Empirical Spatial Analysis on Fairness of Health Resource Allocation

Zai-Xiang WANG¹,²,a,*, Xiao-Di LIU¹,b and Jing ZHAO¹,c

¹Academy of Public Health, Weifang Medical University, Weifang, Shandong, China
²The Co-Innovation Center of Prediction and Management of Major Social Risks for Healthy Shandong, Weifang Medical University, Weifang, Shandong, China

awangzx@wfmc.edu.cn, b1103191577@qq.com, c969083548@qq.com

*Corresponding author

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Abstract. The paper aims to establish the method to evaluate the demographic fairness, regional fairness and comprehensive situation of health resource allocation and carry out the empirical analysis. With the DEA (Data Envelopment Analysis) method. According to the principle of the Gini coefficient, we established regionalized variables to evaluate demographic fairness and regional fairness of health resource allocation and performed the spatial analysis and evaluation with related spatial analysis methods and ArcGIS software. We analyzed and evaluated the demographic fairness, regional fairness and comprehensive situation of the allocation of health resources in Shandong Province in 2014. The demographic fairness was optimal in Zibo, Dongying, and Weihai and the regional fairness was optimal in Zibo and Jinan. The overall health resource allocation in Shandong Province is in the radial pattern with two centers of Zibo and Jinan. Allocation of health resources is a multidimensional comprehensive problem which is closely related to various factors, such as economy, population, and regional development space. Compared with the conventional analysis methods, the combination of spatial analysis methods and ArcGIS software can reveal the advantages and disadvantages of health resource allocation.

Introduction

Allocation of health resources is the basis of the sustainable development of health industry [1]. Since health resources are limited in each country and region, efficient, rational, and fair allocation of health resources has gained the worldwide attention.

With the development in economy and technology, health awareness is enhanced and the demands for health services are increased. Efficient, rational, and fair allocation of limited health resources can effectively meet the demands for the medical and health services. The medical and health service is people’s major basic demands and one of the key health indicators in the evaluation system by world health organization (WHO) [2].

China’s health care policy is recognized as “the health care project with the widest coverage on the earth”. China has solved the health care problem of 22% of the world’s population with 2% of the world’s health resources [3-4]. After years of development, China and the world economic situation and patterns have been changed significantly. A variety of medical and health problems have appeared although Chinese medical and health budget is largely increased. Especially, various defects occur in the fairness of the distribution of medical and...
health resources. Therefore, it is necessary to re-examine and review the distribution of health resources and services.

In recent years, the spatial analysis method shows the unique advantages in the health evaluation field. Some scholars applied the spatial analysis method in the health service, health management decision making, and epidemiology and achieved good results [4-6]. In this paper, considering three factors of the demographic fairness, regional fairness of health resource allocation, we established regionalized variables and comprehensively evaluated health resource allocation in Shandong Province, China with the spatial statistical analysis method and ArcGIS spatial analysis software. In this paper, health resource allocation problem was comprehensively evaluated from various perspectives and the Gini coefficient was decomposed to establish regionalized variables for analyzing relative fairness and spatial distribution.

**Materials and Methods**

**Materials**

The study object is the allocation status of health resources in Shandong Province, China. The original evaluation indicators of health resource allocation fairness include population, city area, and the main indicators of health resources including health agency quantity, bed quantity, and professional health personnel quantity. The data are mainly from Shandong Statistical Yearbook in Shandong Province, China from 2008 to 2014. Comprehensive evaluation layer data are from the national fundamental geographic information system of China. The main layers are mainly the vector data layer of the administrative area of Shandong Province, Layer projection is the Lambert Conformal Conic projection.

**Methods**

**Fairness Regionalized Variable.** Fairness regionalized variable of health resource allocation was constructed from the basic principles of the Gini coefficient to describe the demographic or regional fairness.

The Gini coefficient is a comprehensive evaluation index of the internal income difference among residents, as shown in Fig. 1.

![Figure 1. Gini coefficient diagram.](image)
Gini coefficient is calculated as:

\[ G = \frac{A}{A+B}, \]  

(1)

where \( A \) is the area of the part enclosed with Line \( a \) (Line of absolute equality) and Curve \( b \) (Lorenz curve). \( B \) is the area of the part enclosed with Line \( c \), Curve \( b \), and horizontal axis.

Area \( A \) can be decomposed into corresponding regional areas \( S_i (i=1, 2, \ldots, m; \ m \ is \ the \ number \ of \ regions) \) as:

\[ A = \sum_{i=1}^{m} S_i. \]  

(2)

Thus the Gini coefficient can be decomposed into:

\[ G = \frac{A}{A+B} = \sum_{i=1}^{m} \frac{S_i}{A+B} = \sum_{i=1}^{m} H_i', \]  

(3)

where \( H_i' (i=1, 2, \ldots, m) \) is the contribution rate of each region to the province’s Gini coefficient and represents a relative fairness degree in the study area. It is also an initial regionalized variable for evaluating regional relative fairness.

Considering demography and geographical features, we selected the vertical axis to indicate the cumulative percentage of the health resources in regions and the horizontal axis to indicate the cumulative percentage of the population or geographic in corresponding area for the calculation of the Gini coefficient in the province in our previous study. According to Eq. (3), with regional data of health resources, initial indicators \( H_i' \), which can measure demographic or regional relative fairness degree of each region, can be obtained. \( H_i' \) is divided into 5 levels according to natural breaks (jenks) classification method in the ArcGIS software to get \( H_i \) which can measure demographic or regional relative fairness degree of each region. The higher the level of \( H_i \) is, the higher the relative fairness degree is.

Finally, the regionalized variables of demographic and geographical fairness were calculated as follows:

\[ R_{\text{region}}' = \kappa_1 H_1 + \kappa_2 H_2 + \kappa_3 H_3, \]  

(4)

\[ R_{\text{people}}' = \mu_1 H_1 + \mu_2 H_2 + \mu_3 H_3, \]  

(5)

where \( H_1 \) represents the relative fairness degree level of the quantity of health institutions per one thousand population (one square kilometer); \( H_2 \) represents the relative degree level of bed number per one thousand population (one square kilometer); \( H_3 \) represents the relative fairness degree level of the quantity of technical health personnel per 1000 population (one square kilometer); \( \mu_1, \mu_2, \mu_3, \kappa_1, \kappa_2, \) and \( \kappa_3 \) are weight coefficients.

The initial fairness regionalized variables \( (R_{\text{people}}' \ and \ R_{\text{region}}' \) of each region were calculated. Then, according to the breaks classification method, regional variables were divided into 5 levels and the levels of fairness regionalized variables \( (R_{\text{people}}' \ and \ R_{\text{region}}' \) were obtained. It is concluded that the large level of fairness regionalized variables \( (R_{\text{people}}' \ and \ R_{\text{region}}' \) indicate the higher level and the higher fairness degree.

**Comprehensive Regionalized Variable.** With health resource allocation demographic fairness, regional fairness data of regionalized variable in the ArcGIS database, the
comprehensive evaluation index variable of health resource allocation, Z values, was calculated as follows:
\[ Z = \omega_1 R_{\text{people}} + \omega_2 R_{\text{region}}, \]  
(6)
where \( \omega_1, \omega_2 \) are weight coefficients.

The calculated results of this study are given in SAS8.1. Result images were presented in ArcGIS 10.0.

**Weight Coefficient of Comprehensive Evaluation.** Firstly, 10 health management experts or relevant experts were selected randomly from various regions to score the important degrees of demographic fairness, regional fairness of health resource allocation, the important degrees of demographic fairness, regional fairness of health resource allocation can be as:
\[ R_{\text{region}} = 0.35H_1 + 0.35H_2 + 0.37H_3, \]  
(7)

**Weight Coefficient of Fairness Evaluation.** According to the above method, demographic and regional fairness for the allocation of health resources formula can be calculated as follows:
\[ R_{\text{people}} = 0.35H_1 + 0.35H_2 + 0.23H_3 + 0.37H_4, \]  
(8)

**Fairness Spatial Analysis of Health Resource Allocation**

In this paper, health resource allocation data in Shandong Province in 2014 were selected for spatial analysis and discussion.

**Demographic Fairness Analysis of Health Resource Allocation**

According to Eq. (8), demographic fairness spatial analysis of health resources allocation was performed in ArcGIS10.0. The results are shown in Fig. 2. In Shandong Province, the demographic fairness distribution of health resources is optimal in Rizhao, Laiwu, Dongying, and Zaozhuang, and the worst in Heze, Jining, and Jinan. The most significant difference occurs around Laiwu. In the general demographic fairness distribution layout pattern of health resources, health resources are decreased from north to south and increased from west to east. The pattern is related to the level of economic development of each region. The regions with the high economic development level and large population occupy the large quantity of health resources, while the quantity of health resources in the less developed region is relatively less.

![Figure 2. Demographic fairness classification of the allocation of health resources.](image-url)
Regional Fairness Analysis of Health Resource Allocation

According to Eq. (9), regional fairness spatial analysis of the allocation of health resources was performed in ArcGIS10.0. The results are shown in Fig. 3. In Shandong Province, the regional fairness distribution of health resources is optimal in Rizhao and Heze and the worst in Dezhou, Laiwu, Jining, and Linyi. The most significant difference occurs around Jinan and Zibo. The overall layout pattern is the radial shape with the center of Zibo. In the general regional fairness distribution layout pattern of health resources, health resources are decreased from north to south and increased from west to east. Compared with the results of demography, the overall decreasing trend is more obvious in the direction from north to south.

![Figure 3. Geographic fairness classification of the allocation of health resources.](image)

Comprehensive Evaluation Spatial Analysis of Health Resource Allocation

According to Eq. (7), comprehensive evaluation spatial analysis of the health resource allocation was performed in ArcGIS10.0 and shown in Fig. 4. In Shandong Province, the comprehensive evaluation of health resource allocation is optimal in Dongying and Rizhao and the worst in Binzhou, Linyi, and Jining. Health resources are accumulated around Jinan and are significantly more than that in other regions, showing the decreasing trend from north to south.

![Figure 4. Comprehensive evaluation classification of the allocation of health resources.](image)

Discussion

The relative demographic fairness degrees of health resource allocation are high in Rizhao, Laiwu, Dongying, and Zaozhuang. In 2014, the population in the above 4 cities accounted for 10% of the total population in Shandong Province and GDP in the above 4 cities accounted for
14% of the total GDP in Shandong Province. The population proportion was less than the proportion of GDP in Shandong Province [10]. In the above 4 cities, the economic level and consumption level are relatively high and the profit of private health institutions is high. Therefore health resources are rich. Therefore, the fairness of health resource allocation in the above 4 cities is better than that in other regions. However, the population in Heze, Jining, and Jinan accounted for 24% of the total population in Shandong Province and GDP in Heze, Jining, and Jinan accounted for 20% of the total GDP in Shandong Province. In Heze, Jining, and Jinan, the population proportion was more than the proportion of GDP in Shandong Province.

The regional fairness of health resource allocation is closely related to the region area and the economic development level. The differences in economic development level among different regions are large and the fairness is generally low in the regions with the large area, such as Linyi and Jining. If the level of economic development is higher, government can put more money into the health service, and pay more attention to fairness. At the same time, Linyi and other cities are around mountains with complex terrain. Therefore, it is difficult to establish health institutions.

The economic development levels in Qingdao and Jining are absolutely different, but the overall evaluation is almost the same. The difference may be interpreted in two aspects. Firstly, the weight coefficient calculated with the principal component analysis method shows the large deviation. Secondly, government sectors focus on demographic fairness and regional fairness.

In general, the overall allocation of health resources is not reasonable in Shandong Province. Health resources are mostly concentrated in the economically developed regions, such as Jinan, Zibo and Weifang and spread to the surrounding regions. The internal structure of the allocation of health resources is not rational and there is a big optimization space. Therefore, government should adjust the layout, make scientific configuration, and design scientific plans to improve the fairness of health resource allocation.

The analysis method in this study showed some advantages and difficulties. The allocation of health resources is a multidimensional space question closely related to factors, such as economy, population and regional development. Through the combination of the spatial analysis method and ArcGIS software, the evaluation results are shown in visual images, which can reveal the reasonable and deficiencies in the spatial layout of health resources and offer more information. The combination of the spatial analysis method and ArcGIS software has greater advantages and application prospect than traditional statistical methods. Its application difficulty lies in the selection, establishment, and regionalized quantification of evaluation indicators as well as the determination of evaluation equations.

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