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Spatial Correlation Analysis on the Resource Allocation Efficiency of Regional Higher Education in China

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Abstract

This analysis may promote the regional development of higher education, resolve problems associated with inadequate resources, and improve efficiency of resource allocation. In this study, we examined the efficiency of resource allocation for higher education in 31 Chinese provinces using data envelopment analysis (DEA); spatial correlation was used concurrently for analytical purposes. Our aims through this study are to promote the optimal allocation of resources and healthy development of higher education.

Keywords: *Higher education; resource allocation; efficiency; spatial correlation*

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Introduction

With the rapid development of higher education in China, the contrasting deficiencies in adequate resources have become increasingly problematic. In fact, the contradiction between the unlimited growth potential for higher education and the limited availability of relevant resources has become a major handicap for sustainable development. Therefore, we have reexamined the current allocation of resources from the angle of theory and practice to determine if it is reasonable and feasible. More importantly, we attempted to identify the fundamental cause of inefficient allocation of educational resources to provide a reliable basis for countermeasures.

Furthermore, differences in resource allocation for higher education exist based on regions in China, so a reasonable approach to distribution of limited educational resources to the most appropriate locations will maximize social benefits and meet the social demand for higher education. China's National Plan for Medium and Long-term Educational Reform and Development clearly focuses on improvement of the quality quantity, structure, and benefits of higher education that should be balanced in the future, especially in the middle and western regions, which are key areas for coordinated regional development of higher education. As the Chinese government and communities pay more and more attention to the country's educational system, allocation efficiency of resources is an important indicator of their commitment to higher education. However, the output of education in many aspects is difficult to measure; likewise, it is relatively difficult to measure the allocation efficiency of educational resources.

For this study, we measured and analyzed the allocation efficiency of China's regional resources for higher education and then conducted a correlation analysis of the super-efficiency values of spatial resources to provide information about their allocation for researchers and promote the optimization of regional resource allocation and interactive development between higher education and regional economies.

Analysis of regional resource allocation efficiency of higher education

2.1 Research methodology

Data envelopment analysis (DEA), put forward by A. Charnes, W. Cooper and E. Rhodes(1978), evaluates relative validity of a method based on the concept of relative efficiency; it is used to evaluate the efficiency of decision-making units with various input/output combinations according to a mathematical programming model. It directly uses unit inputs and outputs of samples to build a mathematical model for efficiency measure. To make up for shortcomings in efficiency among the decision-making units that cannot be directly compared by the DEA's C^2R model, Andersen and Petersen (1993) proposed an ultra-efficiency model to compare efficiency among units. The basic idea behind ultra-efficiency models is the decision-making unit will be excluded from the set of the decision-making units during the evaluation of the efficiency. Therefore, the frontier of its production of a decision-making unit that does not meet DEA efficiency will not change, and the efficiency value will be the same as that calculated by the C^2R model; for effective decision-making units in DEA, the production possibilities frontier will move backwards, resulting in a calculated efficiency value that is greater than that calculated by the C^2R model. Based on this basic idea, the ultra-efficiency model can be expressed as:

$$\begin{aligned} &\mathrm{Min}_{\lambda,\theta}\theta \\ &\text{s.t.} \\ &\sum_{j=1}^{n} x_j\lambda_j \le \theta x_0 \\ &\sum_{j=1}^{n} y_j\lambda_j \ge y_0 \\ &\lambda_j \ge 0 \quad j=0,1,2,,,k\text{-}1,k\text{+}1,,,n \end{aligned}$$

For an inefficient decision-making unit, estimated results of efficiency were consistent with the C^2R model results. The efficiency values for the effective decision-making unit were generally $\theta > 1$, which indicates that at its inputs while increasing θ ratio of θ–1. The decision unit appeared to remain relatively effective within the collection; that is, the efficiency value was still maintained at one (1) or more.

2.2 Sample selection and data description

Efficient allocation of resources is based on less manpower and consumption of material and financial resources to realize the full functions of higher education (i.e., talent training, scientific research, and social services). Based on the above considerations, the Regional Higher Education Resource Allocation Efficiency Measurement Index System was constructed, as shown in Table 1. Regional institutions of higher education that provided input/output resource data for 31 provinces from 1998 to 2006 were selected from the *China Statistical Yearbook (1998-2006)*, *Educational Statistics Yearbook of China(1998-2006)*, *China Statistical Yearbook on Science and Technology(1998-2006)*, and *China Statistical Yearbook of Education Funding(1998-2006)*. To reflect the real situation of higher education resource allocation in China, the GDP deflator index was adopted to adjust the data in this paper and eliminate price factors. EMS analysis software was used to calculate ultra-efficiency values of regional higher education resource allocation.

Table 1. Regional higher education resource allocation efficiency measurement index system

Index level	Specific targets and symbols	Indicator description
Educational resource inputs index	Campus Staff (person) X1	Human resource input factors
	The end of the total value of fixed assets (thousand) X2 The end of book number of copies (thousand) X3	Reflection of the material resources in the elements of index
	Education expenditure (thousand) X4	Reflection of financial resources (input factors)
Educational resource outputs index	The specialist in the number of students (person) Y1	Reflection of training personnel functions
	Scientific and technological activities to raise the amount (million) Y2 Research and development expenditure (million) Y3	Reflection of scientific research functions
	Technology services number of projects Y4	Reflection of social services functions

2.3 Results of analysis of the efficiency measure

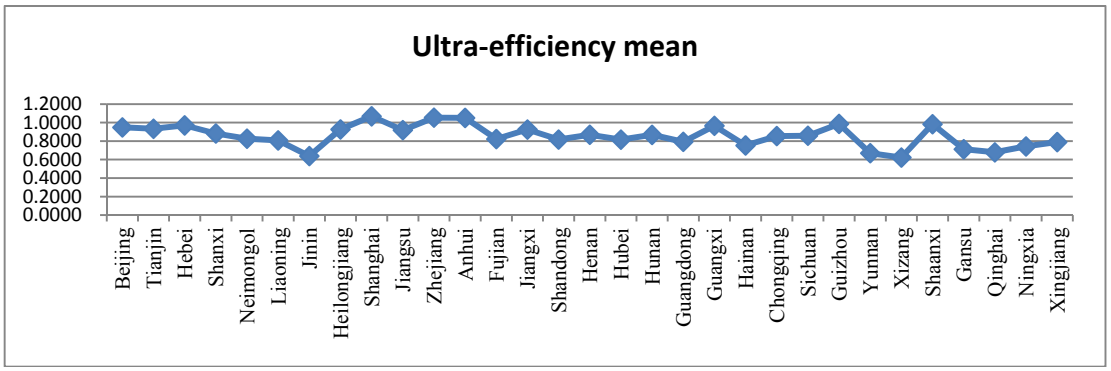

Figure 1. 1998–2006 Ultra-efficient means of higher education resources by province

For this paper, the super-efficiency values of higher education resource allocation for 31 provinces between 1998 and 2006 were obtained through the DEA method. It can be seen from Figure 1 that the vast majority of the average values were less than 1 (< 1), indicating that regional higher education resource allocation efficiency is not presently high in China. Findings are consistent with the configuration of educational resources planned mainly by the Chinese government Compared to 1998, however, provincial resource allocation efficiency in 2006 has improved, mainly because it supports China's initiative for higher education system innovation and reform. The efficiency values in 1999 were lower than in 1998, mainly because of the expansion of higher education that caused a decrease in configuration efficiency. At the same time, there were substantial differences in the configuration

efficiency among regions (i.e., eastern and western regions). The configuration efficiency in the eastern region was significantly higher than in the western region, and the Shanghai region had the highest value (> 1). Allocation of higher education resources super-efficiency values were low in Inner Mongolia, Liaoning, Jilin, Hainan, Yunnan, Tibet, Gansu, Qinghai, Ningxia, Xinjiang, and particularly in Tibet (where resources were at the lowest level and allocation efficiency was the lowest). However, the average efficiency values in Shaanxi and Guizhou Provinces in the western region were higher, indicating that higher education resource allocation in these provinces was more reasonable, providing a reference for other regions**.**

Spatial dependence analysis of resource allocation efficiency of regional higher education

3.1 Introduction of the theoretical method

Since the early 1990s, spatial thinking has gradually been accepted by mainstream economists, based on the influence of Paul Krugman and others. Spatial correlation research can help us further measure regional agglomeration economies (Goodchild, 2000). Exploratory spatial data analysis (ELDA) is an econometrics model for analyzing regional dependence and spatial correlation on the premise of the data without any a priori theory or hypothesis; combination methods using principles of statistics and maps, charts/graphics, and visualization technology are used to put forward a hypothesis (Anselin; 1995, 1996) through identification, analysis, and induction of the nature of spatial data.

3.1.1 Global Moran's I Index

In the field of spatial econometrics, Moran's I Index is used to detect the spatial correlation, as shown below (Moran, 1950):

$$\text{Moran's I} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}} \quad (1)$$

where $S^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x}_i)$; $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_j$; n is the total number of regional units; x_i and y_i respectively reflect regional observations; and W_{ij} is the spatial weight matrix element.

$$W_{ij} = \begin{cases} 1 & \text{When the regional i and j adjacent} \\ 0 & \text{When regional i and j are not adjacent} \end{cases}$$

i = 1,2,…,n; j = 1,2,…,m;

Moran's I value must range from −1 to 1; a value greater than 0 is a positive correlation and a value less than 0 is a negative correlation. The higher the value, the greater the spatial distribution. When the value is close to 0, the spatial interaction between variables is not obvious.

3.1.2 Local Moran's I index

Local Moran's I is defined as follows:

$$I_i(d) = Z_i \sum_{j \neq i}^{n} w'_{ij} \; Z_j \quad (2)$$

where Z_i is the standardized transformation of x_i $Z_i = \frac{x_i - \bar{x}}{\sigma}$, w'_{ij} is the standardized weight matrix (per line add up to of l), asymmetric.

3.2 Spatial correlation test

This study adopted the ultra-efficient value for higher education resource allocation from the 31 provinces, municipalities, and autonomous regions in China (excluding Hong Kong, Macao, and Taiwan regions) in 1998 and 2006.

3.2.1 Spatial distribution of higher education resource allocation efficiency on sub-bitmap

Spatial distribution of resource allocation efficiency in 1998 and 2006 is shown in sub-bitmaps in Figure 2 (deeper color indicates a higher level of efficiency), one graph as 1998 and the other as 2006.

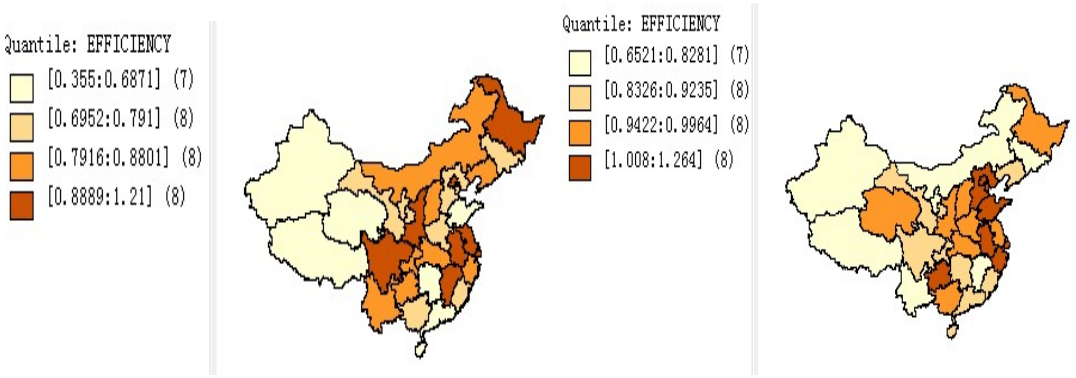

Figure 2. 1998 and 2006 higher education resource allocation efficiency (spatial)

As Figure 2, in this figure, label one map 1998 and the other 2006shows, the areas with the highest resource allocation efficiency for higher education in 1998 and 2006 were the eastern and middle regions; efficiency was relatively high in the southwestern region of Guizhou in 2006, indicating a reasonable configuration. Resource allocation efficiency was lowest in most of the western region. Overall, resources for higher education were more prevalent in the eastern region due to its geographical location and rapid economic development. Additionally, abundant human resources and intellectual capital for economic development had an impact on resource allocation efficiency in these areas. In recent years, deepening reform resulted in an increase in the quantity of resources for higher education in the central region, but the yield structure was unreasonable and caused lower allocation efficiency; thus, the push for educational development did not appear to have a noticeable effect on the economy. In contrast, a large gap existed in access to and application of resources between regions, which resulted in lower resource allocation efficiency for higher education, especially in the western region.

Used the EMS analysis software to calculate ultra-efficiency values of regional higher education resource allocation for 31 provinces in 1998 and 2006 are shown in Table 2.

Table 2. Ultra-efficient value of regional allocation of resources for higher education in 1998 and 2006

Region	1998	2006	Region	1998	2006	Region	1998	2006
Beijing	0.8889	1.0081	Anhui	0.9717	1.0727	Sichuan	0.9574	0.8864
Tianjin	0.7088	1.2642	Fujian	0.7401	0.8417	Guizhou	0.8111	1.0213
Hebei	0.7104	1.0166	Jiangxi	0.9631	1.1013	Yunnan	0.7916	0.7401
Shanxi	0.8375	1.0507	Shandong	0.6264	0.9422	Xizang	0.3550	0.6985
Neimongol	0.8492	0.8386	Henan	0.7060	0.9747	Shaanxi	0.9676	0.9964
Liaoning	0.8396	0.8281	Hubei	0.8541	0.9905	Gansu	0.6952	0.8326
Jinin	0.7066	0.7419	Hunan	0.6817	0.8803	Qinghai	0.5678	0.7098
Heilongjiang	0.9491	0.9469	Guangdong	0.5624	0.9235	Ningxia	0.7008	0.6521
Shanghai	1.2098	1.0917	Guangxi	0.7910	0.9477	Xingjiang	0.4772	0.8012
Jiangsu	0.9778	0.9634	Hainan	0.4936	0.8763			
Zhejiang	0.8518	1.0303	Chongqing	0.8801	0.8866			

3.2.2 Moran's I Index of higher education resource allocation efficiency

Based on the super-efficiency data of higher education resource allocation in China and spatial correlation, Moran ' s I Index values of allocation efficiency in China’s 31 provinces from 1998 to 2006 are shown in Table 3.

Table 3. Moran's I Index for 1998–2006 higher education resource allocation efficiency

Period (year)	Moran's I	P-value	Mean	SD
1998	0.2523	0.0100	-0.0383	0.1043
1999	0.2518	0.0100	-0.0178	0.1085
2000	0.1770	0.0460	−0.0336	0.1098
2001	0.2543	0.0090	−0.0360	0.1089
2002	0.1613	0.0620	−0.0340	0.1157
2003	0.1692	0.0460	−0.0367	0.1130
2004	0.1613	0.0470	−0.0343	0.1122
2005	0.2509	0.0170	−0.0287	0.1179
2006	0.3482	0.0020	−0.0354	0.1086

From Table 3, it can be seen that the global spatial correlation of higher education resource allocation efficiency in China was remarkable because the results of Moran's I Index calculations can be observed. The large values in 2005 and 2006 indicate a deepening spatial dependence of allocation efficiency in China; simultaneously, regional autocorrelation indicates elevated intensity.

3.2.3 Analysis of local spatial autocorrelation

The Moran Scatterplot (Figure 3) and a LISA map further describe higher education resource allocation efficiency through spatial correlation. In the LISA map, High-High and Low-Low performance represent positive local correlation based on typical spatial agglomeration. High-High refers to a high-value cluster, while Low-Low refers to a low-value cluster. High-Low and Low-High clusters are indicative of negative local spatial autocorrelation (also known as spatial outliers).

Based on the Moran's I Index values of allocation efficiency in China's 31 provinces from 1998 to 2006. The Moran Scatterplot for 1998 and 2006 higher education resource allocation efficiency are showed in Figure 3 one graph as 1998 and the other as 2006.

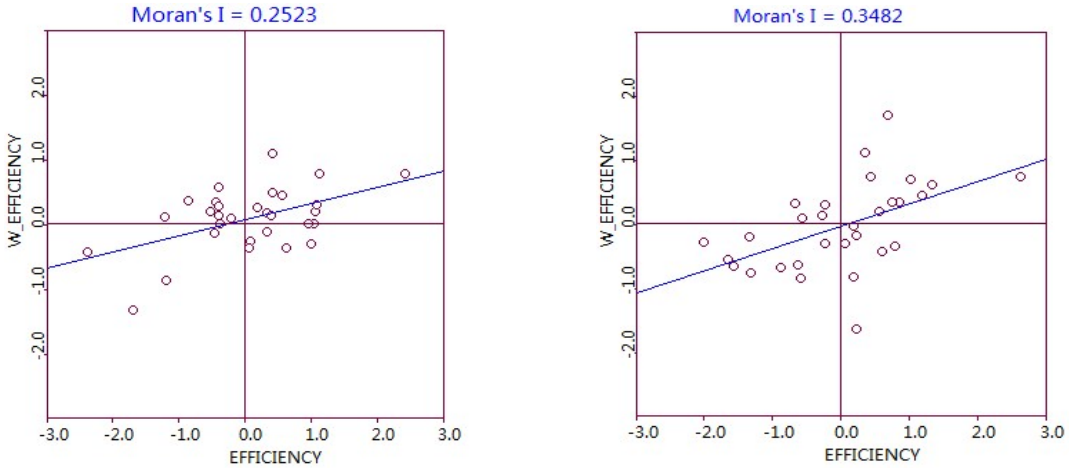

Figure 3. Moran Scatterplot for 1998 and 2006 higher education resource allocation efficiency

In order to better describe the higher education resources allocation efficiency of spatial correlation, we draw the following LISA space maps in Figure 4 one graph as 1998 and the other as 2006.

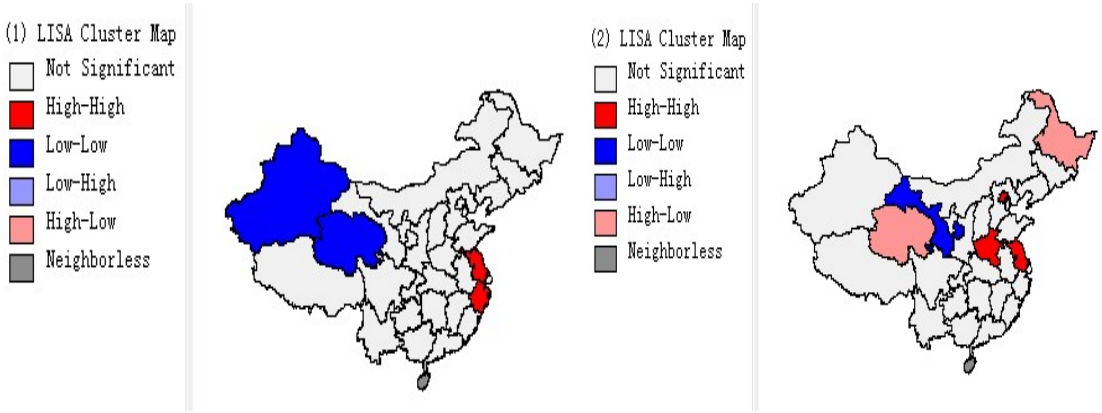

Figure 4. LISA space maps for 1998 and the 2006 higher education resource allocation efficiency in China

From Figure 4, it can be seen that most provinces are located in the first and third quadrants belonging to the High-High and Low-Low concentration clusters; these results indicate a positive spatial correlation for similarity of values. We can also see from the figure that the spatial structure of the local agglomeration of China's higher education resource allocation efficiency does not present an obvious correlation in most areas, although a few provinces in the western area belong to the Low-Low concentration cluster and the eastern areas belong to the High-High concentration cluster. Our findings showed that in contrast to 1998, Xinjiang was not in the Low-Low value cluster in 2006; at the same time, Anhui joined the High-High cluster, and Heilongjiang and Qinghai joined the High-Low cluster.

The correlation between Hainan and other areas was not strong due to its geographical location (on an island) and transportation infrastructure. Upon inspection, the global autocorrelation index was significant, but Figure 4 shows that partial area didn't exist local autocorrelation, and global autocorrelation was mainly caused by the local autocorrelation. There was local correlation for a few areas in China because of the complex spatial structure. In the western region, a local positive correlation was present for Xinjiang and Qinghai in 1998, but not in 2006; thus, resource allocation efficiency of higher education in the western region had improved because of educational reform. The efficiency of spatial variability also illustrated the existence of spatial heterogeneity.

Conclusions

In order to evaluate effectively the resource allocation efficiency of higher education in China, the DEA method was used for measurements in 31 provinces from 1998 to 2006; super-efficiency values according to region were also analyzed in this paper. By using exploratory spatial data analysis (ESDA) technology, the spatial correlations of resource allocation efficiency among regions in 31 provinces from 1998 to 2006 were empirically analyzed. Results indicated that resource allocation efficiency for higher education in China had a significant spatial correlation, so geographical effects should not be ignored in such analyses because they provide theoretical and empirical evidences for education reform. The large gap among eastern, middle, and western regions indicated that efficiency in the western region was lower than in the eastern region, so regional differences in resource allocation should be fully considered in efforts to achieve the balanced development of higher education. The allocation mechanism of balance should be established to narrow gaps in social, economic, and educational development levels in different regions and promote the coordinated development of higher education.

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