An improved algorithm of the spatial coordination analysis on higher education resources and employment population

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Abstract. The traditional evaluation criteria of coordination analysis were based on the classification of fixed interval index. Clustering methods serve to redefine the criteria and improve the accuracy of the coordination analysis. The improved algorithm was adopted to analyze the spatial coordination between Chinese higher educational institutions and employment population. It was discovered:1.The regional imbalance of the higher educational institutions was less serious than that of the employment population;2.Although the coordination level of developing regions in the south-central and north-east was lower than that of western border and eastern coastal regions, all those regions globally maintained a high level of coupling and coordination; 3. Inclusive regional development strategies could be adopted to optimize the coordination between education and employment.

Keywords: Spatial coordination analysis, Higher education, Employment population.

1 Introduction

The efficient interaction between the higher educational institutions and the employment population is the solution to the contradiction between the needs of social development and the imbalanced development of higher educational institutions in the process of educational modernization. In the traditional research regarding the distribution of the higher educational institutions, scholars mainly used correlation analysis methods to address the causal relationship among the number of the higher educational institutions, employment population, GDP and other variables. However, the number of educational institutions changes in the process of the education system evolution, while employment population is related to the variables such as population base, economy and industry. Therefore, the higher educational institutions and the employment population are two separated subsystems, each of which operates and evolves independently. Hence, the

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coordination relationship between them should be investigated from the perspective of adaptation and fitness of the two. Based on this logic, coordination analysis, a systematic analysis method introduced from physics, may better suits for analyzing the interaction relationship between education and population.C. Liao (1999) , Y. Liu (2005), L. Qian (2012) developed this analysis method in the research of related topics and G. Yan (2016) has applied this method to the analysis of the coordination of the higher education and industrial industry[1]. Q. Xu (2019), Z. Qi (2020) and J. Hou (2021) addressed the coupling relationship between education and industry [2-4] and Y. Yang (2022) explored the space-time coupling between education and population [5].

2 Algorithm and methods

Coupling analysis is a method analyzing the scaling between two or more subsystems to determine the degree of fitness between the systems and to address the coordination development stage of the whole superior system. This method involves two metrics. One is coupling degree investigating the adaptation, interaction and fittness between the two subsystems. The other is coordination degree investigating the development level or stage of the superior parent system.

2.1 Establish the analysis vectors

In this study, the spatial range covered 31 provincial regions in Chinese mainland, where a new 4+3 regional framework was established by superimposing the traditional 4 regions in the western, eastern, central and northeastern China on the 3 regions of the Belt and Road, the Beijing-Tianjin-Hebei region and the Yangtze River Economic Belt region. The educational data were collected from the *list of higher educational institutions* published by the Ministry of Education P.R. China, and the data of regional employment population were from the National Bureau of Statistics P.R. China.With the list of educational institutions, the numbers of all educational institutions, universities, colleges, public educational institutions and non-public educational institutions in 31 provinces were sorted out to set the vectors Y_i^j (i =1,2.. 5; j =1,2...31) and the numbers of employment population in the provincial region were set as Y_6^j . In addition, the vectors of educational institutions and employment population in the 3+4 regions were established as well.

2.2 Data Undimensionalization

In order to avoid the numerical scale interference caused by different statistical units the vectors of educational institutions and employment population in each region were processed by Max-Min method. The algorithm is as follows:

$$X_i^j = (Y_i^j - \min_{j=1}^{31} Y_i^j) \Big/ (\max_{j=1}^{31} Y_i^j - \min_{j=1}^{31} Y_i^j) \tag{1}$$

2.3 Coupling degree

The coupling degree between each of the 5 types of educational institutions and the employment population in region j was calculated by the following algorithm:

$$C_{i6}^{j}=2\left[\frac{X_i^j\cdot X_6^j}{\left(X_i^j+X_6^j\right)\left(X_6^j+X_i^j\right)}\right]^{1/2}=\frac{2\left(X_i^jX_6^j\right)^{1/2}}{X_i^j+X_6^j} \tag{2}$$

2.4 Coordination degree

The coordination algorithm between each of the 5 types of educational institutions and the employment population is as follows:

$$D_{i6}^{j}=\left[\frac{X_i^j+X_6^j}{2}C_{i6}^{j}\right]^{1/2}=\left(X_i^j+X_6^j\right)^{1/4} \tag{3}$$

2.5 Establishment of evaluation criteria

Different from the traditional classification criteria of coordination analysis, this study used SPSS 25 to cluster the coupling degree and coordination degree in 31 regions and modified the evaluation criteria for relativity. In this way, the different coupling and coordination criteria were established as shown in Tables 1 and 2.

Table 1. Clustering evaluation criteria of the coupling stage.

Coupling Stage	Coupling Degree Clustering Interval				
	Edu. Insti.	Univ.	Colle.	Pub. Edu. Inst.	N-P. Edu. Inst.
Low	[0,0.88)	[0,0.84)	[0,0.83)	[0,0.86)	[0,0.90)
Relative Low	(0.88,0.91)	(0.84,0.9)	(0.83,0.86)	(0.86,0.9)	(0.9,0.95)
Moderate	(0.91,0.95)	(0.91,0.95)	(0.86,0.91)	(0.9,0.93)	(0.95,0.95)
Relative High	(0.95,0.98)	(0.9,0.96)	(0.91,0.94)	(0.93,0.97)	(0.95,0.98)
High	(0.98,1]	(0.96,1]	(0.94,1]	(0.97,1]	(0.98,1]

Table 2. Clustering evaluation criteria of the coordination stage.

Coordination Stage	Coordination degree clustering interval				
	Edu. Insti.	Univ.	Colle.	Pub. Edu. Inst.	N-P. Edu. Inst.
Low	[0,0.15)	[0,0.18)	[0,0.17)	[0,0.15)	[0,0.13)
Relative Low	(0.15,0.42)	(0.18,0.39)	(0.17,0.42)	(0.15,0.44)	(0.13,0.35)
Moderate	(0.42,0.64)	(0.39,0.64)	(0.42,0.65)	(0.44,0.64)	(0.35,0.67)
Relative High	(0.64,0.82)	(0.64,0.84)	(0.65,0.84)	(0.65,0.84)	(0.67,0.91)
High	(0.82,1]	(0.84,1]	(0.84,1]	(0.64,0.83]	(0.91,1]

The above calculation results and evaluation criteria were used to analyse the spatial coordination between the higher educational institutions and the employment population.

3 Results and discuss

The regional data of the educational institutions and the employment population were calculated and analyzed by using the method proposed above. The following are the findings and discussion regarding the spatial distribution characteristics of the educational institutions and the employment population in Chinese provincial regions.

3.1 The distribution difference between the higher educational institutions and employment population

Comparing the index of educational institutions with the employment population, it was discovered that except Guangzhou and Beijing the indexes of all 5 types of educational institutions in the other 29 regions were greater than the indexes of employment population. The significant difference is mainly the result of two aspects. First, the regional difference of employment population in proportion was greater than that of educational institutions while the interval length of employment population was greater than the higher educational institutions, which reduced the non-dimentional values of employment population. Another factor contributing to this was the regional difference in the distribution of the higher educational institutions and the employment population themselves.

3.2 Evaluation with the traditional criteria

After investigating the spatial coupling degree and coordination degree between educational institutions and employment population respectively in 31 regions, it was found that the distributions of educational institutions and employment population in each region were significantly in a high level of spatial coupling while the quantity affected the coordination development. According to the traditional coupling evaluation criteria, except Ningxia region which was in a relative high level of coupling stage, the distributions of educational institutions and employment population in the other 30 regions were all in the high-level of coupling stage. Furthermore, by examining the coordination degrees, obvious coordination differences were found in those regions, which was related to the difference in the number of educational institutions and the employed population. In fact, this difference in coordination shows the difference in the comprehensive development level of education and employment among regions. Regions with high coordination meant that they had a large number of educational institutions and employment population and consequently the development level of education and employment development was high.

3.3 Evaluation with the modified clustering criteria

People would suppose the coupling and coordination state of education and population in remote or underdeveloped regions had more room for improvement. However, the data in this study didn't support this view. It was confirmed that small size didn't not mean low coupling. Although the traditional criteria confirmed that the overall education and population had a high level of spatial coupling, it was still necessary to carry out further analysis to find the specific differences between regions so as to determine the focus of governance. A comparative analysis of the spatial coordination between higher educational institutions and employment population in regions supported the conclusion by using the cluster evaluation criteria for coupling and coordination shown in Tables 1 and Tables 2.

Statistical results of the coupling and coordination degree between educational institutions and employment population showed that the coupling degrees in 31 regions were relatively different while most of them were mostly in the relative high level coupling stage. In terms of type distribution, the number of regions with highest coupling degree between all the educational institutions and employment population was 13 in the moderate stage and then it was 8 in the relative high level coupling stage. For the relativity between the universities and employment population, the relative low level stage covered the most regions (13), and the relative high level coupling covered 12 regions. For the colleges, public educational institutions and non-public educational institutions, the regions with relative high level coupling covered regions of 14,11 and 13 respectively.

When examining the coordination, either using the traditional fixed interval classification criteria or cluster classification criteria, all types of educational institutions gave priority to moderate coordination regions.

3.4 The regional development strategies

Since the 13th Five-Year Plan, China developed 3+4 development pattern in which the traditional eastern, central, western and northeast regions were integrated with the Belt and Road, the Bejing-Tianjin-Hebei regions, and the Yangtze River Economic Belt. The spatial coordination analysis to the layout of educational institutions and the employment population under this 3+4 pattern discovered that: within a larger spatial area, the coupling level of the higher educational institutions and the employment population in Northeast China was reduced; the coupling level in the Beijing-Tianjin-Hebei region had not been significantly improved; the coupling degree in the five development regions of the eastern, western, central, the Belt and Road and the Yangtze River Economic Belt had been significantly improved. In other words, except the northeast and the Beijing-Tianjin-Hebei region, the coupling of higher education and employment population in other regions had been significantly improved. Therefore, conclusions can be drawn that the regional development strategies were conducive to improve the coupling state of the educational institutions and the employment population.

4 Summary

Rather than adopting traditional fixed interval evaluation classification method for coupling and coordination stages, a new algorithm was introduced to conduct the spacial coordination analysis and to investigate the systemic relationship between higher education and employment population, thus developing a dynamic evaluation criteria, which helped improve the efficiency and accuracy of the coordination analysis when doing spatial coordination analysis between education institutions and population.

With this new algorithm of the spatial coordination analysis, in terms of the relationship between education and population, the following conclusions were drawn. Firstly, the regional imbalance of the educational institutions was less serious than that of the employment population. Secondly, although the coordination of developing regions in the south-central and north-east China was worse than that of western border and eastern coastal regions, all those regions in the whole maintained a high level of coupling coordination. Thirdly, inclusive regional development strategies could be adopted to optimize the coordination situation of education and employment.

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