Application of Hybrid Moran’s I Index and SE Model on the spatial Impact and time gradient changes of regional development

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Abstract. Spatial econometrics includes space, which has long been neglected in econometrics, into the model. To explore the two themes of spatial dependence and spatial heterogeneity is a branch of econometrics dealing with the spatial relationship of geographical units. Moran's I index test is a method to test the correlation of development in a spatial region, and the combination of spatial econometric model and Moran's I index test can add spatial effect to Moran's I index test and make a series of regression to get the regional correlation. According to the spatial econometric model, this paper collects the changes of per capita GDP scale level and real per capita GDP growth rate from 1980 to 2015, and applies Moran's model to the central, Western and eastern parts of China The results show that the spatial correlation of the development and growth of the eastern region is increasing year by year, the central region shows a fluctuating trend, and the spatial correlation of the western region shows a downward trend The change trend of I value predicts that the imbalance of regional development in China is gradually changing to the national development balance, which is consistent with the actual situation in China. It proves that the model combined with Moran's I index test is accurate and the prediction results are reliable.

1. Introduction
Since the reform and opening up, with the continuous development of regional economy, the status quo has been paid close attention to, especially the financial development and economic growth on the regional economy has become the focus of attention. With the help of good international development situation and rich domestic resources, China's regional economy (Regional Economy) has created an amazing growth miracle, and people's living standards have been significantly improved. Generally speaking, regional economy can not only fully reflect its own development law, but also fully reflect the relationship between its extension and connotation. In this 2020 paper, Zhao Hanbin mentioned that in 2011, Anhui began to implement the strategy of strengthening the provincial capital, dividing Chaohu into Hefei. Between 2015 and 2019, Anhui's GDP increased from 220.56 billion yuan to 3711.4 billion yuan, with an average annual growth of 14%. The gap between Shaanxi and Anhui expanded from 398.4 billion yuan in 2015 to 1132.1 billion yuan. Sichuan's GDP in response to Chongqing's competition by implementing the strategy of strengthening the provincial capital will increase from 3005.3 billion yuan in 2015 to 4661.58 billion yuan in 2019, with an average annual growth of 11.6% in four years, about 2.2 percentage points higher than Shaanxi's 9.4%. In his 2016 paper [1]. Huang Qunhui found that the investment in domestic manufacturing industry continued to
decline, from an average growth rate of 30.6% in 2000-2007 to an average growth rate of 13.4% in 2008-2017. During this period, the domestic economic growth also showed a significant decline, from an average growth rate of 10.54% in 2000-2007 to an average growth rate of 8.31% in 2008-2017 [2]. From 2003 to 2018, China's economy grew rapidly, with GDP increasing from 13742.2 billion yuan to 50820.55 billion yuan, an increase of 2.7 times, with an average annual growth rate of about 8.52% (based on the price level in 2003) [3]. Zhu Dezhong and Lin Ming mentioned in the literature that from 1990 to 2017, Nanjing's GDP has increased from 17.65 billion yuan to 1171.5 billion yuan, with an average annual growth rate of about 17% [4]. In 2009, Zhang Kun proposed in his research on global financial development that the growth rate of global output was - 0.6%, that of developed economies was - 3.4%, and that the global economy suffered a "cold current" [5].

However, most scholars in the study of the relationship between financial development and economic growth in regional economy, do not consider the impact of spatial factors, but also ignore the impact of geographical and spatial factors. The actual situation is that economic and trade exchanges between different economic regions, the flow of capital, technology, talent and other production factors make any economic region is not an independent individual There is spatial correlation in economic growth. This paper divides China's regional economy into central, Eastern and western regions, studies the differences between them and correlation, and uses the spatial econometric model to study the three regional economies of financial development and economic growth.

2. Algorithm and principle

Regional economy refers to the part of national economy distributed in various administrative regions, which reflects the objective law of economic development in different regions. It has the characteristics of comprehensive and regional, and is also known as regional economy. As a kind of production complex, regional economy is distributed in specific areas in the form of entity. Economic growth refers to the continuous increase of per capita output at constant prices in the long run. It is about the change trend of the total economic scale. It is generally measured by the actual per capita GDP. Spatial econometric model is an economic model which is opposite to the classical econometric model. It is developed on the basis of the classical econometric model. With the development of spatial econometrics, spatial econometric model is gradually used in economic research. In most spatial analysis, the standard method is to start with non-spatial linear regression model, and then test whether the benchmark model needs to be extended to a model with spatial interaction effect. There are three kinds of spatial interaction effects in spatial econometric model: exogenous interaction effect is the independent explanatory variable of specific unit and depends on other units; endogenous interaction effect is the value of explained variable of one unit depends on the value of explained variable of adjacent unit; The interaction effect between the error terms is the missing variables in the model, which is spatially related and can also be understood as a correction effect. Spatial error model (SEM) and spatial lag model (SLM) are two common spatial econometric models. The spatial error model mainly discusses whether the observation value of a certain area is affected by the error of the explained variables in the adjacent area. Spatial lag model mainly studies whether a certain area has diffusion effect on nearby area, also known as spatial spillover effect. When we analyze various economic phenomena, we should choose a better model according to different situations, so as to better explain the economic phenomena studied.

Spatial lag model:

Compared with time series, spatial lag model (also called spatial autoregressive model, named SLM model) is more complex because the influence of spatial autoregressive model can come from many directions. After simplified by matrix vector, the basic setting of spatial lag model is as follows:

\[ Y = \rho W Y + X \beta + e \]  

(1)

Among them, \( X \) is the exogenous explanatory variable, \( Y \) is the explanatory variable, \( \beta \) is the regression coefficient of the exogenous variable \( x \), \( \rho \) is the influence degree of the spatial factors on
the economic objects; E is the error disturbance term satisfying the classical hypothesis. The spatial weight matrix \( W \) is a symmetric matrix with \( n \) rows and \( N \) columns whose main diagonal element is 0.

**Spatial error model:**

The space error model (SEM model) is simplified by matrix vector as follows:

\[
Y = X\beta + u, \quad u = \lambda Wu + e
\]

(2)

Where \( e \) is the error perturbation term satisfying the classical hypothesis, \( \lambda \) is the influence degree of spatial factors on the research object, and \( Y, X, \beta \) and \( e \) are the same as above.

**Spatial Durbin model:**

The basic setting of Spatial Durbin model (SDM) can be simplified by matrix vector as follows:

\[
Y = \rho WY + X\beta - \rho WX\beta + e
\]

(3)

In practical application, the model can be written equivalently as follows:

\[
Y = \rho WY + X\beta_1 + WX\beta_2 + e
\]

(4)

Where \( Y, X, \beta \) and \( e \) are the same as above.

**General spatial econometric model:**

The general spatial econometric model is the synthesis of spatial lag model and spatial error model:

\[
Y = \rho W^1 Y + X\beta + u, \quad u = \lambda W^2 u + e
\]

(5)

The spatial weight matrix \( W^1 \) and \( W^2 \) are used to express the influence of spatial factors on different research objects. \( Y, X, \rho, \lambda, \beta \) and \( e \) are the same as above.

### 3. Experimental design

There are many correlation tests to study the spatial regional economic phenomena. The commonly used methods are Moran’s I index test, Geary’s C index test and GETIS-Ord G index test. Moran’s I index test is used in this paper. Its basic formula is as follows:

\[
\text{Moran’s I} = \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (x_i - \bar{x})(x_j - \bar{x}) / S_x^2 \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}
\]

(6)

In formula (6), \( X_i \) and \( X_j \) are used to represent the observed values of variables in the \( i \) and \( j \) regions respectively, \( \bar{x} \) is the mean value of the observation samples, \( n \) is the total number of observation areas, and \( W_{ij} \) is the spatial weight matrix, and \( W_{ij} \) satisfies the following conditions:

\[
W_{ij} \begin{cases} 
1 \\
0 
\end{cases}
\]

(7)

The spatial weight matrix does not need to be calculated manually and can be directly generated by importing vector map into GeoDa software. This paper studies the economic regions of China’s 31 provinces, the spatial weight matrix is a \( 31 \times 31 \) square matrix, because the table is relatively large, so the paper only shows part, as shown in Table 1 below:

**Table 1.** Spatial weight 0-1 matrix of 31 provinces in China based on adjacency rule (local).

|          | Beijing | Tianjin | Hebei | Shanxi | Neimenggu |
|----------|---------|---------|-------|--------|-----------|
| Beijing  | 0       | 1       | 1     | 0      | 0         |
| Tianjin  | 1       | 0       | 1     | 0      | 0         |
| Hebei    | 1       | 1       | 0     | 1      | 0         |
| Shanxi   | 0       | 0       | 1     | 0      | 1         |
| Neimenggu| 0       | 0       | 1     | 1      | 0         |

China’s regional economy as a whole can be divided into three major economic regions, the eastern, the central and the western regions. The division of China’s three major economic regions is shown in Table 2:
Table 2. Division of eastern and western China.

| Economic region | Number of provinces | The specific provinces |
|-----------------|---------------------|------------------------|
| The east        | 12                  | Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, Hainan |
| The central region | 9          | Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan |
| The western region | 10         | Chongqing, Sichuan, Guizhou, Yunnan, Xizang, Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang |

4. Results and discussion

Firstly, this paper collects the changes of the scale level of per capita GDP and the growth rate of real per capita GDP in China from 1980 to 2015, and then extends to the central, Eastern and Western China, as shown in the following figure:

![Figure 1. Real per capita GDP and real per capita GDP growth rate from 1980 to 2015.](image)
According to the previous theoretical introduction, this paper calculates the Moran's I value of China's three major economic regions from 1980 to 2014 to analyze the spatial cluster characteristics of economic growth. Using R software, the Moran's I values of central, Eastern and Western China from 1980 to 2015 calculated by spatial weight matrix based on adjacency relationship are as follows:

![Figure 2. Moran' I changes in the eastern region.](image)

Figure 2 shows the Moran's of eastern China over the years I value shows that it has been in an upward trend from 1980 to 2015. It can be seen that the economic and trade exchanges, capital, technology, talent and other production factors in the Eastern Economic Region meet the conditions for sustainable financial development and economic growth in the region. The slope of the trend line is generally 0.005, which is caused by the fact that most of the eastern coastal areas belong to optimized development zones. The resources and environment in the East are in a state of easy growth.

![Figure 3. Moran' I changes in the central region.](image)
Figure 3 shows the Moran's of central China over the years I value, it can be seen that from 1980 to 2015, it has been in a fluctuating trend, and its slope tends to zero in a negative direction. It can be seen that the fluctuation degree is relatively large. Then the regional economic development of the central region is not as good as that of the eastern region. The reason for this result may be the lack of resources and environmental talents. The key development zones and key development areas in the central region are basically key development areas Hair area.

![Figure 3: Moran's I value of central China](image)

**Figure 3.** Moran's I value of central China.

Figure 4 shows the Moran's of central China over the years I value, we can see that from 1980 to 2015, it has been in a downward trend, the slope is about -0.02. Through the analysis of relevant data, the reason for this change trend is not only the lack of human resources, but also the reason that a large area of Western China with fragile ecological environment and lagging economic development belongs to restricted development zone and prohibited development zone.

As can be seen from figures 2, 3 and 4, the eastern, central and western regions show three different trends of spatial correlation. The spatial correlation of economic growth in the eastern region is increasing year by year, the central region is showing a fluctuating trend, and the western region is showing a downward trend. Since this paper studies the long-term trend of economic growth, it only analyzes the trend of Moran' I value, without considering the specific value. The different spatial correlation among the eastern, central and western provinces will lead to the change of the economic gap among the three regions, and then affect the change of the economic gap among the provinces in China. The reason for this difference may be related to the exchange and connection of economic activities between provinces. From a national perspective, the spatial correlation is constantly strengthened. Specific to different regions, it shows different spatial correlation change trends. The different trends of Moran I value can be used to explain the change of economic gap between regions.

From 1980 to 2015, China's actual per capita GDP scale level has been in an upward stage. According to the trend chart in Figure 1, the growth momentum is relatively fierce, and has been maintaining a steady rise, with an average growth rate of 8.77%. The fluctuation of per capita GDP growth rate represents the different speed of economic growth, but it is not always rising trend, reflecting the expansion of economic gap. According to the trend of large regional economy, only the eastern part of the country continues to rise, Moran I value also changes from -0.08 to 0.06, while the central part has been maintained at about 0.25, while the western part has decreased from 0.3 to 0.0.
5. Conclusions
There is a strong positive spatial correlation between economic growth and financial development among the three regions in China, and the spatial agglomeration characteristics of economic growth are obvious, that is, the economically developed areas and economically developed areas are clustered together, and the economically backward areas and economically backward areas are clustered together. From the perspective of national spatial correlation, economic growth has a strong spatial correlation on the overall level of China. Due to the different economic structure and economic growth conditions in the central, Eastern and western regions, the spatial correlation among the provinces in the three major economic regions is also different, and the economic growth also shows different spatial agglomeration characteristics, which leads to different trends of economic disparity. The economic growth of China's three major regional economies has strong spatial autocorrelation. According to the data results of the 36 years from 1980 to 2015, Moran 'L value of per capita GDP gives at least two aspects of information: one is that the economic growth of each province has strong spatial autocorrelation; the other is that Moran' I value shows a continuous growth trend from 1980 to 2015, Although it has declined since 2008, the overall trend is still increasing. With the passage of time, the spatial autocorrelation becomes more and more obvious. The eastern provinces still have a strong positive spatial correlation with other neighboring areas within the economic zone, and present a spatial structure of high high (H-H) aggregation distribution. This spatial agglomeration degree is constantly strengthened with the passage of time. In the fourth section, we analyze the regional economy Moran's of central, Eastern and Western regions. From the discussion of I value, it can be concluded that the economic growth rate of China's regional economy is very different. Whether it is the scale of economic growth or the rate of economic growth, the eastern region is obviously greater than the central and western regions. The eastern, central and western regions show positive correlation, the correlation slope coefficient is 0.005, the correlation slope coefficient is about 0, the negative correlation, the correlation slope coefficient is -0.02. At the same time, it is obvious that since the reform and opening up, China's economic development strategy has undergone several transformations and adjustments, from the regional economic imbalance to the balanced development of the national economy as the leading factor.

References
[1] Zhao Hanbin. Promote the formation of high-quality regional economic development pattern, and consolidate the foundation for Shaanxi to catch up and surpass in the new era [J]. New West, 2020 (Z5): 45-46
[2] Huang Qunhui. On the supply side structural reform of China's industry [J]. China industrial economy, 2016, 9 (5): 23
[3] Wang Liping, Yu Xiaoting. Financial development, infrastructure and regional economic growth [J]. Industrial technology economy, 2020,39 (05): 31-37
[4] Zhu Dezhong, Lin Ming. The impact of financial development on economic growth: a case study of Nanjing [J]. Journal of Pingdingshan University, 2020,35 (05): 74-79
[5] Zhang Kun. Financial development and global economic rebalancing [J]. International finance research, 2015 (02): 14-22