Research on Equity of Medical Resources in China Based on Spatial Analysis

Chaoqun Yao
19221296@bjtu.edu.cn

School of Science, Beijing Jiaotong University, Beijing, China

Abstract—To study the equity of medical resources in China, the paper collected the relevant data of 31 provincial administrative regions in China from 2015 to 2019 and quantified the equity of medical resources in China. The research shows that there exists spatial aggregation of medical resources in China, and medical resources in the eastern region are superior to those in the western region. Overall, the equity of the comprehensive level of medical resources in China is good, and the equity of the material resources is significantly higher than that of human resources. At the same time, the research also finds that medical resources have the feature of spatial autocorrelation and there exists a positive correlation between medical resource and economic investment.

Keywords-Equity of medical resources; TOPSIS; Theil index; spatial analysis

1 INTRODUCTION

Nowadays, Chinese medical level has been significantly developed. However, the allocation of health resources still needs to be improved. At the same time, the aging trend of our country is becoming more and more obvious, and the number of the elderly population is gradually increasing, which makes the people's demand for medical resources increased as well. Therefore, the problem of how to improve the equity of medical resources has become an urgent problem to be solved.

The equity of medical resources can be divided into spatial equity and population equity. The research represented by TOPSIS method, GIS analysis and spatial aggregation analysis [1][2][6] mainly studied the spatial allocation equity of medical resources. The researches which introduced Gini coefficient and Lorenz curve [3][5] analyzed the spatial equity or population equity of medical and health resources through descriptive analysis. And the method of combining Gini coefficient and Theil index is mainly used to study the interregional differences of medical resources. At the same time, the number of researches on the equity of medical and health resources in a provincial administrative region is more [1]~[6][15], while the number of studies on the equity of medical and health resources for the whole country is relatively small [7]~[10].

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This research mainly studied the equity of medical resources in China, and considered the dynamic changes of the equity of medical resources in China from 2015 to 2019. At the same time, considering that there are differences in geographical environment and economic development in different regions, and the geographical conditions of regions with similar geographical locations are similar, the allocation of medical resources also has certain similarity, which means there exists spatial autocorrelation.

2 MATERIALS AND METHODS

2.1 Materials

The data were collected from Chinese Health Statistics Annual (2015-2019). To measure the equity of the medical resource in China, the following indicators are included: indicators for measuring resources of health institutions including number of hospitals, number of tertiary hospitals, number of secondary hospitals and number of primary health institutions; indicators to measure human resources including the number of health care personnel, number of practicing physicians, number of registered nurses, number of doctor in community health center service, number of doctors in primary medical institutions; and indicators to measure facilities resources including number of beds in medical institutions.

2.2 Methods

2.2.1 TOPSIS Evaluation Method Based on Entropy Weight

As a commonly used and highly recognized evaluation method, the traditional TOPSIS evaluation analysis method can extract the information in the original data, and reflect the differences between various evaluation objects. In order to make the evaluation model more objective and scientific, this paper introduces the entropy weight method to determine the weight of each evaluation indicators. Compared with other commonly used evaluation methods, this evaluation method has the strongest ability to extract information contained in the original data, and the introduction of entropy weight improves the objectivity of the evaluation system.

The formula to calculate the entropy weight is given as follows:

$$E_j = -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij}\ln(p_{ij}) \tag{1}$$

$$p_{ij} = \frac{\hat{x}_{ij}}{\sum_{i=1}^{n}\hat{x}_{ij}} \tag{2}$$

where $\hat{x}_{ij}$ denotes the score of the j-th indicator of i-th evaluation object, n represents the number of evaluation object.

The formula (3) is used to calculate the entropy weight of each indicator.

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{m}(1 - E_j)} = \frac{1 - E_j}{m - \sum_{j=1}^{m} E_j} \tag{3}$$

2.2.2 The Conception of Theil Index

Theil index was originally used by economists to measure the income imbalance of samples within or between groups [12][13], and later was used to measure the imbalance of medical resources, which can be used for equity evaluation. As a traditional measurement of equity, Gini coefficient was mainly used to analyze the population distribution or geographical area distribution and medical resources distribution similarity. To measure the imbalance of resource distribution within or between regions, Theil index is introduced into the fairness evaluation. Theil index has the following expression:

$$T = \sum_{i=1}^{k} w_i \ln\left(\frac{w_i}{e_i}\right) \tag{4}$$

where w_i denotes the proportion of health resource indicators of the i-th provincial administrative region in the sum of provincial administrative regions, e_i represents the proportion of the population of the i-th provincial administrative region in the total population of each provincial administrative region.

2.2.3 Spatial Analysis

2.2.3.1 Spatial Autocorrelation Analysis

Spatial autocorrelation analysis is used to analyze that if there is spatial correlation, which means whether the distribution of medical resources relates to geographic position. Moran's I index is used in the research to analyze spatial correlation. Geoda was used in this research to calculate the Moran's I index.

2.2.3.2 Geographically Weighted Regression Analysis

Based on spatial autocorrelation analysis, we conducted the geographically weighted regression analysis. Compared with the traditional global regression analysis model, the geographically weighted regression analysis takes the influence of geographical location of the dependent variable into account, which makes the model more accurate in some cases and objectively reflects the influence of geographical location on the dependent variable [13][14].

3 RESULTS AND DISCUSSION

3.1 Result of TOPSIS Evaluation Method

According to the TOPSIS analysis method based on entropy weight, we obtained the weight of each index in the evaluation model from 2015 to 2019, and found that the number of primary medical institutions and the number of beds in medical institutions in various regions have the highest weight in the whole evaluation model. According to the weight of each evaluation index, we calculated the scores of 31 provincial administrative regions in the evaluation model from 2015 to 2019.

Since the results composed of the scores of each provincial administrative region from 2015 to 2019, it can be seen as time series data. Therefore, we use the method of weighted moving average in time series analysis to calculate the average of the data of different years in various provincial administrative regions. And the earlier the time is, the lower the weight is. The weights given by the evaluation results from 2015 to 2019 are 0.11, 0.11, 0.22, 0.22 and 0.33. Then the final evaluation score is obtained and sorted. The provincial administrative regions ranked top 10 are as follows (Fig.1).

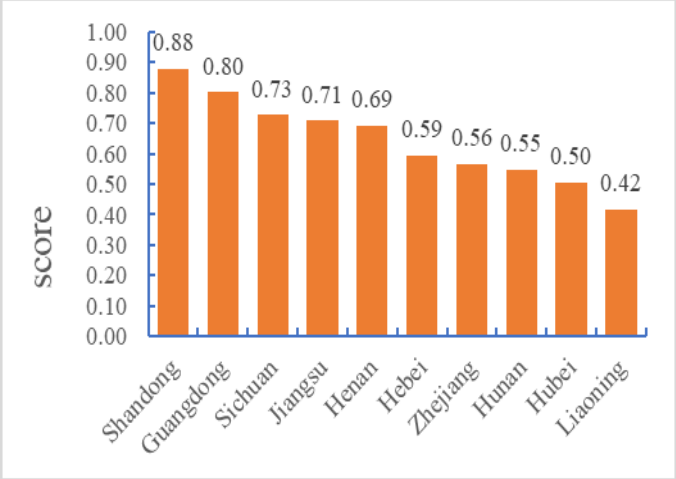

Figure 1. Results of TOPSIS evaluation

In order to analyze the spatial correlation of medical resources preliminarily, we clustered the provincial administrative regions according to the result in the evaluation model, the results are shown in the map (Fig.2). According to the clustering result, 31 regions can be clustered into three categories named area A, area B and area C. The provincial administrative regions represented by Jiangsu, Guangdong and Sichuan are regions of area A, and the provinces in area A have a high level in the number of hospitals, medical human resources and medical equipment resources, so they behave well in different aspects.

Figure 2. Result of cluster

Beijing, Shanghai, Tianjin, and Zhejiang, as the representative of the provinces for the area B, the provinces in the area B have good medical resources, but in terms of the per capita level, their resource is not abundant, although there are more tertiary hospitals, the number of top hospitals is more, but there is a certain gap in the total number of hospitals and the number of primary medical institutions, which is mainly due to its small provincial area. Taking Beijing and Shanghai as an example, although they both have more tertiary hospitals, but their provincial area is small, which leads to result that the number of primary medical institutions is small, but the resident population is still large, which eventually leads to the problem that large amount of people sharing limited medical resources. And the provinces represented by Xinjiang and Tibet belong to C regions, and the level of medical resources is low. From the geographical distribution point of view, the medical resources in the eastern region are more perfect than that in the western region, and the distribution of medical resources has a certain spatial aggregation, especially in the southern North China, eastern China, northern South China, and Sichuan.

3.2 Analysis of Equity Based on Theil Index

3.2.1 Result of Theil Index

Based on the above analysis, Theil index was introduced to conduct equity evaluation analysis. Based on the results of TOPSIS evaluation analysis, the research calculated the Theil index of each evaluation index in 31 provinces from 2015 to 2019 (Table 1).

Table 1 Theil index of evuation index

Year	2015	2016	2017	2018	2019
Comprehensive strength	0.0468	0.0167	0.0161	0.0160	0.0153
Hospitals	0.0467	0.0481	0.0453	0.0419	0.0424

Tertiary hospitals	0.0635	0.0631	0.0632	0.0628	0.0597
Secondary hospitals	0.0472	0.0478	0.0424	0.0398	0.0396
Primary health institutions	0.0599	0.0594	0.0591	0.0579	0.0583
Health care personnel	0.1485	0.0105	0.0098	0.0095	0.0090
Practicing physicians	0.1693	0.0180	0.0171	0.0171	0.0160
Registered nurses	0.1184	0.1489	0.0111	0.0104	0.0100
Doctors in community health center service	0.1527	0.1489	0.1453	0.1416	0.1359
Doctors in primary medical institutions	0.0112	0.0090	0.0081	0.0086	0.0091
Doctors in township hospitals	0.0390	0.0385	0.0383	0.0434	0.0436
Beds in medical institutions	0.0075	0.0080	0.0083	0.0088	0.0089

According to the definition of Theil index, if the Theil index is closer to 0, it means that the equity of China' s medical resources is higher. It can be seen from the results that the equity of comprehensive level of medical resources in China is higher. From the perspective of time, the equity of medical resources in China has always maintained a relatively stable state.

After comparing the medical institutions resources, medical human resources and medical facilities resources, we found that the Theil index value of medical facilities resources is the smallest, the Theil index value of medical and health institutions resources is the second, and the Theil index value of medical and health human resources is the largest, which indicates that the equity of medical facilities resources is the best, and the equity of human resources is the worst.

According to the Theil index value of various indicators measuring human resources in health care, it is found that the equity of the number of nurses is better than that of practicing physicians. The equity of the number of doctors in primary medical institutions is good, and among the indicators representing primary medical resources, the equity of the number of doctors in township health centers is higher than that in community health centers.

According to the Theil index value of various indicators to measure the resources of medical institutions, it is found that the equity of secondary hospitals is the best, while the equity of tertiary hospitals is poor, and the fairness of primary health institutions is moderate.

3.3 Spatial Analysis

Equity analysis based on Theil index mainly focuses on the equity of population and the differences between regions. In order to measure the spatial fairness of medical resources and

the correlation between medical resources and geographical location better, our research introduced spatial autocorrelation analysis and geographical weighted regression model.

3.3.1 Spatial Autocorrelation Analysis

Before spatial analysis, it is necessary to prove whether the equity of medical resources will be affected by geographical location. Therefore, spatial autocorrelation analysis is needed first. In our research, Geoda was used to calculate the Moran 's I index (table 2). According to the calculation results, the Moran 's I index of from 2015 to 2019 are not equal to 0. Therefore, it can be proved that there exists spatial correlation between the distribution of medical resources and geographical location in China. Therefore, the next step of geographical weighted regression analysis is reasonable.

Table 2 the result of Moran's I index

Year	2015	2016	2017	2018	2019
Moran's I	0.141	0.135	0.123	0.107	0.111
P value	0.057	0.069	0.08	0.1	0.093

3.3.2 Geographical Weighted Regression

To analyze the factors whom influences the distribution of medical resources in China and improve the equity of medical resources, this paper takes the distribution of medical resources in China as the dependent variables, and takes the life expectancy and medical costs of various regions as the independent variables for geographically weighted regression analysis. Since the geographical distribution of medical resources in China has not changed significantly in different years, this paper only used the data of 2019 for analysis, and similar results can be obtained in other years. Our research used Python to conduct geographically weighted regression and the regression coefficients of each variable are shown in the next figure (Fig.3 and Fig.4).

Figure 3. Regression coefficient of population life expectancy

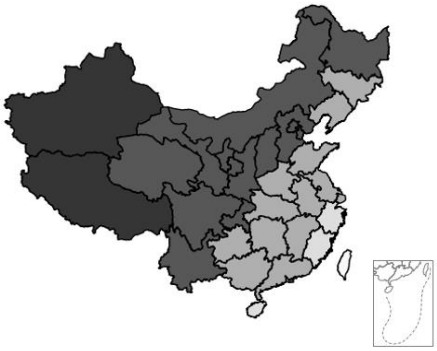

Figure 4. Regression coefficient of medical costs

According to the analysis results, the regression coefficients of population life expectancy and medical expenditure in each province are positive, and the regression coefficients of the total health expenditure which can reflect the economic input in each province further indicates that there is a positive correlation between population life expectancy and economic input and the level of medical resources.

Geographically, the correlation between population life expectancy and medical resources shows a trend of increase from northeast to southwest. As an indicator reflecting the health of the population, population life expectancy has a positive interaction with the level of medical resources. The higher the medical level is, the higher the population life expectancy is, and the population life expectancy will also have an interaction on the level of medical resources. The higher the population life expectancy is, the higher the demand for high-level medical resources is, thus promoting the demand of medical resources.

The correlation between economic input and medical resources is gradually increasing from southeast to northwest, and the correlation between economic input and medical resources level in the northwest province represented by Xinjiang and Tibet is higher, which further shows that when each province can increase the same economic input, the development of medical resources level in the northwest region is more obvious.

4 CONCLUSIONS

4.1 There Exists Spatial Aggregation of Medical Resources in China

Overall, the medical resources in the eastern region of China are much better than that in the western region. At the same time, there exists spatial aggregation of medical resources in China. According to the characteristics of medical resources in various regions, it can be found that China 's medical resources can be divided into three area with different characteristics. The first area represented by Guangdong and Jiangsu have a high level of medical resources. The second area represented by Beijing, Shanghai and Tianjin have many high-level medical

institutions, while primary medical institutions need to be improved. The medical resources of the last area represented by Xinjiang and Tibet are weak.

4.2 Equity of Physical Resources is Higher than that of Human Resources in Medical Resources in China

Medical facilities resources and human resources are material resources. The controllability of physical resources is strong, so the equity of physical resources can be improved through macro-control. The mobility of human resources is strong, the controllability is weak, and for the factor that health technicians are more willing to choose good wages and comfortable working environment it is easily affected by the subjective intention of health technicians.

Our country has taken practical action to improve the equity of medical resources, which has improved the equity of material resources, while human resources are difficult to control.

4.3 There Exists Spatial Autocorrelation in Equity of Medical Resources in China

It is found that the equity of medical resources in China is affected by geographical location. In order to analyze the influencing factors furtherly, this paper conducts geographically weighted regression analysis. Through the analysis, it is found that there is a positive correlation between the medical expenditure, the life expectancy of the population in each region and the level of medical resources. The higher the economic input is, the higher the level of medical resources is. At the same time, the correlation between population life expectancy and medical resources gradually increases from northeast to southwest, so the correlation between economic input and medical resources gradually increases from southeast to northwest. After looking up relevant literature, it is found that similar conclusions have not been drawn in previous studies.

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