ESDA Analysis of Spatial Characteristics of Scientific and Technological Talents

Xiankun Li1,*

1Department of Economics, Shanghai University, Shanghai, China

*Corresponding author e-mail: xiankun_95@163.com

Abstract. This paper uses exploratory spatial data analysis (ESDA) to study the spatial distribution pattern and spatial correlation of scientific and technological personnel in Shandong province by selecting the panel data of the full-time R&D personnel in 17 cities of Shandong province in China from 2009 to 2018. The results show that the distribution pattern of the talents in Shandong province tends to be discrete and random in general, and the test results of Moran’s I measured by global autocorrelation are not significant. From the local spatial autocorrelation analysis, Moran scatter plots show that the distribution of the talents in Shandong province has certain spatial differences and most cities did not pass local indicators of spatial association (LISA) test. The plots further show the heterogeneity of the spatial distribution of scientific and technological talents in Shandong province, which makes it clear that the core areas of the cities under the jurisdiction of Jinan-Qingdao metropolitan area are mostly positive spatial autocorrelation, while most peripheral areas show negative spatial autocorrelation.

Keywords: ESDA, LISA, Scientific and Technological Talents, Shandong Province

1. Introduction

With rapid new high-tech and knowledge economy growth, the technology competitiveness of a state or region has provided a great opportunity to economic and social development. Improving the competitiveness above requires that the country must put vigorously efforts in attracting and cultivating scientific and technological talents. Shandong Province has a large population and a large potential of human resources, which lays a certain foundation for technological progress in the province. That’s why Shandong Province has issued a series of policies to cultivate and attract scientific and technological talents. However, when it comes to those scientific talents, there are a lot of issues to be dealt with such as unreasonable number, low quality, unreasonable structure and so on. There are some differences in talent distribution among 17 cities.

Spatial autocorrelation sometimes is a special method that can effectively solve some complicated problems, the spatial distribution of phenomena for example. Back in the year of 1950, Moran succeeded to move from traditional correlation coefficient of one-dimensional to two-dimensional space in the concept of spatial analysis based on biological phenomena and therefore successfully figured out Moran index [1]. After that, Geary brought forward the Geary coefficient which is similar
with the Durbin Watson statistics of regression analysis [2]. Since then, spatial autocorrelation has been becoming one the most widely used tools in geographic spatial analysis, especially thanks to the hard work of Cliff and Ord. Moran and Geary’s research has helped Anselin further proposed a method of spatial autocorrelation on local aspect [3]. Getis and his partners proposed a spatial relation index with distance statistics [4]. In particular, the establishment of Moran’s scatter plots analysis method marks the hugely upgrading of spatial autocorrelation analysis. While chinese research papers on the area are gradually developing in theories, methods and technologies with more and more practices and applications [5].

Relevant literature on the issue of scientific and technological talents in Shandong province is remerging [6-8]. Unfortunately, there is no discussion on the spatial distribution characteristics of the talents in Shandong Province, so we intend to explore the spatial distribution mode of those people and its internal mechanism through quantitative analysis and empirical analysis. Moreover, the paper reveals the spatial distribution of the talented persons in all cities of Shandong Province, deepens the research on the problem of the talents, and then provides policy reference for the implementation of talents policies in Shandong Province. I hope that it can provide useful reference for the development of intelligent team in other areas.

2. Data Sources and Research Methods

2.1. Data source and description

In this paper, we choose the full-time R&D personnel in 17 cities of Shandong province to represent the level of the qualified people in each city. The paper analyses the data only from 2009 to 2018 as the difficulty of accessing the data and the necessarily demand of spatial distribution mode exploration. The research space is set as 17 cities in Shandong Province, including 15 prefecture level cities and 2 sub provincial cities. In order to make a vertical comparison, this paper divides 17 cities into two regions. Namely, Jinan, Qingdao, Yantai, Weihai, Zibo, Weifang, Rizhao, Dongying, belong to Jinan-Qingdao metropolitan area cities (the core cities) and the rest cities are classified as peripheral cities. The data of full-time R&D personnel in 17 cities are obtained from the statistical yearbook of Shandong Province, which is the basic work preparation for later analysis. By transforming the data into a logarithmic form, the level of full-time R&D personnel in 17 cities from 2009 to 2018 are shown in Table 1.

Table 1. The level of scientific and technological talents in Shandong Province from 2009 to 2018.

| City        | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | Mean |
|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| Jinan       | 10.31 | 10.42 | 10.51 | 10.59 | 10.67 | 10.76 | 10.86 | 10.79 | 10.82 | 10.89 | 10.66|
| Qingdao     | 10.17 | 10.46 | 10.58 | 10.62 | 10.71 | 10.74 | 10.79 | 10.88 | 10.82 | 10.93 | 10.67|
| Zibo        | 9.60  | 9.75  | 9.99  | 9.98  | 9.99  | 9.92  | 9.99  | 10.05 | 10.07 | 10.22 | 9.96 |
| Yantai      | 9.51  | 9.61  | 9.98  | 10.21 | 10.29 | 10.31 | 10.27 | 10.25 | 10.32 | 10.23 | 10.10|
| Weifang     | 9.51  | 9.75  | 9.91  | 10.15 | 10.26 | 10.11 | 10.10 | 10.15 | 10.02 | 9.97  | 9.99 |
| Rizhao      | 7.55  | 7.22  | 7.67  | 7.67  | 7.80  | 8.24  | 8.30  | 8.37  | 8.58  | 8.72  | 8.06 |
| Dongying    | 9.13  | 9.33  | 9.31  | 9.26  | 9.30  | 9.42  | 9.37  | 9.14  | 9.27  | 9.03  | 9.26 |
| Weihai      | 9.13  | 9.12  | 9.32  | 9.34  | 9.34  | 9.41  | 9.47  | 9.49  | 9.59  | 9.66  | 9.48 |
| Mean        | 9.36  | 9.52  | 9.66  | 9.73  | 9.80  | 9.87  | 9.90  | 9.90  | 9.94  | 9.94  | 9.76 |
| Zaozhuang   | 8.12  | 8.58  | 8.78  | 8.86  | 8.85  | 8.66  | 8.65  | 8.79  | 8.94  | 8.77  | 8.70 |
| Jining      | 8.76  | 8.82  | 9.18  | 9.40  | 9.56  | 9.52  | 9.74  | 9.81  | 9.92  | 9.71  | 9.44 |
| Taian       | 9.14  | 9.22  | 9.43  | 9.41  | 9.52  | 9.70  | 9.68  | 9.59  | 9.61  | 9.55  | 9.48 |
| Laiwu       | 7.71  | 7.31  | 7.56  | 8.23  | 8.33  | 8.39  | 8.40  | 8.41  | 8.33  | 8.53  | 8.12 |
| Linyi       | 8.75  | 8.85  | 9.09  | 9.32  | 9.47  | 9.49  | 9.69  | 9.61  | 9.65  | 9.69  | 9.36 |
| Dezhou      | 7.63  | 7.80  | 8.41  | 8.83  | 9.02  | 9.13  | 8.93  | 9.12  | 9.15  | 9.37  | 8.74 |
| LiaoCheng   | 8.73  | 8.72  | 8.86  | 8.78  | 8.85  | 8.92  | 8.86  | 8.94  | 9.05  | 8.98  | 8.85 |
| Binzhou     | 8.81  | 8.85  | 9.05  | 9.22  | 9.41  | 9.39  | 9.42  | 9.46  | 9.31  | 9.29  | 9.22 |
| City | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Mean |
|------|------|------|------|------|------|------|------|------|------|------|------|
| HeZe | 7.68 | 7.85 | 8.23 | 8.20 | 8.54 | 8.68 | 8.59 | 8.84 | 8.86 | 8.51 | 8.40 |
| Mean | 8.37 | 8.45 | 8.73 | 8.92 | 9.06 | 9.10 | 9.11 | 9.16 | 9.19 | 9.16 | 8.92 |
| Total Mean | 8.87 | 8.98 | 9.20 | 9.32 | 9.43 | 9.48 | 9.50 | 9.53 | 9.56 | 9.55 | 9.34 |

2.2. Research methods

Exploratory spatial data Analysis (ESDA), which combines statistics with modern graphic computing technology, uses intuitive methods to identify spatial dependence, spatial correlation and spatial autocorrelation among data. ESDA is essentially a data-driven exploration process, which means “let data speak for themselves”, and it is one of the core contents of spatial analysis technology. At present, there are two kinds of ESDA analysis tools for analysis: Global Spatial Autocorrelation and Local Spatial Autocorrelation.

2.2.1. Global Spatial Autocorrelation. Global Spatial Autocorrelation describes the spatial distribution pattern between regions as a whole, and uses a single numerical value to reflect the correlation degree of the whole research region. Common indicators are Global Moran’s I index and Geary’s C. As Global Moran’s I is more suitable for global spatial autocorrelation analysis, it is favoured by most scholars [9-10], so Global Moran’s I index is selected in this paper:

$$I = \frac{n\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (X_i - \bar{X})(X_j - \bar{X})}{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \sum_{i=1}^{n} (X_i - \bar{X})^2}$$ (1)

Where I represents Global Moran’s I, $X_i$ and $X_j$ are the observation values of region i and j, respectively, n is the total number of observation regions, and $W_{ij}$ is the space weight matrix. In addition, the calculated global Moran’s I value must be subject to Z statistical test, where its standardized form is as follows:

$$Z = \frac{I - E(I)}{\sqrt{VAR(I)}}$$ (2)

The Z statistic can be used to test the significance of the original hypothesis (There is no spatial correlation between the observations of regional observation units). P-value of the standardized Z always decide the significance level. If the P-value is less than the given significance level (generally 0.05), the original hypothesis will be rejected, indicating that the spatial correlation of the spatial observations is significant [11].

The value range of Global Moran’s I is generally [-1, 1]. If the value of I is positive and significant, it indicates that there is a positive spatial correlation between the observations, and similar observation regions show a clustering phenomenon (The high value is surrounded by high values; the low value is surrounded by low values). If I is negative and significant, it indicates that there is a negative spatial correlation between the observation regions, and the dissimilar observation regions show a clustering phenomenon (The high value is surrounded by low values; the low value is surrounded by high values). If the value of I is 0, the inter-regional observations are randomly distributed.

2.2.2. Local Spatial Autocorrelation. Many scholars proposed the Local Indicators of Spatial Association (LISA) to gauge the local spatial correlation, so as to reveal the atypical characteristics of local space. Common LISA analysis tools include Local Moran’s I and Moran scatter plots.

Local Moran’s I is calculated by the following formula:

$$I_i = (X_i - \bar{X}) \sum_{j=1}^{n} W_{ij} (X_j - \bar{X})$$ (3)

Its statistical test is the same as Global Moran’s I. If I is positive and significant, it indicates that the area i is surrounded by similar values (The high value is bounded by high values; the low value is...
bounded by low values). If I is negative and significant, it indicates that the area i is surrounded by dissimilar values (The high value borders on low values; the low value borders on high values).

Local Moran’s I is visualized in the Moran scatter plots, which can easily describe the heterogeneity of regional space and the atypical characteristics of spatial distribution. The abscissa and ordinate respectively represent the observation value of area and its space lag value (the space weighted mean of the adjacent areas). Among them, quadrants I and III represent positive spatial correlation, which indicate agglomeration areas and depression areas of scientific and technological talents respectively. The former represents that high observation values are surrounded by high observation values (HH); the latter represents that low observation values are surrounded by low observation values (LL). Quadrants II and IV represent negative spatial correlation, which indicate hollow and isolation areas of intelligent team respectively. The former represents low observation values surrounded by high observation values (LH); the latter means high observation values surrounded by low observation values (HL) [12]. In addition, the trend line of scatter plots shows the strength of spatial correlation.

In addition, combining Moran scatter plots and Local Moran’s I can get the LISA Cluster Map and the Significance Map, which show the spatial distribution pattern more clearly and intuitively, and help to further analyse the heterogeneity characteristics of spatial observations.

3. **Empirical Results and Analysis**

3.1. **Spatial bitmap**

Before making a concrete analysis, we can take a look at the distribution status of talents. As shown in Figure 1, from 2009 to 2018, the changes in the spatial distribution pattern of qualified people in 17 cities of Shandong Province are mainly concentrated on the peripheral areas. Among them, the city with the largest distribution of the talents in the province is the fourth range city with the deepest color, and the distribution of intelligent manpower gradually decreases from the third range to the first range. Comparing two figures, we can see that the number of cities included in the four levels has not changed, among which the fourth level contains five cities, while the first, second and third levels occupy four cities respectively. At all levels, the core cities of Jinan, Zibo, Weifang, Qingdao and Yantai have always been ranked at the fourth level, which is the best area for the talents; the third level of Weihai and Taian has not changed; in addition, Rizhao and Heze have always been at the first level, which is the area with the least distribution of the talents. In the cities with changed ranks, it can be found that the grades of Dongying and Binzhou increased from the second level to the third level, Zaozhuang from the first level to the second level. While the grades of Jining and Linyi declined from the third level to the second level. Dezhou from the second level to the first level.

![Spatial bitmap of S&T talents in Shandong in 2009 (left) and 2018 (right).](image)

3.2. **Global Moran’s I**

Table 2 shows the estimated Global Moran’s I and p-values of technological persons in Shandong Province from 2009 to 2018. It can be seen from the table that the Global Moran’s I value is negative
in each year, which means that the talents in each city present a spatial agglomeration between different values, that is, cities with more (less) talents tend to be closer to cities with less (more) talents. However, Global Moran’s I did not pass the 5% test ($p > 0.05$). The results show that, on the whole, the spatial negative correlation of intelligent team in Shandong Province is weak, and its distribution has certain discrete random characteristics, which is obviously different from the spatial distribution pattern shown in the spatial bitmap. It can be explained as follows: Global Moran’s I is only a general statistical value, and it is difficult to observe the local characteristics existing in different geographical locations. In view of this, further analysis of local autocorrelation is particularly important.

Table 2. Global Moran’s I.

| Year | Moran’s I | P-values |
|------|-----------|----------|
| 2009 | -0.1030   | 0.397    |
| 2010 | -0.1303   | 0.375    |
| 2011 | -0.1562   | 0.324    |
| 2012 | -0.1461   | 0.332    |
| 2013 | -0.1692   | 0.304    |
| 2014 | -0.1424   | 0.338    |
| 2015 | -0.2048   | 0.204    |
| 2016 | -0.2072   | 0.218    |
| 2017 | -0.2259   | 0.167    |
| 2018 | -0.1829   | 0.256    |

3.3. Moran scatter plots

As shown in Figure 2, Moran scatter plots show the distribution of technological fellows by calculating Local Moran’s I in Shandong Province in 2009 and 2018. Comparing the two figures, it can be found that the talents in each city of Shandong Province has obvious spatial differentiation characteristics, especially the positive spatial correlation area covered by Global Moran’s I. The specific features are as follows.

First, from the perspective of core areas, there is a positive spatial correlation as a whole. Among them, Yantai, Zibo, Qingdao and Weifang form the agglomeration area of the fellows; Jinan forms the isolation area; Rizhao forms the hollow area; and Weihai and Dongying transform from the early agglomeration area to the hollow area of the talents.

![Figure 2. Moran scatter plots of S&T talents in Shandong in 2009 and 2018.](image)
Secondly, from the perspective of the peripheral areas, there are still some differences despite their overall negative spatial correlations. For example, Taian forms a agglomeration area of the talents; Laiwu, Binzhou, Liaocheng and Dezhou form the typical hollow areas; Zaozhuang and Heze have transformed from the depression areas to the hollow areas; Jining and Linyi have changed from the depression areas to the isolation areas. On the whole, the trend of technological fellows in peripheral areas is declining.

It can be seen that the distribution of the talents in Shandong Province has certain spatial differences. The scatter plots show that the atypical areas (positive spatial correlation areas) are mainly distributed in the core regions, while the typical areas (negative spatial correlation areas) are mainly distributed in the peripheral regions.

3.4. Cluster Map and Significant Map

The above Moran scatter plots do not demonstrate what the specific significance level is. Luckily, the LISA Cluster Map and Significance Map obtained by combining Moran scatter plot and Local Moran’s I overcome the weakness, which makes it possible to explore the spatial distribution pattern and explain the form of the geospatial pattern.

Figure 3 shows the Significance Map of local spatial autocorrelation (LISA) and its corresponding Cluster Map of the talents in Shandong Province in 2018. Among them, different colours are used to identify the cities that pass the significance level test, and correspond to different quadrants of Moran scatter plots, while red (HH), dark blue (LL), light blue (LH) and pink (HL) are used to represent the agglomeration areas, depression areas, hollow areas and isolated areas of scientific and technological talents respectively.

![Map](image)

**Figure 3.** LISA Cluster Map and Significance Map of S&T talents in Shandong Province in 2018.

First, as a coastal city, Yantai in the core area enjoys the strength of higher levels of socio-economic growth and educational investment. So, its surrounding areas that are able to form a talented agglomeration area are affected by a strong diffusion effect. Second, in the peripheral areas, Laiwu, as an important coal resource city in China, only pays attention to the development of the coal industry for a long time, and neglects the investment in education. Especially the extensive coal industry only needs simple labor force, which further promotes its neglect of education. So Laiwu shows a significant hollow area of the talents in 2018. Third, further analysis shows that some cities have not passed the test including the core cities of Qingdao and Weifang and peripheral cities of Heze, Jining and Linyi. While three of above peripheral cities are expected to be the engines of scientific and technological talents development. The result indicates that the five cities discussed herein are not significant agglomeration areas. That’s why they have not had a significant diffusion effect on the surrounding areas.

In addition, most regions fail to pass the LISA test, which further proves that technological talents in Shandong Province has certain discrete random distribution characteristics from the overall level.

4. Conclusion

Analyzing the spatial distribution pattern of scientific and technological talents in Shandong Province by Spatial bitmap and ESDA method, we can draw the following conclusions:
 Firstly, since entering the new century, the number of technological talents in Shandong Province has been rising rapidly. In addition, the spatial bitmap reveals the unbalanced characteristics of the spatial distribution of the talents. Put another way, the dominant cities hugely attaining the scientific and technological talents are typically in the core areas, while the most peripheral areas are at a disadvantage for attracting the talents.

Secondly, the global spatial autocorrelation analysis shows that the distribution of the talents in Shandong province is negative in spatial autocorrelation. But this feature is not significant, which means that the spatial distribution of intelligent teams in Shandong Province tends to be a discrete and random distribution mode as a whole.

Thirdly, Moran scatter plots, LISA Cluster Map and Significance Map show the local autocorrelation and heterogeneity of the spatial distribution of the talents in the whole province. Most of the core areas have positive spatial correlation. Especially Yantai has formed a significant agglomeration area of the talents. Jinan has formed an isolated area, but it is not significant. Most of the peripheral areas show negative spatial correlation, among which Liaocheng, Dezhou, Binzhou and Laiwu have formed typical hollow areas of the talents, which may come down to the spatial polarization of Jinan.

In addition, it can be found that there are two abnormal cities in the core area, Dongying and Rizhao. Although all of them are located in the coastal area and have a high level of economic development, they are less likely to attract qualified persons. They also in particular form hollow areas of talents.

In conclusion, Shandong Province should plan the talent development strategy in line with the talent distribution mode of each city, and form the regional advantage complementary, so as to realize the coordinated development of the scientific and technological talents of the whole province. Only in this way, Shandong can finish the transformation from a large province of human resources to a strong province of talents. From the perspective of policy guidance, first of all, Shandong should update the structure of financial expenditure, and continue to increase the intensity of education expenditure to promote the growth of technological talents, especially in the peripheral areas. Secondly, the implementation of a new round of “westward policy” focuses on the use of the advantages of talents in the core areas of the agglomeration areas to support the peripheral areas of the hollow areas, so as to realize the cross-gradient development of intelligent team in the peripheral areas. Shandong should keep this policy for a long time. Thirdly, the policy maker should pay attention to the diffusion effect of Jinan and the development of surrounding areas. As a result, Jinan will be transformed from an isolated area of talents to an agglomeration area. Finally, the government should increase financial support in the peripheral cities including Heze, Jining and Linyi, and take advantage of the cultural advantages of Jining and the population scale advantages of Heze and Linyi to lead the peripheral areas out of the talent dilemma. In addition, for the two abnormal areas (Dongying, Rizhao) in the core area, the government should improve and guarantee the education system, emphasize the importance of education scale and level, and increase education expenditure to cultivate talents.

References
[1] Moran P.A.P. Notes on continuous stochastic phenomena[J]. Biometrika, 1950, 37(1/2): 17-23.
[2] Geary R.C. The contiguity ratio and statistical mapping[J]. The incorporated statistician, 1954, 5(3): 115-146.
[3] Anselin L. Exploratory spatial data analysis in a geocomputational environment[J]. Geocomputation, a primer. Wiley, New York, 1998, pp.77-94.
[4] Getis A, Ord J K. The Analysis of Spatial Association by Use of Distance Statistics[J]. Perspectives on Spatial Data Analysis, 2010: 127-145.
[5] Tobler W. On the first law of geography: A reply[J]. Annals of the Association of American Geographers, 2004, 94(2): 304-310.
[6] Bo S, Xingzhou L. Problems and Countermeasures in the integration of science, technology and economy in Shandong Province[J]. Economic Research Guide, 2009, (23): 122-123. (in
Chinese)

[7] Lixin Z, Lijie C. Study on the ecological environment evaluation of scientific and technological talents in the city based on the non integer rank wrsr -- a case study of 17 cities in Shandong Province [J]. Research on science and technology management, 2016, (2): 83-86. (in Chinese)

[8] Hongjuan Y, Minghai Y. Research on the influencing factors of the construction of regional high-level scientific and technological talents based on the survey data of Shandong Province [J]. Science and technology and economy, 2015167 (28): 86-90. (in Chinese)

[9] Bin M, Jinfeng W, Wenzhong Z, Xuhua L. Study on regional differences in China based on spatial analysis method [J]. Geosciences, 2005 (4): 393-400. (in Chinese)

[10] Ziming Z, Xinhua Q. Study on spatial development of Southern Fujian Delta Based on Moran’s I [J]. Economic geography, 2009 (12). (in Chinese)

[11] Feng L, Jianhua X. Spatial statistical analysis of regional economic differences in China [J]. Journal of East China Normal University, 2007 (2): 44:51. (in Chinese)

[12] Zhenshan Y, Jianming C, Xiaolu G. Using exploratory spatial data to analyze the urban spatial economic development model of Beijing[J]. Journal of geography, 2009 (8). Vol.64:945-955. (in Chinese)