Approaches to Spatial Trajectories of Hebei Economic Gravity Center During Jing-Jin-Ji Integration in China
Shu-guang LIU and Xiao-li CHEN
School of Economics, Ocean University of China, Qingdao, China
*Corresponding author

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Abstract. With the rapid integration of Beijing, Tianjin and Hebei (Jing-Jin-Ji), the economy of Hebei Province has also achieved great development. This paper applies the economic center of gravity model to study the dynamic evolution process of Hebei's economic center of gravity since 2004, and concludes that its economic center of gravity shows the southeast-northeast-southwest-southeast-south moving characteristics; then the principal component analysis method is used to extract the economic development. The level of economic development of openness, secondary industry and tertiary industry is the main factor affecting the economic center of gravity. As for policy recommendation, the paper suggest the regional economic open-up and improvement of industrial structure to balance regional economic development in Hebei Province.

Introduction

The researches of the economic center of gravity mainly focuses on the three aspects of the economic center of gravity movement, the factors affecting the movement of economic center of gravity, and the relationship between economic center of gravity and regional economic development. In terms of the economic center of gravity, Qiao Jiajun and Li Xiaojian (2005) found that in the past 50 years, the trajectory of China's economic center of gravity showed a moving feature from north to south, with a moving distance of about 173.14km[1]. Lin Siyu, Wang Liangjian and Ma Zhong (2014) used the theory of gravity to analyze the dynamic evolution of population and economic center of gravity in Hunan Province since 1990. It is concluded that the population center of gravity and the economic center of gravity move in the same direction, showing the movement from southwest to northeast[2]. Xu Guoliang et al (2014) used the center of gravity model to calculate the economic center of gravity of the countries and regions around the South China Sea between 1991 and 2011 and explore the evolution process[3]. In terms of the factors affecting the movement of economic center of gravity, Zheng Weimin (1991) focused on the impact of socio-economic factors on the economic center of gravity[4]. Xu Jiawei et al (2011) believed that the industrial structure and economic crisis were important factors that affect the economic center of gravity and expand the inter-regional development gap[5]. Hu Anjun and Liu Yuanchun (2013) thought that some factors such as human capital, fixed asset investment, and consumption levels were the driving forces driving the economic center of gravity[6]. In terms of the relationship between economic center of gravity and regional economic development. Liu Weidong (1993) believed that the movement of economic center of gravity was an important measure of regional balanced development. Promoting the rational movement of economic center of gravity was the key to achieving regional equilibrium[7]. Zhou Minliang (2000) thought that the movement of economic center of gravity can be used as an important reflection of inter-regional differences[8]. Chen Huixiong (2004)[9], Wang Xin and Li Zhijun (2008)[10], Zhong Yexi and Lu Yuqi (2011)[11], Mu Xiaofei and Lei Lei (2011)[12] considered the relationship between the change of economic center of gravity and regional economic development. Fu Juan (2014) used the regional center of gravity model and other methods to explore the dynamic mechanism of the economic center of gravity impact on the regional economy[12].

The concepts related to the development of Beijing-Tianjin-Hebei region first came from the "Capital Economic Circle" in 1982[14]. After a series of discussions, the "Langfang consensus"
reached in 2004 marked the formal establishment of the idea of economic integration between Beijing, Tianjin and Hebei. Hebei Province, as a member of the Jing-Jin-Ji region, occupies an important position. This paper intends to explore the changes in the economic focus of Hebei Province since 2004 in the process of integration of Beijing, Tianjin and Hebei, and analyze its main factors. Therefore, this paper first uses the economic center of gravity model to analyze the trajectory of Hebei’s economic center of gravity transfer, and then uses principal component analysis to explore the main factors affecting the movement of Hebei's economic center of gravity. This will have certain economic value in enhancing the status of Hebei Province in the development of the Jing-Jin-Ji region and promoting the coordinated development of the regional economy.

Method and Data

Method

Economic Gravity Calculation Model.

(1) Geometric center formula

The geometric center, also known as the "center of gravity", is an indicator for the spatial layout of the study. The calculation method is mainly represented by the average of the geometric coordinates of a series of spatial objects.

\[
X = \frac{\sum_{i=1}^{n} x_i}{n} \quad Y = \frac{\sum_{i=1}^{n} y_i}{n}
\]

(1)

Where \( n \) is the total number of spatial objects, \( x_i \) and \( y_i \) are the coordinate values of the corresponding i-th spatial object, and \( X \) and \( Y \) are the geometric center coordinate values respectively.

(2) Economic barycenter model

This model mainly refers to some related principles in mechanics to associate the index attributes of the region studied, such as the economic index (GDP), and selects the values of some attributes as the corresponding weights. Then the weighted average values obtained are calculated and compared.

\[
X = \frac{\sum_{i=1}^{n} G_i x_i}{\sum_{i=1}^{n} G_i} \quad Y = \frac{\sum_{i=1}^{n} G_i y_i}{\sum_{i=1}^{n} G_i}
\]

(2)

Where, the geographical center (administrative center) coordinates of the unit I are \((x_i, y_i)\), and \( G_i \) refers to the GDP value of the corresponding unit.

(3) Distance of center of gravity movement

In order to more clearly focus on the moving path, it is necessary to determine the moving distance of the center of gravity. Let \( d \) denote the distance moved by the center of gravity of the i-th year (relative to the j-th year), then:

\[
d_{i,j} = c \times \sqrt{(y_i - y_j)^2 + (x_i - x_j)^2}
\]

(3)

Where \((x_i, y_i), (x_j, y_j)\) represent the longitude and latitude values of the center of gravity of Hebei Province in the i-th and j-th years, respectively; \( c \) is a constant, usually taking 111.111, meaning the unit of the Earth’s surface coordinates (degrees) A factor that translates into a plane distance (km).

(4) Center of gravity movement direction

The calculation formula for the moving direction of the economic center of gravity in different years is as follows:

\[
\theta_{i,j} = n\pi + \arctan\left(\frac{y_j - y_i}{x_j - x_i}\right)(n = -1, 0, 01)
\]

(4)

In the above formula, \( \theta \) represents the angle of movement between different years of economic
center of gravity \((-180^0 < \theta < 180^0)\). In this paper, the positive east direction is \(0^0\), if it is rotated in the counterclockwise direction, it is marked as positive, and if it is rotated in the clockwise direction, it is negative.

**Principle of Factor Analysis.** Assuming that the original variable is \(x_1, x_2, \ldots, x_p\) and the correlation coefficient matrix is \(R\), \(\lambda_1, \lambda_2, \ldots, \lambda_p\) as its eigenvalues, \(e_1, e_2, \ldots, e_p\) are its standardized orthogonal eigenvectors, part \(i\) principal component is \(y_i = e_{1i}x_1 + e_{2i}x_2 + \ldots + e_{pi}x_p, i = 1, 2, \ldots, p\), they are linear combinations of the original variables, and not related to each other\(^{[17]}\). Then the calculation formula of the principal component is:

\[
\begin{align*}
   y_1 &= e_{11}Zx_1 + e_{12}Zx_2 + \ldots + e_{1p}Zx_p \\
   y_2 &= e_{21}Zx_1 + e_{22}Zx_2 + \ldots + e_{2p}Zx_p \\
   &\vdots \\
   y_p &= e_{p1}Zx_1 + e_{p2}Zx_2 + \ldots + e_{pp}Zx_p
\end{align*}
\]

(5)

Let the ratio of the variance of the \(k\) principal components to the total variance be \(P_k = \frac{\lambda_k}{\sum_{i=1}^{p} \lambda_i}\), the variance of the first \(m\) principal components occupies a large part (80% or more) of the total variance, then \(m\) principal components are substituted for the original \(p\) variables.

**Data**

Hebei Province includes Shijiazhuang City, Tangshan City, Xingtai City, Langfang City, Zhangjiakou City, Handan City, Cangzhou City, Chengde City, Qinhuangdao City, Baoding City, Hengshui City\(^{[18]}\). In this paper, the GDP value is mainly used to represent the level of economic development\(^{[19]}\). The data mainly comes from the 2004-2017 Statistical Communique of National Economic and Social Development in Beijing, Tianjin, Hebei and Hebei provinces.

**Results**

**Evolution of Economic Center of Gravity in Hebei Province**

The economic center of gravity in Hebei Province is distributed between 116.22°E~116.35°E and 38.73°N~38.80°N in 2004-2017. It is concentrated in the Wen'an County of Langfang City, Hebei Province. Compared with the geographic center of Hebei Province (116.127°E, 39.55°N), the economic center of gravity is in the southeast, and the overall movement shows the southeast-northeast-southwest-southeast. During these 14 years, the economic center of Hebei Province has moved by approximately 14.487 km. The economic focus of the Jing-Jin-Ji region is mainly distributed between 115.43°E~115.85°E and 38.91°N~39.06°N in 2004-2017. It is concentrated in the map at the junction of Beijing and Baoding City of Hebei Province. The Jing-Jin-Ji region economic center of gravity moves roughly toward the northeast-southwest-north-southwest. During these 14 years, the economic center of the Jing-Jin-Ji region has moved by approximately 30.755 km. The trajectory of the economic center of gravity movement in Hebei Province and the movement of the economic center of gravity in the Jing-Jin-Ji region have a tendency to move to the northeast in 2008-2014, indicating that during this period, the economic development of Beijing and Tianjin to the economy of Hebei Province. The direction of movement of the center of gravity has a certain effect.
Figure 1. 2004-2017 moving track of economic center of gravity in Hebei province and Beijing-Tianjin-Hebei region.

**Analysis on the Evolution Path of Economic Center of Gravity in Hebei Province**

From 2004 to 2005, the economic center of gravity in Hebei Province as a whole moved to the southeast as the main trend, the distance of economic center of gravity shift was about 7.873 km, region between the economic development gap presents a growing trend. From 2005 to 2014, in addition to the small fluctuations in 2006-2007 and 2011-2013, Hebei Province's economic center of gravity as a whole moves to the northeast, and the distance of economic center of gravity shift was about 9.758 km. From 2014 to 2016, the economic center of gravity of Hebei Province as a whole to move to the southwest as the main trend, the economic center of gravity of Hebei Province moved gradually to the southeast, and the distance between the center of economic gravity of Hebei Province was about 6.718 km. From 2016 to 2017, the economic center of gravity in Hebei Province gradually moved to the southeast, with a moving distance of 6.718 km, and the distance from the geographic center gradually increased. It shows that the economic development gap between the south and the north of Hebei Province has been alleviated, and the economic development difference between the east and west regions has been enlarged.
Analysis of Influencing Factors

Model Setting and Variable Selection

In the quantitative analysis of the influencing factors of the economic center of gravity transfer in Hebei Province under the integration of Jing-Jin-Ji, it is necessary to select relevant indicators according to the objective and feasibility principles. The construction of the specific indicator system is shown in Table 1.

| Primary indicator          | Secondary index                                      |
|----------------------------|-----------------------------------------------------|
| industrial structure       | Added value of primary industry ($t_1$)             |
|                            | Added value of secondary industry ($t_2$)           |
|                            | Added value of tertiary industry ($t_3$)            |
| infrastructure construction| Fixed assets investment completion ($t_4$)          |
| Government revenue         | Value added of Transportation Post Tourism ($t_5$) |
| Domestic and foreign trade linkage | Revenue ($t_6$)                                |
| scientific and technological level | total volume of import and export trade ($t_7$) |
|                            | Total utilization of foreign capital ($t_8$)         |
|                            | Number of patent applications ($t_9$)                |

Factor Analysis Result

According to the calculation, the interpretation of the total variance of the first three components reaches 85.5%. According to the principle that the cumulative variance contribution rate is about 80% (the eigenvalue is greater than 1), the first $m$ components are selected as the principal component, so the first three can be selected. The main components are analyzed. It can be seen from the gravel map of Fig. 3 that the eigenvalues of the first three principal components are all greater than 1, and according to the principle of extracting the corresponding principal components\textsuperscript{[20]}, it is further confirmed that the first three components can be selected as the main component.
Table 2. Eigenvalue and variance contribution table.

| Element | Initial eigenvalue | Extract square sum load | Rotation squared load |
|---------|--------------------|-------------------------|----------------------|
|         | Total up variance % | accumulate %            | Total up variance %  | accumulate %          | Total up variance % | accumulate %          |
| 1       | 4.815              | 53.499                  | 4.815                | 53.499                | 2.821               | 31.342                |
| 2       | 1.214              | 13.490                  | 1.214                | 13.490                | 2.752               | 30.573                |
| 3       | 1.037              | 11.520                  | 1.037                | 11.520                | 1.493               | 16.594                |
| 4       | .746               | 8.294                   | .746                 | 8.294                 | .463                | .841                  |
| 5       | .534               | 5.929                   | .534                 | 5.929                 | .224                | .601                  |
| 6       | .345               | 3.837                   | .345                 | 3.837                 | .084                | .598                  |
| 7       | .157               | 1.743                   | .157                 | 1.743                 | .015                | .051                  |
| 8       | .088               | .980                    | .088                 | .980                  | .049                | .436                  |
| 9       | .064               | .708                    | .064                 | .708                  | .000                | .000                  |

Extraction method: principal component analysis.

Figure 3. Gravel Map.

In this paper, the variance maximization method is used to orthogonally rotate the factor load matrix to make the factor have naming explanatory. At the same time, from Table 3, we can see the correlation between each principal component and each related indicator, so as to facilitate the naming of each component.

Table 3. Factor load matrix after rotation by principal component analysis.

|          | Z(t₁) | Z(t₂) | Z(t₃) | Z(t₄) | Z(t₅) | Z(t₆) | Z(t₇) | Z(t₈) | Z(t₉) |
|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1        | .939  | .851  | .681  | .655  | .118  | .463  | .224  | .084  | -.192 |
| 2        | .112  | .140  | .387  | .610  | .877  | .841  | .601  | .598  | -.051 |
| 3        | .038  | .387  | .199  | .065  | .015  | .049  | .508  | .436  | -.921 |

By observing the correlation between each component in Table 4 and each index log, we can name each principal component and make it have corresponding economic meaning.
Table 4. Principal component nomenclature explanation table.

| Principal component | High load index | Economic implications               |
|---------------------|-----------------|------------------------------------|
| 1                   | Foreign capital utilization, total import and export trade | Economic development openness       |
| 2                   | Foreign capital utilization, total import and export trade | Secondary industry development level |
| 3                   | Foreign capital utilization, total import and export trade | Tertiary industry development level  |

Conclusion

From the point of view of the transfer track of the economic center of gravity in Hebei Province, the movement track of the economic center of gravity in Hebei Province fluctuates from 2004 to 2017, but generally moves along the direction of southeast-northeast-southwest-southeast. At the same time, this also reflects that the economic development of Hebei Province presents an unbalanced development situation, and the development gap between the internal cities, especially between the eastern and western cities is gradually widening. Therefore, in the future economic development, Hebei Province should pay attention to improving the regional economic openness and industrial structure to gradually improve the regional economic development model, to promote the overall development of regional economy.

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