Equity and Efficiency analysis of health resources allocation in Guangxi County based on Balance index model: evidence from an ethnic minority region in Western China

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Abstract. Background: Equity and efficiency in the allocation of health resources directly affects health equity and is a prerequisite for the achievement of health equity. This study analyzed the equity and efficiency of health resource allocation in Guangxi County to provide rational research evidence for improving the equity of health resource allocation in China and developing countries in the world. Methods: Gini coefficient and Malmquist index were used to evaluate the equity and efficiency of health resource allocation in Guangxi County. Fairness-Efficiency Index (FEI) model is constructed to analyze equity and efficiency together. Results: From 2015 to 2020, the Gini coefficient was in a relatively fair state. The total factor productivity of 14 cities in Guangxi is all less than 1. According to the size of the FEI value, the 14 cities in Guangxi can be divided into three classes: 1 city in Class I, 8 cities in Class II, and 5 cities in Class III. Conclusion: From 2015 to 2020, the geographical equity needs to be improved. The FEI of medical and health resource allocation in ethnic and border counties needs to be improved. It's suggested that the government should establish a stable health development mechanism that is suitable for the undeveloped ethnic minority and border areas to increase the FEI.

Keywords: equity; Efficiency; Health resources; County; Western China

1 Introduction

Allocating health resources is a global challenge in the human health services market(1). It is essential to consider both efficiency and equity when allocating health resources, both of which are of equivalent importance(2). China is confronted with a challenge in terms of equality and efficiency in the allocation of health resources and the use of health services in the context of rapid economic growth(3). Few studies have focused on underdeveloped county areas in western China. In China's urban system, the county plays a central role in connecting the above with the following and is a major spatial vector to promote urbanization. Previous studies have found that, firstly, in

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recent years, domestic research on the combination of equity and efficiency of health resource allocation is relatively scarce (4, 5). The research objects are mostly at the provincial and municipal levels, and there was a lack of research at the county level (1, 6). The research on the county health resource allocation in Guangxi during the “13th Five-Year Plan” (2015-2020) is insufficient (7). Guangxi is the only ethnic minority autonomous region bordering the sea in the west of China and the only coastal area in the west, an important hub of the Maritime Silk Road, and a unique position in the strategic pattern of the large-scale development of the western region and the overall situation of the country's opening to the outside world. Numerous studies have proved that the equity and efficiency of health resource allocation still need to be improved (7). In this study, Fairness - Efficiency Index (FEI) model was built to explore the best balance between fairness and efficiency of health resource allocation. To provide scientific evidence for further promoting health development in Western China and developing countries in the world.

2 Method

2.1 Data Sources

The data in this paper were obtained from Guangxi Health Statistical Yearbook (2016-2021), Guangxi Statistical Yearbook (2016-2021), and the County-related data were provided by the Health Statistics Information Center of Guangxi. Based on the previous research studies the indicators were selected.

2.2 Indicators

The equity indicators included health technicians (practicing doctors, assistant practicing doctors, registered nurses, pharmacists, and technicians), hospitals (integrated Chinese and Western hospitals, General hospitals, Chinese medicine hospitals, Maternal and child hospitals, Specialized hospitals, and Ethnic medicine hospitals), and bed numbers. The efficiency indicators included input indicators (hospitals， health technicians， bed numbers), and output indicators (bed occupancy in the hospitals, outpatient numbers, and inpatient numbers).

2.3 Region Division

The Guangxi Zhuang Autonomous Region is an old revolutionary area, border, coastal, and underdeveloped ethnic minority areas in western China. There are 14 cities in Guangxi, with a total of 71 counties under its jurisdiction. Guangxi can be divided into three economic zones: Beibu Gulf Economic Zone, Guixi Resource Rich Zone, and Xijiang Economic Belt.

2.4 Measuring Tools

Gini coefficient.

The Gini coefficient has been developed by Corrado Gini from Lorenz's curve, which has been used extensively in determining the equality of the distribution of resources(8). The Gini coefficient (Gini) ranges from 0 to 1, and the closer it is to 0, the fairer it is. Gini < 0.2 is absolutely fair, 0.2 ~ 0.3 is relatively fair, 0.3 ~ 0.4 is relatively fair, 0.4 ~ 0.5 is relatively unfair, and > 0.5 is fair with great differences. The calculation formula is:

$$Gini = \frac{1}{2}\sum_{i=1}^{n} |Xi - Yi| \qquad (1)$$

Where Xi represents the relative portions of three input indicators, and Yi represents the relative proportion of the population or geography, or economics. n represents the total number of regions in the Guangxi County.

Malmquist Index.

Malmquist index, also known as Total factor productivity change (TFPC), can be decomposed into Technical efficiency change (TEC) and Technical change (TC), TFPC=TEC×TC. TEC includes Pure technical efficiency change (PTEC) and Scale efficiency change (SEC), TEC=PTEC×SEC(9). TC mainly reflects the influence of policy and other objective factors on TFPC. TFPC, TEC, TC, PTEC and SEC all increased more than 1, indicating improvement(10).

Fairness - Efficiency Index (FEI) model

In this study, Factor analysis, Bootstrap Method, and Cluster analysis were used to build the Fairness-Efficiency Index (FEI) model. Factor analysis is a statistical analysis method of dimensional reduction based on the covariance matrix or correlation matrix. It can be used to find hidden representative impact factors in multiple variables, classify indicators of the same nature into one factor, and screen out common factors, so as to reduce the number of evaluation indicators and reduce the dimension of variables. Factor analysis can group several closely related variables into one class. The correlation between potential factors and indicators determines the indicators mainly determined by each potential factor. We selected the index with the largest factor loading coefficient as the evaluation index of this study (11). Bootstrap Method (Bootstrapping), proposed by Bradley Efron (12-14), is used to calculate the standard error. The Bootstrap test made up for the defect of insufficient sample size and improved the reliability and validity of the model by calculating a 95% confidence interval. For data sets with small samples, the self-help method has a good effect and can effectively overcome the defect that small samples cannot obtain an asymptotic effective estimation (15). Cluster analysis is an ideal multivariate statistical technique. It is a multivariate statistical method that can integrate and screen the characteristics of evaluation indicators and represent them graphically by tree graph and cluster icicle graph (16).

3 Result

3.1 Fairness Analysis

As shown in Table 1, from 2015 to 2020, in terms of population and GDP, the Gini coefficients of all kinds of health resources showed no obvious change trend and were mostly lower than 0.3, which was in a fairly fair state. In terms of geographical dimension, the Gini coefficient of health resources in various counties showed a fluctuating trend, but all were lower than 0.3, which was in a fairly fair state.

Table 1. Gini coefficient of county health resources in Guangxi from 2015 to 2020

Year/Index	2015	2016	2017	2018	2019	2020
By geography						
Hospital	0.219	0.254	0.285	0.283	0.286	0.283
Medical and technical personnel	0.208	0.208	0.264	0.247	0.24	0.298
Beds	0.241	0.241	0.275	0.275	0.259	0.266
By population						
Hospital	0.278	0.24	0.203	0.185	0.175	0.149
Medical and technical personnel	0.103	0.093	0.099	0.095	0.075	0.117
Beds	0.092	0.094	0.093	0.093	0.105	0.129
By GDP						
Hospital	0.244	0.198	0.165	0.177	0.198	0.135
Medical and technical personnel	0.107	0.158	0.146	0.167	0.138	0.139
Beds	0.105	0.164	0.144	0.155	0.135	0.151

3.2 Efficiency Analysis

From 2015 to 2020, the average of technical efficiency, technological change, pure technical efficiency, and scale efficiency of the 14 prefecture-level cities in Guangxi was 1.01, 0.9, 1.006, and 1.004, respectively, indicating that the technical efficiency, pure technical efficiency and scale efficiency of Guangxi were all improved. From the perspective of 14 cities, the total factor productivity of 14 cities in Guangxi is all less than 1, suggesting that the efficiency of county health resource allocation is in a state of decline from 2015 to 2020. The decrease in total factor productivity in Baise City was the most obvious (0.854) (Table 2).

Table 2. Changes in the efficiency of health resources allocation in 14 cities of Guangxi from 2015 to 2020

City	Technical efficiency change	Technological change	Pure technical efficiency	Scale efficiency	Total factor productivity
Nanning	1.01	0.904	1	1.01	0.913
Liuzhou	1.039	0.9	1.033	1.006	0.935
Guilin	1.001	0.904	1	1.001	0.905
Wuzhou	1	0.892	1	1	0.892
Beihai	1	0.905	1	1	0.905
Fangchenggang	1	0.959	1	1	0.959
Qinzhou	1	0.886	1	1	0.886
Guigang	1	0.909	1	1	0.909
Yulin	1	0.894	1	1	0.894
Baise	0.993	0.86	1	0.993	0.854
Hezhou	1.009	0.919	1.006	1.003	0.927
Hechi	1.019	0.885	1.014	1.005	0.902
Laibin	1.017	0.897	1.017	1	0.912
Chongzuo	1.05	0.886	1.017	1.032	0.93
Mean value	1.01	0.9	1.006	1.004	0.909

3.3 Construction of equity-efficiency balance index model

Before factor analysis, the correlation coefficient (Kaiser-Meyer-Olin, KMO) test and Bartlett spherical test was passed (KMO=0.646 and Bartlett spherical test P <0.001), which is suitable for factor analysis. In selecting the equity-efficiency equilibrium index model, the initial eigenvalues and factor loads are calculated first. The factor is extracted and named according to the principle that the eigenvalue is greater than 1. In the fairness index, the characteristic value of one factor is greater than 1, and its percentage of variance is 81.94%, while the percentage of variance of the other two indexes is 13.604% and 4.455%, respectively. Among the efficiency indicators, the characteristic value of one efficiency indicator factor is greater than 1, and the accumulated percentage of variance is 70.828%, indicating that the characteristic value of the common factor selected by the research has contained most of the information (Table 3 and Table 4).

Through factor analysis and matrix score, the number of beds, the number of health personnel, and the number of medical institutions were selected as fairness evaluation indicators. The measurement of efficiency can mainly judge the allocation efficiency of health resources through the input-output process, so selecting a single particle index cannot reflect the efficiency. Therefore, the representative total factor productivity efficiency is selected as the efficiency evaluation index through factor analysis and matrix score.

Table 3. Total variance interpretation of health resource allocation and service supply equity indicators

Composition	Initial eigenvalue			Extract the sum of loads squared		
	Total	Percentage of variance	Cumulative percentage	Total	Percentage of variance	Cumulative percentage
1	2.458	81.941	81.941	2.458	81.941	81.941
2	0.408	13.604	95.545	-	-	-
3	0.134	4.455	100	-	-	-

Table 4. Total variance explanation of health resource allocation efficiency index

Composition	Initial eigenvalue			Extract the sum of loads squared		
	Total	Percentage of variance	Cumulative percentage	Total	Percentage of variance	Cumulative percentage
1	1.417	70.828	70.828	1.417	70.828	70.828
2	0.583	29.172	100	-	-	-

The Bootstrap method was employed to test the model by self-sampling to assess its quality and enhance its reliability and validity by calculating the 95% confidence interval. The Bootstrap method estimated the mean value of FEI and its 95% confidence interval. The basic steps are as follows: (1) The resampling technique is adopted to extract n=14 samples from the original samples, which allows repeated sampling. (2) Calculate the given statistic T according to the extracted samples. (3) Repeat the above 1000 times to get 1000 statistics T. (4) The sample mean of the above 1000 statistics T was calculated to construct the 95% confidence interval (Table 5).

Table 5. Self-sampling results of equity-efficiency balance index

Value	FEI	Self-service sampling			
		S	SE	95% confidence interval	
				Lower limit	Upper limit
Average value	0.82	0.002	0.012	0.797	0.844
Median	0.827	0.002	0.014	0.788	0.837

Test of equity-efficiency balance index model of medicine and health resource allocation.

The number of institutions, the number of health technicians, and the utilization rate of hospital beds were selected as external criteria to conduct cluster analysis on 14 prefecture-level cities and counties in Guangxi. This study conducted a correlation analysis between the equilibrium model and the clustering results of external criteria to evaluate the balance between fairness and efficiency of health resource allocation in Guangxi County. The results show that the equilibrium model correlates with the clustering results of external criteria (Figure 1 and Figure 2).

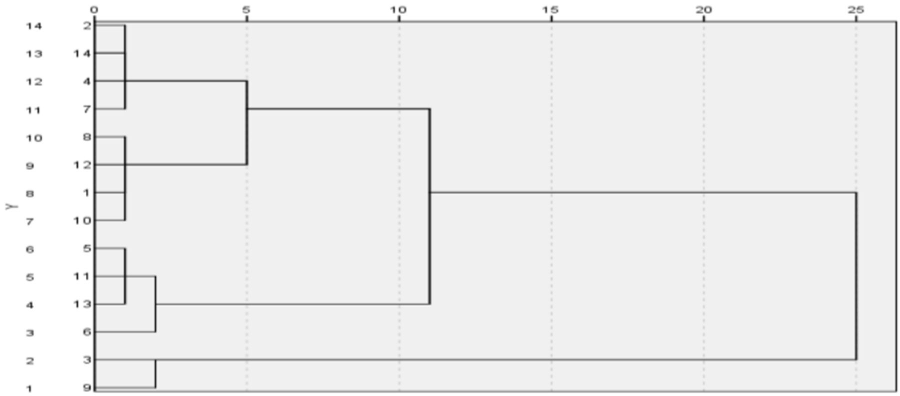

Fig. 1. Tree diagram of cluster analysis

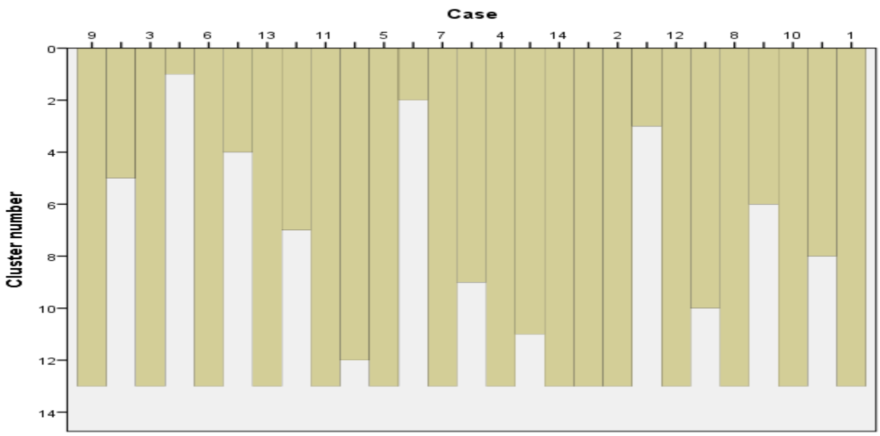

Fig. 2. Diagram of cluster analysis

Equity-efficiency balance index and regional distribution.

According to the component matrix, the weights of the three indexes in the Fair Index (FI) were determined: 0.34, 0.31, 0.35. Based on Gini fair value of each index, FI= number of beds in medical and health institutions ×0.35+ number of health technicians ×0.34+ number of medical and health institutions ×0.31. According to the component matrix, the weights of the three indexes in the Efficiency Index (EI) were determined: 0.44, 0.40 and 0.16. Based on DEA efficiency value of each index, EI= total factor productivity ×0.5+ comprehensive efficiency ×0.5. (Table 6)

Table 6. Component matrix of health resource allocation equity-efficiency index

Index	Matrix score	Weight
Medical technician	0.917	0.34
mechanism	0.848	0.31
Number of beds	0.948	0.35
Total factor productivity	0.842	0.5
Comprehensive efficiency	0.842	0.5

The FEI formula of health resource allocation in this study is FEI=EI-FI. That is, the closer FEI is to 1, the more balanced the fairness and efficiency of health resource allocation in the region. From 2015 to 2020, Guigang City had the best equity efficiency in county health resource allocation, while Guilin City had the worst equity efficiency in county health resource allocation. From the perspective of three economic zones in Guangxi, the equity-efficiency of health resource allocation in the counties of Xijiang Economic Zone is the best, while the equity-efficiency of health resource allocation in the counties of Beibu Gulf Economic Zone is relatively the worst. (Table 7).

Table 7. Equity-efficiency balance index of health resources allocation in Guangxi counties in 2020

City	FEI	FEI classification
Nanning	0.829	2
Liuzhou	0.837	2
Guilin	0.768	1
Wuzhou	0.855	2
Beihai	0.783	1
Fangchenggang	0.737	1
Qinzhou	0.858	2
Guigang	0.939	3
Yulin	0.824	2
Baise	0.835	2
Hezhou	0.79	1
Hechi	0.788	1
Laibin	0.831	2
Chongzuo	0.809	2
Beibu Gulf Economic Zone	0.802	2
Resource rich area of west Guangxi	0.811	2
Xijiang economic belt	0.835	2

Note: Class 1: ≤0.790, Class 2 :0.790-0.858, Class 3: ≥0.939

4 Discussion

Most of the previous research on health resource allocation in China has focused on the country as a whole or on a particular province, while few studies have paid attention to the underdeveloped county areas in western China. Moreover, the equity and efficiency of health resource allocation in Western China are lower than those in Eastern and Central China(17). This study comprehensively analyzed the equity and efficiency of health care resource allocation in the Guangxi County from 2015 to 2020 to provide rational research evidence for Chinese government policymakers and provide a research basis for future studies and assist the government in further optimizing primary health resource allocation not only in western China but also in developing countries around the world.

The distribution of health resources in Guangxi County is generally fair: the fairest distribution according to the geographical area was lower than that according to the population. Evidence suggests that equity in allocating health resources by population is more equitable than that of the geographic area(5). In addition, the distribution of health technicians is better than that of hospitals. This finding is in line with the other studies in China(18). When allocating health resources, the government only considers demographic factors and ignores geographical factors (19). The supply of health resources in Guangxi is impacted by a gap in economic development (20).

The FEI of county health resource allocation in the Xijiang Economic Belt is the best, while Beibu Gulf Economic Zone (an economically developed region in Guangxi) is relatively the worst, which suggested great regional disparities in Guangxi. The FEI of health resource allocation in ethnic minority areas is lower than the average level in Guangxi, which means there are still insufficient health resources. The level of fairness and efficiency in the allocation of health resources in Fangchenggang, which borders Vietnam, is the lowest in Guangxi, with an FEI of 0.737. The reason is that the economic development level of Fangcheng Port is relatively low in Guangxi. The reason is that the economic development level of Fangchenggang is relatively low in Guangxi. Therefore, the relative lack of medical and health resources in Fangchenggang has led to a low FEI. The regional differences that still exist in China, especially between the economically developed and underdeveloped regions in China (21). It is crucial to take into account special factors like the salary and promotion of health workers in ethnic minority and border areas. To ensure the sustainable development of health services in undeveloped regions, the government should establish a stable health development mechanism that is suitable for the undeveloped ethnic minority and border areas.

5 Limitation

Only the Gini coefficient and Malmquist index were used in this study to assess equity and efficiency of health resources. To obtain a more precise evaluation, future studies should combine more analytical methods.

6 Conclusion

This study uses multiple methods to combine the fairness and efficiency of health resource allocation at the county level from different angles, to provide a scientific basis for health resource allocation in developing countries. Based on the analysis above, we find that the distribution of health resources in the Guangxi County is generally fair. The FEI of medical and health resource allocation in ethnic minority areas is lower than the average level in Guangxi, which means there are still insufficient health resources. When allocating health human resources, it is crucial to take into account special factors like the salary and promotion of health workers in ethnic minority and border areas. Additionally, to ensure the sustainable development of health services in undeveloped regions, the government should establish a stable health development mechanism that is suitable for the undeveloped ethnic minority and border areas.

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