in the Tibet Autonomous Region, the study population does not include the Tibet Autonomous Region, Hong Kong Special Administrative Region, Macao Special Administrative Region and Taiwan Province. Therefore, the study population is TCM hospitals in 30 provinces (autonomous regions and municipalities directly under the central government).

2.2 Research Methods

1) Factor analysis

Factor analysis is a statistical analysis method of dimensionality reduction of data, by analysing the correlation between multiple variables, from which a small number of factors that can reflect the overall characteristics are extracted, to achieve the use of a smaller number of indicators to reflect the vast majority of the information of the original variables[3]. This method is applicable to the comprehensive evaluation of multiple indicators, in order to make the evaluation results more scientific and reasonable, this paper firstly standardises the data, and then uses the factor analysis method to screen out the main influence indicators.

2) Data envelopment analysis

Data envelopment approach is a non-parametric method, there is no distribution and scale requirements for indicators, and its use of extreme values to determine the production frontier, avoiding the use of subjective criteria to determine the efficiency, strong objectivity, especially suitable for multi-input and multi-output multi-objective decision-making unit performance evaluation[4]. Currently, the commonly used models of DEA method mainly include CCR model, BCC model and Malmquist index model[5]. In this paper, we mainly use the CCR-BCC model of data envelopment analysis, the CCR model is to calculate the integrated efficiency value under the situation of constant returns to scale, and the BCC model is to calculate the pure technical efficiency and scale efficiency value under the situation of variable returns to scale. Comprehensive efficiency is a comprehensive measure and evaluation of the decision-making unit's resource allocation capacity, resource use efficiency and other aspects of capacity, pure technical efficiency reflects the production efficiency of input factors at a certain optimal scale, and scale efficiency reflects the gap between the actual scale and the optimal production scale. Using the CCR technical efficiency inverse model, the comprehensive efficiency, pure technical efficiency and scale efficiency values of health resource allocation in Chinese medicine hospitals in 30 provinces and cities across the country in 2019, as well as the specific values of input redundancy or output insufficiency, can be calculated.

3) Statistical analysis

Excel 2021 was used for data entry and organisation, and then a database was created. IBM SPSS Statics 26.0 was used to conduct factor analysis on several indicators, from which the input and output indicators that best reflect the efficiency of health resource allocation were selected. After determining the input and output variables, data envelopment analysis was conducted with the help of DEAP 2.1 software.

2.3 Selection of Evaluation Indicators

The key to the evaluation of health resource allocation efficiency lies in the selection of appropriate input and output indicators. By reviewing the relevant literature on health resource allocation efficiency[6-8], it is found that the input indicators of healthcare resource analysis and evaluation research mainly include human, financial and material aspects, specifically TCM personnel, per capita hospitalisation cost, number of healthcare institutions and other indicators; the output indicators mainly include the number of discharges, the number of consultations, the use of hospital beds, hospital income and other healthcare service-related indicators. Using the DEA method to evaluate the comprehensive efficiency, it is very important to select the appropriate indicators, the sample of the DEA model needs to meet: sample capacity > 2xNxM, where N is the number of input indicators, M is the number of output indicators, to meet the requirements of the sample capacity of the DEA model[9]. In summary, the number of institutions, the number of beds, the number of on-the-job employees, health technicians, practitioners, managers, per capita hospitalisation costs, and total expenditures are selected as the input indicators, numbered V1-V8 in order; the number of discharges, the number of consultations, the average length of stay, the bed occupancy rate, the income from the financial allocation, and the total income are selected as the output indicators, numbered W1-W6 in order.

1) Input indicators

Before using SPSS software to factor analyse the eight input indicators, the KMO and Bartlett sphericity test was conducted on each indicator, resulting in a KMO value of 0.833 and a Bartlett sphericity test significance of 0.000. Statisticians generally set the KMO at around 0.6, with a significance level of less than 0.05, which indicates that there is a correlation between the selected indicators and it is suitable for doing factor analysis[10]. Factor analysis of the cast variables can obtain the principal component variance contribution ratio and rotated component matrix (Table 1). This factor analysis extracted four male factors and the cumulative contribution rate of variance reached 98.715%, indicating that these male factors can represent the information of the majority of variables. From Table 1, we can obtain the input indicators with the highest correlation with the four public factors were in total expenditure, number of institutions, per capita hospitalisation cost and management personnel.

Table 1 Rotated matrix of input indicator components.

Input indicators	Components			
	1	2	3	4
Number of institutionsV1	0.522	0.832	—	—
Number of bedsV2	0.819	0.441	—	—
Number of employees on boardV3	0.886	0.393	—	—
Health techniciansV4	0.894	0.377	—	—
PractitionerV5	0.898	0.405	—	—
Managerial staffV6	0.693	0.443	—	0.557
Per capita hospitalisation costV7	—	—	0.995	—
Total expenditureV8	0.931	—	—	—

2) Output indicators

The same process as the selection of input indicators, SPSS software was used to carry out the KMO and Bartlett sphericity test for the six output indicators, resulting in a KMO value of 0.710 and a Bartlett sphericity test significance of 0.000. This indicates that there is a correlation between the selected indicators, which is suitable for factor analysis. Factor analysis of the output variables can get the principal component variance contribution ratio and rotated component matrix (Table 2). This factor analysis extracted 3 male factors and the cumulative contribution rate of variance reached 90.288%, indicating that these male factors can represent the information of the majority of variables. From Table 2, it can be obtained that the input indicators with the highest correlation with the 3 public factors were in total revenue, bed occupancy rate, and average inpatient days, respectively.

Table 2 Rotated matrix of output indicator components.

Output indicators	Components		
	1	2	3
Number of dischargesW1	0.621	0.601	—
Number of consultationsW2	0.933	0.265	—
Average length of stayW3	—	-0.212	0.963
Bed occupancy rateW4	0.120	0.863	-0.320
Income from financial allocationsW5	0.950	—	—
Total revenueW6	0.966	0.206	—

3. Results

3.1 DEA analysis of health resource allocation efficiency

According to the selection of the above evaluation indexes, this paper selects Chinese medicine hospitals in 30 provinces and cities across the country in 2019 to analyse and evaluate the efficiency of health resource allocation, and the data of input-output indexes in 2019 are shown in Table 3. Using DEAP2.1 software, the data in Table 3 are brought into the CCR-BCC model to operate, and the value of health resource allocation efficiency of Chinese medicine hospitals nationwide in 2019 is obtained (Table 4).

Table 3 Input-Output of Health Resources in Traditional Chinese Medicine Hospitals by Region of the Country, 2019.

regions	Iutput indicators				Output indicators		
	Number of institutions	Per capita hospitalisation cost	Managerial staff	Total expenditure/thousand	Average length of stay	Bed occupancy rate	Total revenue/thousand
Beijing	162	23359.8	2052	2500.82	11.4	69.7	27023335
Tianjin	55	18027.6	756	888.72	11.1	76.6	7789515
Hebei	249	9567.2	2098	2690.84	8.9	76.5	18115221
Shanxi	218	9698.8	766	1220.36	10.4	69.4	8847001
Neimenggu	122	8861.5	620	1082.75	9.3	57	6589333
Liaoning	193	10313.2	1560	1728.94	10.8	61.7	12369736
Jilin	114	10485.5	1504	1101.34	10.4	72.6	7667486
Heilongjiang	169	9272.8	1805	1406.76	10.8	72.2	9309216
Shanghai	21	19272.3	622	2301.6	8.5	98.3	22287860
Jiangsu	151	11803.1	2098	4035.02	9	89.3	33861065
Zhejiang	179	11616.7	1926	3117.08	9.7	86.8	30803440
Anhui	125	7822.6	1378	1998.08	8.7	86.2	14741901
Fujian	82	9600.7	730	1553.5	8.9	79.5	11918340
Jiangxi	110	8583.1	916	1473.89	9.2	84.6	11234729
Shandong	320	10081.4	2518	4140.82	9.2	81.1	29528495
Henan	317	8662.5	3442	3100.17	10	86.4	24522849
Hubei	126	9793.9	1770	2337.93	9.8	90.8	18897997
Hunan	187	8433.1	2203	2484.4	9.1	87.3	18000065
Guangdong	170	12394.5	2795	5198.69	8.9	86	46798531
Guangxi	102	9280.6	1280	1615.01	8.5	87.6	13067021
Hainan	22	10469.9	284	402.5	8.5	67.7	2949850
Chongqing	128	8527.5	1268	1374.3	9.2	84.3	10238393
Sichuan	247	8528	2684	3253.09	10	94.4	25775331
Guizhou	98	6177.6	1088	1206.76	8.1	86.1	9172488
Yunnan	158	6480.8	753	1654.35	8.9	85.5	12369140
Shaanxi	168	7922.7	2601	1742.23	9.3	80.2	11232422
Ganshu	124	6168.9	558	871.29	8.5	82.7	5993565
Qinghai	14	9376.6	58	308.08	9.3	87.1	1957522
Ningxia	29	8086.9	170	343.55	9.1	83	2221325
Xinjiang	61	7857.5	499	1204.51	9.2	101.3	8277072

As can be seen from Table 4, the mean values of comprehensive efficiency, pure technical efficiency and scale efficiency of health resource allocation in TCM-type hospitals in 30 provinces and cities across the country are 0.990, 0.998 and 0.992, respectively, which indicates that the overall allocation efficiency of health resources is relatively high. If the values of integrated efficiency, pure technical efficiency and scale efficiency are all equal to 1, it means that the decision unit DEA is effective; if one of the efficiency values is equal to 1, it means that the decision unit DEA is weakly effective, otherwise it is non-DEA effective. From Table 5, it can be concluded that of the 30 provinces (cities), 25 provinces and cities (83.33%) are DEA effective, indicating that the health resources in these provinces and cities are fully utilized; 4 provinces and cities (13.33%) are weakly DEA effective, indicating that the health resources in these provinces and cities are fully utilized under the current scale but the scale is not optimal; the remaining 1 province and city (3.33%) is non-DEA effective, indicating that the decision unit is non-DEA effective; otherwise, it is non-DEA effective.) is non-DEA valid, indicating that the inputs and outputs of this province and city do not match. In terms of returns to scale, four provinces and municipalities, Hebei, Liaoning, Henan and Shaanxi, have diminishing returns to scale, indicating that the rate of increase in output in these provinces and municipalities has not kept pace with the rate of increase in inputs;

Hunan has increasing returns to scale, indicating that the scale of inputs in this province and municipality is on the small side, and that appropriately increasing the scale of inputs is conducive to improving overall efficiency.

Table 4 Efficiency values of health resource allocation in Chinese medicine hospitals nationwide, 2019.

regions	Combined efficiency	Technical efficiency	Scale efficiency	Return on scale
Beijing	1.000	1.000	1.000	—
Tianjin	1.000	1.000	1.000	—
Hebei	0.887	0.888	0.998	drs
Shanxi	1.000	1.000	1.000	—
Neimenggu	1.000	1.000	1.000	—
Liaoning	0.956	1.000	0.956	drs
Jilin	1.000	1.000	1.000	—
Heilongjiang	1.000	1.000	1.000	—
Shanghai	1.000	1.000	1.000	—
Jiangsu	1.000	1.000	1.000	—
Zhejiang	1.000	1.000	1.000	—
Anhui	1.000	1.000	1.000	—
Fujian	1.000	1.000	1.000	—
Jiangxi	1.000	1.000	1.000	—
Shandong	1.000	1.000	1.000	—
Henan	0.999	1.000	0.999	drs
Hubei	1.000	1.000	1.000	—
Hunan	0.987	1.000	0.987	irs
Guangdong	1.000	1.000	1.000	—
Guangxi	1.000	1.000	1.000	—
Hainan	1.000	1.000	1.000	—
Chongqing	1.000	1.000	1.000	—
Sichuan	1.000	1.000	1.000	—
Guizhou	1.000	1.000	1.000	—
Yunnan	1.000	1.000	1.000	—
Shaanxi	0.866	1.000	0.866	drs
Ganshu	1.000	1.000	1.000	—
Qinghai	1.000	1.000	1.000	—
Ningxia	1.000	1.000	1.000	—
Xinjiang	1.000	1.000	1.000	—
mean	0.990	0.998	0.992	—

Table 5 Distribution of health resource allocation efficiency evaluation of hospitals of Chinese medicine category in 2019 by region of the country.

Evaluation results	efficiency value	Number of decision modules	Proportion	Regions
DEA effective	Combined efficiency, pure technical efficiency and scale efficiency = 1	25	83.33%	Beijing, Tianjin, Shanxi, Neimenggu, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Hubei, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Gansu, Qinghai, Ningxia and Xinjiang.
DEA weakly effective	Pure technical or scale efficiency = 1	4	13.33%	Liaoning, Henan, Hunan, Shaanxi
Non-DEA effective	Combined, purely technical and scale efficiencies<1	1	3.33%	Hebei

3.2 DEA weakly effective and non-DEA effective analyses

Using DEAP2.1 software, we can calculate the target values and slack values of health resource inputs and outputs of the above four weakly effective DEAs and one non-DEA effective province and city, and the results are shown in Table 6.The reasons for ineffective DEAs are generally redundant resource inputs or insufficient outputs. Analysing Table 6, it can be found that the non-DEA effective provinces and municipalities have redundant health resource inputs in four indicators, including the number of institutions, management personnel, per capita hospitalisation cost and total expenditure, and insufficient outputs in bed occupancy rate. Throughout the four provinces and cities of Liaoning, Henan, Hunan and Shaanxi where the DEA is weakly effective, the target and actual values of health resource input and output are the same, and there is no situation of redundant resource input or insufficient output, and the scale of health resource input and output of Chinese medicine hospitals in the above four provinces and cities is relatively reasonable. Combined with the analysis in Table 4, it can be concluded that the comprehensive efficiency and scale efficiency of the above four provinces and cities have not reached the highest level, with Henan Province having the highest comprehensive efficiency in the allocation of health resources, Hunan Province the second highest, and Shaanxi Province the lowest, at only 0.866.

Table 6 Target and slack values of health resource inputs and outputs of TCM hospitals in DEA weakly effective and non-DEA effective provinces and cities.

Regions	Variable	Input indicators				Output indicators		
		Number of institutions	managerial staff	Per capita hospitalisation costs	Total expenditure/ thousand yuan	Average length of stay	Bed occupancy rate	Total revenue thousand yuan
Hebei	Actual value	249	9567.2	2098	2690.84	8.9	76.5	18115221
	Target value	158.72	8497.62	1598.07	2390.01	8.9	85.22	18115221
	Relaxation value	-90.29	-1069.59	-499.93	-300.83	0	8.72	0
Liaoning	Actual value	193	10313.2	1560	1728.94	10.8	61.7	12369736
	Target value	193	10313.2	1560	1728.94	10.8	61.7	12369736
	Relaxation value	0	0	0	0	0	0	0
Henan	Actual value	317	8662.5	3442	3100.17	10	86.4	24522849
	Target value	317	8662.5	3442	3100.17	10	86.4	24522849
	Relaxation value	0	0	0	0	0	0	0
Hunan	Actual value	187	8433.1	2203	2484.4	9.1	87.3	18000065
	Target value	187	8433.1	2203	2484.4	9.1	87.3	18000065
	Relaxation value	0	0	0	0	0	0	0
Shaanxi	Actual value	168	7922.7	2601	1742.23	9.3	80.2	11232422
	Target value	168	7922.7	2601	1742.23	9.3	80.2	11232422
	Relaxation value	0	0	0	0	0	0	0

4. Discussions

The comprehensive efficiency of health resource allocation in Chinese medicine hospitals in 30 provinces and cities in China was 0.990 in 2019, indicating that the Party Central Committee and the government have placed Chinese medicine in a prominent position and made remarkable achievements in the reform and development of Chinese medicine. However, due to the excess input of health resources such as the number of health institutions, management personnel, and total expenditure, the DEA of health resource allocation in some provinces and cities is relatively ineffective. From the analysis of this paper, it is found that more than 2/3 of the provincial and municipal TCM hospitals in the country have achieved effective DEA health resource allocation, i.e., the inputs and outputs of resources are appropriate in scale and reasonable in structure; in the northern region, there are provinces and municipalities with relatively ineffective DEA health resource allocation, i.e., the inputs and outputs of resources are not matching, and there is an over-investment of resources, which leads to a low utilisation of resources; and in the central region, there are provinces and municipalities where DEA health resource allocation is ineffective due to scale is insufficient resulting in weakly effective DEA of health resource allocation in the provinces and cities. Therefore, the input of health resources in Chinese medicine hospitals across the country should be rationally planned in light of the actual situation in order to narrow the gap in health resource allocation between different provinces and municipalities in the south and north.

In the process of analysing the efficiency of health resource allocation in non-DEA effective provinces and cities, it can be found that the comprehensive efficiency and technical efficiency of health resource allocation in Hebei province are not high, only 0.888 and 0.887; while the scale efficiency is higher, reaching 0.998. However, the diminishing returns to scale of the province, reviewing the actual and target values of the input-output of the province's health resources, it can be see that the ideal number of health resource input institutions, managerial personnel, per capita hospitalisation cost and total expenditure of Chinese medicine hospitals in the province exceeded the actual values by 90.29, 1,069.59, 499.93 and 300.83, respectively, indicating that Chinese medicine hospitals have redundancy of resource inputs in the process of health resource allocation, which leads to poor utilisation of health resources. In the process of analysing the efficiency of health resource allocation in provinces and cities with weakly effective DEA, it can be found that Chinese medicine hospitals in provinces and cities with weakly effective DEA in terms of health resource allocation meet expectations in terms of inputs and outputs, but their returns to scale do not reach the ideal state, and there is a situation of incremental or decremental returns to scale. For example, Hunan Province has increasing returns to scale, and four provinces and cities, including Hebei, Liaoning, Henan and Shaanxi, have decreasing returns to scale. Therefore, when Chinese medicine hospitals formulate health resource allocation planning, they need to reasonably adjust the scale of health resource inputs, appropriately expand or compress the scale of resource inputs according to the actual situation, optimize the scale and structure of resource inputs, maximize the use of health resources, and avoid the waste of resources.

5. Conclusion

The data envelopment analysis method is a non-parametric test method developed on the basis of the concept of relative efficiency evaluation, which is widely used in the efficiency evaluation of multiple inputs and multiple outputs[11]. In this paper, based on previous studies on the efficiency of health resource allocation, we start from the characteristics of health resources in Chinese medicine hospitals and select the indicators that best reflect the inputs and outputs of health resources, which include the input dimensions of human, financial, and physical resources, and the output dimensions of medical service quality and service efficiency. After checking a large amount of literature, we found that there is no complete efficiency evaluation standard system research, to improve the health resource allocation efficiency of the national Chinese medicine hospital, we need to establish a diversified evaluation index system, such as patient satisfaction, physician daily average number of diagnosis and treatment, and other dimensions of the indicators of the workforce and other skills, for a comprehensive and objective evaluation of the health resource allocation efficiency, so as to select a more reasonable allocation of resources. This is used to comprehensively and objectively evaluate the efficiency of health resource allocation, so as to choose a more reasonable resource allocation plan, maximise the utilisation of resources and improve the quality of medical services.

References

[1] Zhang Wentian, Kong Fanyue, Wang Quan, et al. Study on the current situation of equity in health resource allocation in China and the forecast of equity during the 14th Five-Year Plan[J]. China Health Care Management,2022,39(3):161-165,207.

[2] Xu Chao,Wang Xiaoyu,Xu Jingju,et al. Research on the equity of health resource allocation in

Chinese medicine hospitals in China[J]. China Hospital,2022,26(5):6-9.

[3] Chen Shuying, Huang Xiaoguang, Wang Mengyuan, et al. Evaluation of research input and output efficiency of tertiary hospitals based on factor analysis and data envelopment method[J]. Journal of Nanjing Medical University (Social Science Edition), 2018, 18(1):47-52.

[4] Xu Ke, He Ruixian, Qiu Tinglin. Application of data envelopment analysis to evaluate the operational efficiency of surgical units[J]. China Health Statistics, 2022, 39(2):260-262.

[5] Lu Wenliang, Zeng Cheng, Chen Lili, et al. Evaluation of hospital operational efficiency based on data envelopment analysis[J]. China Digital Medicine, 2017, 12(11):92-94.

[6] Tian Haoguo, Yang Ling. Research on the evaluation of resource allocation efficiency of medical and health services in Jiangsu Province[J]. Modern Hospital Management, 2022, 20(1):1-4

[7] Fan Dianlin, Deng Meng, Qin Xianjing, et al. Evaluation of health resource allocation efficiency in Guangxi based on data envelopment analysis[J]. Guangxi Medicine, 2021, 43(2):216-220

[8] Tang Lijian, Wang Changqing, Qian Dongfu. A study on the status quo and efficiency of health resource allocation in nursing homes in Jiangsu Province[J]. China Health Care Management, 2022, 39(2):115-119

[9] Qin Jifang. Evaluation of allocation efficiency of health resources in Guangxi Chinese medicine based on data envelopment analysis[J]. Health Soft Science, 2022, 36(6):45-50

[10] Wen Xiaotong, Chen Feiyu, Yuan Zhaokang, et al. Comprehensive Evaluation of Patient Satisfaction in Different Places Based on Factor Analysis. Chongqing Medicine, 2019, 48(4):654-659.

[11] Song Shan,Wei Lin,Liu Yangchen,et al. Evaluation of nursing human resource efficiency based on data envelopment analysis[J]. Journal of Nursing,2021,28(13):1-5.