Spatio-temporal evolution of economic polycentric pattern at county level in Shandong Province

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Abstract. From the perspective of economy and comprehensive development level, this study used the gravity model, spatial autocorrelation analysis and principal component analysis to quantitatively measure the spatiotemporal evolution pattern of multi-centers at county level in Shandong Province. The results show that the economic ties among counties in Shandong Province are getting closer and closer. By 2016, Jinan-Zibo-Qingdao and Jining, Zaozhuang have basically formed three strong economic ties. The amount of counties with high-high GDP and low-low GDP are decreasing, while the amount of counties with low-high GDP are increasing. The gap between the density of output value and the level of economic development is narrowing, showing a trend of multi-center development. In the future development, Shandong Province should strengthen the integration of resources within the province, form a reasonable industrial division of labor, strengthen the cooperation among enterprises, promote the regional integration construction, and realize the multi-center spatial development model of cooperation.

Keywords. Economic polycentric pattern, spatio-temporal evolution, county level, Shandong Province.

1 Introduction

With the strengthening of economic globalization and the advancement of urbanization, as the product of regional high industrialization and urbanization, polycentric urban area has gradually replaced the city and become the basic regional unit participating in international competition and division of labor [1]. In recent years, the regional development model of polycentric cities plays a more and more important role in promoting the formation of reasonable spatial organization structure and improving regional competitiveness. Therefore, it is of great significance to study the development mode of multi-center city for regional follow-up development [2]. Western studies on this issue are earlier, focusing on the concept connotation, measurement and empirical research of polycentric urban area, and its application in urban planning [3-6].

With the continuous improvement of China's industrialization and the acceleration of urbanization, the inter-city links are gradually diversified and frequent, and the related

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research on multi-center cities in China is gradually enriched. Some scholars comment on the related research of Western polycentric city and summarize the experience of foreign multi-center city planning and construction [4, 7-8]. Some scholars have studied the polycentric urban areas from different perspectives based on morphological poly-centricity [9] and functional poly-centricity [10], based on the traffic flow and social media. However, there are few studies on the provincial urban agglomerations which are in the initial stage of development or are in the process of development. Shandong Province established the development strategy of Shandong Peninsula urban agglomeration with Jinan-Qingdao as the dual core in 2005. However, in recent years, with the rapid development of Yantai, Zibo, Weifang, Dongying and other cities, the dual core development strategy has been difficult to summarize the spatial development pattern of Shandong Province.

2 Materials and methods

2.1 Study area

Shandong Province, as one of the most economically and populous provinces in China, has a unique economic and historical position. Shandong Peninsula urban agglomeration is located in the middle and lower reaches of the Yellow River and the Bohai rim area, which is one of the important urban agglomeration areas in China. Nowadays, Shandong Province is the first comprehensive experimental area for the transformation of new and old kinetic energy. Further quantitative measurement of multi-center in Shandong Province is conducive to seize the opportunity and realize the high quality and sustainable development of urban agglomeration.

2.2 Indicators and data sources

The evaluated indicators mainly include GDP (10^8 yuan), the value-added of secondary/tertiary industry (10^8 yuan), Total retail sales of consumer goods (10^8 yuan), Fixed asset investment (10^8 yuan), Local financial revenue (10^8 yuan), GDP per unit area (10^8 yuan / km^2), GDP per capita (yuan), Land area (km^2), Total population (10,000 people) and population density (people/km^2).The data are mainly from Shandong statistical yearbook and China county statistical yearbook from 2002 to 2017.

2.3 Methods

2.3.1 Gravity model

The gravity model is used to quantitatively calculate the spatial interaction strength of economic aggregate among counties in Shandong Province. The formula is as follows:

$$R_{ij} = \frac{\sqrt{PV_i \times PV_j}}{D_{ij}^b} \qquad (i \neq j) \tag{1}$$

where, R_{ij} is the gravity value between i and j counties; P_i and P_j are the population of i and j counties; V_i and V_j are the GDP of i and j counties; D_{ij} is the Euclidean distance between i and j counties; b is the distance friction coefficient. Referring to the existing research and combining with the actual situation of this paper, it is known that

When the value of b is one, the smaller the gravitational coverage area is, the more able to reveal the spatial connection state of county unit system at provincial scale.

2.3.2 Spatial autocorrelation

Spatial autocorrelation analysis can directly reveal the spatial correlation intensity of the regional distribution of GDP per city in Shandong Province.

Global autocorrelation:
$$I = \frac{\sum_{i=1}^{n}\sum_{i=1}^{n} w_{it}(x_i - \bar{x})(x_t - \bar{x})}{\sum_{i=1}^{n}\sum_{i=1}^{n} w_{it}\sum_{i=1}^{n}(x_i - \bar{x})^2 / n} \quad (2)$$

Local autocorrelation:
$$I_i = \frac{(x_i - \bar{x})}{\sum_{i}(x_i - \bar{x})^2 / n}\sum_{t} w_{it}(x_i - x) \quad (3)$$

where x_i or x_t is the index value of county unit i or t; n is the number of county; w_{it} is the spatial weight matrix. I is Moran's index, its value is positive, indicating that the index is close to its adjacent indicators; if the value is negative, it means that the index is quite different from its adjacent indicators.

2.3.3 Comprehensive development level evaluation model

Principal component analysis (PCA) is a statistical method that integrates several variables by dimension reduction technology to replace multiple variables, and makes new variables replace the original information as much as possible. In order to reduce the influence of high correlation index calculation on the real situation, principal component analysis is used to reconstruct m observation variables into n comprehensive variables. The entropy method is used to give each principal component weight [11], and then the comprehensive development level (CDL) of each county is calculated to measure the degree of multi-center development in Shandong.

3 Economic poly-centricity measurement analysis

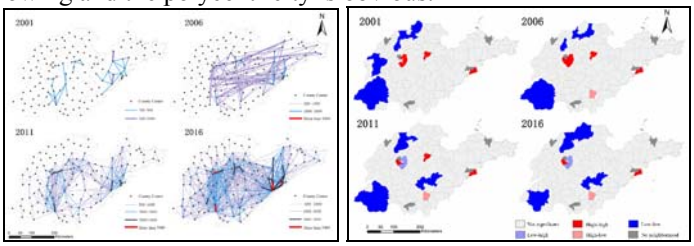
3.1 Economic aggregate and polycentric measurement

This study divides the intercity gravity value into five grades. In 2001, the connection lines among counties in Shandong Province were very few and weak (Fig. 1(a)). The maximum gravity value is "Tengzhou City-Zoucheng City". By 2016, the "line" level pattern of Shandong Province, which is paved by the eastern region led by Huangdao District of Qingdao City and the central Shandong region led by Lixia District of Jinan City, and decorated by "Shinan District-Shibei District" and "Tengzhou City-Zoucheng City", has initially formed. However, the connection lines between Northwest Shandong and Weihai are relatively sparse, which indicates that the central city of Jinan is not enough to drive the northwest areas; Qingdao, the center city of gravity, is also sparse with some Yantai counties and Weihai, and its radiation driving effect needs to be strengthened.

3.2 Land average GDP and multi-center measurement

The calculation results all pass the test at 1% confidence level, and Moran index is positive and the overall trend is declining (from 0.5535 to 0.2576), which shows that the average GDP of county unit is positively correlated in space and the agglomeration effect is weakening, and the regional economic development tends to be balanced and polycentric.

Since 2001, the phenomenon of low-high region has been increasing (Fig. 1(a)). In terms of low-low agglomeration areas, Jiaxiang County, Jinxiang County and Liangshan County of Heze City and Jining City showed an obvious shrinking trend; in 2001, Dongchangfu District, Linqing City, Yanggu County and Chiping County, represented by Liaocheng City, disappeared in 2006. In general, by 2016, the high-high and low-low county units is decreasing (Fig. 1(b)), which indicates that the gap between county units is gradually narrowing and the polycentricity is obvious.



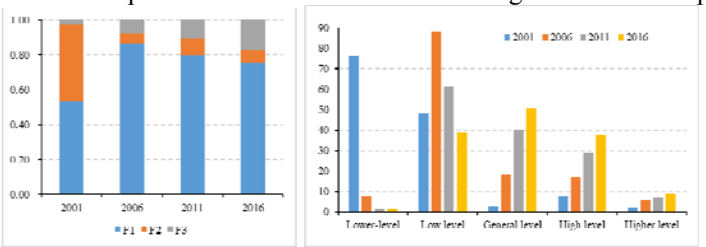
(a) (b)

Fig. 1. Distribution of interaction intensity among counties (a) and spatial autocorrelation agglomeration map of per capita (b).

3.3 Comprehensive development level at county scale

We used the principal component analysis to extract three principal components (the cumulative contribution rate was more than 85%), and entropy method to determine the weight of the three principal components (Fig. 2(a)). According to the CDL, we divided these counties into five level: lower level ([0,0.15]), low level ((0.15 , 0.30]), general level ((0.30,0.40]), high level ((0.40,0.60]) and higher level ((0.60,0.99]) (Fig. 2(b)).

The CDL of most county increased rapidly from 2001 to 2016. In 2001, more than half of the counties were at a low level, while in 2016, most counties were at the general level or above (Fig. 2(b)), it reflects that the development gap between counties is constantly narrowing, and the trend of multi-center development is becoming more and more obvious. This is closely related to the government's active response to the call of the country to develop the county economy. According to Fig. 3, we find that the CDL of all the counties increased, and the development between counties is becoming more and more polycentric.



(a) (b)

Fig. 2. The change trends of weight of three principal components (a) and number of county units at different levels (b).

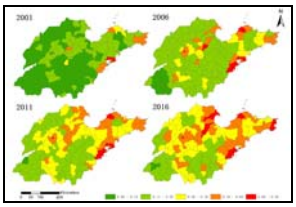


Fig. 3. Temporal and spatial evolution patterns of comprehensive strength scores.

4 Conclusions and discussion

On the whole, the results show that the polycentric pattern of Shandong has been gradually formed, but there is still a large space for development. Due to the insufficient and extensive role of the dual core cities of Jinan and Qingdao established in the original urban development strategy, many local governments ignore the development law of urban clusters and blindly devote themselves to the construction of local industrial clusters, resulting in obvious homogenization of industrial development in various regions and weak competitiveness of industrial clusters. To a certain extent, it makes the cities and counties in Shandong Province present multi-center development, but this kind of internal organic linkage is not strong enough for the future development of Shandong Province. In the future, the government should seize the historical opportunity of the national old and new kinetic energy transformation strategy, high-quality development strategy and the era of strong provincial capital, give full play to the decisive role of market allocation of resources, form a reasonable industrial division, strengthen the division of labor and cooperation among enterprises, and realize the coordinated, complementary and sustainable multi-center space.

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