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Spatial Pattern Evolution and Casual Analysis of County Level Economy in Changsha-Zhuzhou-Xiangtan Urban Agglomeration, China

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Abstract: In order to evaluate whether or not the county units′ economy in the Changsha-Zhuzhou-Xiangtan (Chang-Zhu-Tan) Urban Agglomeration was growing as expected, this study analyzed the spatial economy pattern at county-level by using the Exploratory Spatial Data Analysis (ESDA) method. In this process, the global Moran′s I and local Getis-Ord G_i^* indexes were employed to analyze indicators including per capita GDP and three industrials (i.e. primary, secondary and tertiary industry) from 2000 to 2010. The results show that: 1) the county units′ economy in the Chang-Zhu-Tan Urban Agglomeration has exhibited a strong spatial autocorrelation and an accelerated integration trend since 2008 (Moran′ s I increased from 0.26 to 0.56); 2) there is a significant difference in economy development between the northern and southern county units in the Chang-Zhu-Tan Urban Agglomeration: the hotspot zone with high economic level was formed among the northern county units whereas the coldspot zone with low economic level was located in the southern areas. This difference was caused primarily by the increasingly prominent economic radiation effect of Changsha ′upheaval′; 3) town density, secondary industry, and the integration policy are the major contributors driving the evolution of the spatial economy pattern in the Chang-Zhu-Tan Urban Agglomeration.

Keywords: spatial autocorrelation; spatial heterogeneity; urban agglomeration; county-level economy; Changsha-Zhuzhou-Xiangtan (Chang-Zhu-Tan), China

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1 Introduction

Urban agglomeration is a byproduct of modern civilization formed during the vigorous promotion of industrialization and urbanization. It has turned out to be a major characteristic of global urbanization in the 21st century (Fishman, 2000). Urban agglomerations, which are generally composed of units of different sizes, represent an interconnected system. Unit differences and the superimposed spatial proximity effect among units often correspond to different levels of economic development within an urban agglomeration. Based on this characteristic, the positive effect can strengthen the spatial clustering trend and the leading position of regions with economic development superiorities (Dong *et al*., 2010), thus augmenting the spatial difference of economy within the urban agglomeration. The regional economic disparity not only has become a central issue for both domestic and foreign socioeconomic activities, but also has attracted wide attentions from the academic circle (Goodchild *et al*., 2000; Ertur and Koch, 2006; Wang *et al*., 2012).

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Methods for traditional studies on regional economic disparity and spatial pattern include the Williamson coefficient (Rosenthal and Strange, 2004), the Tsui-Wang exponent (Wang and Tsui, 2000), the Thiel coefficient (Akita, 2003), and the Ellison-Glaeser exponent (Ellison and Glaeser, 1997). However, these independent-data based methods failed to make a deep adjustment on the internal spatial structure of regional economy since they often neglect the spatial autocorrelation and spatial spillover of economic factors as well as the cascading effect. Therefore, they are not able to fully capture the variations and mechanisms of spatial differences in regional economic development (Goodchild and Haining, 1992; Arbia, 2001).

Exploratory spatial data analysis (ESDA) is the integration of a series of spatial methods and techniques based on the principle of statistics. It is centered at spatial correlation measurement and complemented with visual representation functions. ESDA can be used to examine the spatial distribution of events and to reveal the spatial structure based on spatial dependence and spatial heterogeneity (Andrienko and Andrienko, 2006). Currently, ESDA has been applied to investigate various topics such as species distribution (Carl and Kùhn, 2007), population change (Qin and Zhang, 2011), crime (Murray *et al.*, 2001), and regional economy (Patacchini and Rice, 2007). Meanwhile, many researchers are devoting to studying the spatial pattern of regional economy (Gallo and Ertur, 2003; Pu *et al.*, 2005; Jin and Lu, 2009; Guillain and Le Gallo, 2010; Li *et al.*, 2010) and developing associated analysis methods.

Provincial urban agglomeration is an advanced type of urban organization developed during China′s urbanization process. It has energetically driven the socioeconomic development for provinces and has become an important part of China′s urbanization strategy (Wang and Lu, 2011). As the core economic development area of Hunan Province, the Changsha-Zhuzhou-Xiangtan (Chang-Zhu-Tan) Urban Agglomeration lies between the Zhujiang (Pearl) River Delta and golden waterway of the Changjiang (Yangtze) River in the northeast of Hunan Province. After Chang-Zhu-Tan being approved as the national comprehensive reform pilot area for promoting resource-saving and environmental-friendly development in 2007, the Chang-Zhu-Tan Urban Agglomeration has evolved into a key region in the central China. It has also become an important area for the spatial adjustment of productivity in China. This ′dual- importance′ in regional development has established its responsibilities of the economic development of the central China. Therefore, quantitatively analyzing the economy process and evaluating its ′integration′ development trends is theoretically and practically significant for ensuring sustainable development of the Chang-Zhu-Tan Urban Agglomeration in the future. It is the purpose of this study to analyze the spatial economy pattern at county-level in the Chang-Zhu-Tan Urban Agglomeration during 2000 to 2010 in terms of spatial autocorrelation and heterogeneity by using the ESDA method. By doing this, we will better understand this area′s economic development and its driving mechanism, and provide scientifically reasonable solutions to problems in the future.

2 Materials and Methods

2.1 Data sources

The Chang-Zhu-Tan Urban Agglomeration covers 15 county-level units within the ranges of Changsha, Zhuzhou and Xiangtan, including Changsha Proper, Zhuzhou Proper, Xiangtan Proper, Changsha County, Liuyang City, Wangcheng District, Ningxiang County, Zhuzhou County, Liling City, Youxian County, Chaling County, Yanling County, Xiangtan County, Shaoshan City and Xiangxiang City (Fig. 1). This county division was mainly attributed to the conventional study designs and limitations of statistic data availability. Since indicators such as per capita GDP and three industrials (i.e. primary industry, secondary industry, tertiary industry) can effectively reflect disparities of regional economy (Gallo and Ertur, 2003; Pu *et al.*, 2005; Jin and Lu, 2009; Li *et al.*, 2010), they are used as indicators of county level economy in this study. The data of per capita GDP, the primary industry, secondary industry and tertiary industry for the 15 county units within the urban agglomeration during 2000 to 2010 were collected from *Hunan Statistical Yearbook (2000–2010)* (Hunan Provincial Bureau of Statistics, 2001–2011). The illustrated per capita GDP data from 2000 to 2010 used in this study are shown in Table 1.

2.2 Methodology

In this paper, evolution of the spatial economy pattern in the Chang-Zhu-Tan Urban Agglomeration was analyzed using ESDA. Specifically, we used the ESDA functions of global spatial autocorrelation analysis, local spatial autocorrelation analysis, hotspot detection, and variance function analysis. The Global Moran′s I calculated based

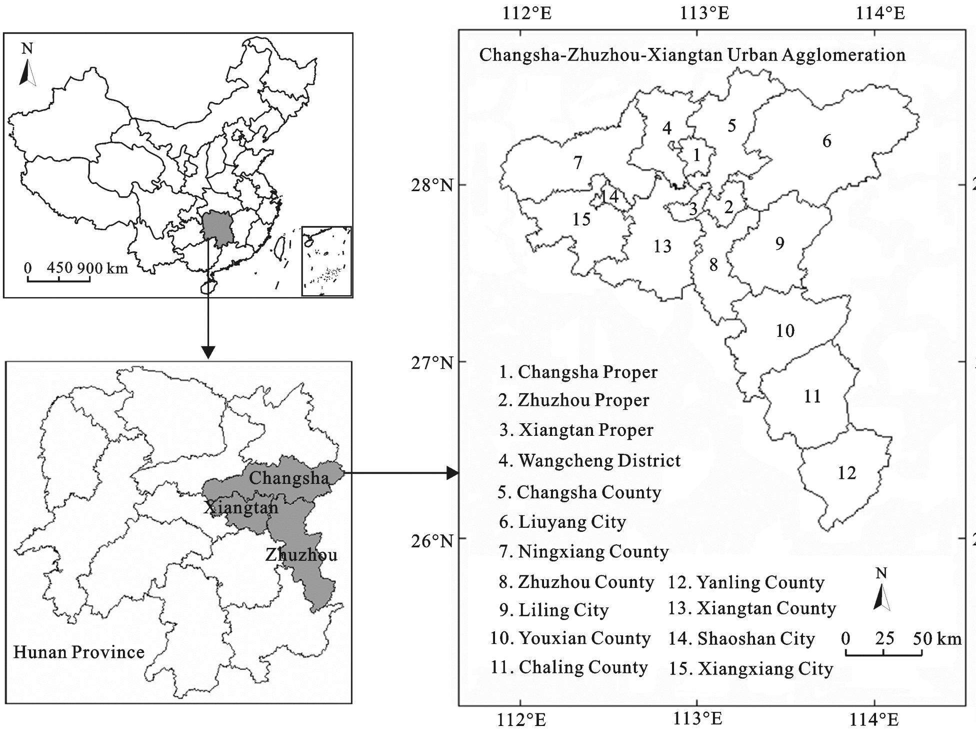

Fig. 1 Sketch of Changsha-Zhuzhou-Xiangtan Urban Agglomeration

Table 1 County level per capita GDP data in Changsha-Zhuzhou-Xiangtan Urban Agglomeration from 2000 to 2010 (yuan (RMB))

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2000	23942	21133	17564	11780	5078	6941	4721	5418	5571	6225	3485	4475	4503	7311	5425
2001	26382	21367	19190	13108	5659	7726	5215	5634	6233	5967	3889	4841	7221	7221	5523
2002	29042	23270	21118	14508	6230	8619	5703	6203	6848	6495	4247	5298	5089	8042	5777
2003	24132	21509	21209	16291	7732	9870	6795	6994	8066	7811	5188	6148	5527	10509	6169
2004	29482	24835	26112	19407	9260	11906	8352	8304	9929	9294	6200	7154	6884	13267	7774
2005	43824	27956	29591	24612	13406	14659	11687	8546	11688	10944	8040	7383	7246	14381	7866
2006	49701	30686	30897	29407	15631	17082	13647	10116	14000	12356	9053	8095	8578	16565	9192
2007	59384	39070	36286	36272	19151	21044	16675	11301	15769	15358	9756	10996	11140	20622	11950
2008	76271	46786	45360	46371	25545	28581	22659	14209	19447	18462	12069	11434	13364	25249	14424
2009	97960	56026	56703	59282	34076	38817	30790	17865	23983	22193	14930	11889	16032	30914	17410
2010	84711	61418	58969	70604	42619	46471	40404	19542	27737	25129	15077	15045	17809	33571	19930

Notes: 1. Changsha Proper; 2. Zhuzhou Proper; 3. Xiangtan Proper; 4. Changsha County; 5. Liuyang City; 6. Wangcheng District; 7. Ningxiang County; 8. Zhuzhou County; 9. Liling City; 10.Youxian County; 11. Chaling County; 12. Yanling County; 13. Xiangtan County; 14. Shaoshan City; 15. Xiangxiang City.

on the per capita GDP of the 15 units from 2000 to 2010 was used to evaluate the evolution of the spatial economy pattern. Local spatial autocorrelation detection was employed to 1) screen out the critical 'transition years' of economic development in the Chang-Zhu-Tan Urban Agglomeration based on the temporal characteristics of Global Moran's I, and 2) explore the evolution of local spatial clusters and economic hotspots through Moran scatterplot and local Getis-Ord G_i^* statistics. During this process, the optimal natural division of Jenks was applied to divide G_i^* statistics of all involved years into four low-high classes to produce evolution diagrams of hotspots and coldspots. The variance function analysis derives a spatial distribution map of the economy through ordinary Kriging interpolation. Furthermore, the spatial variability of economic development in the Chang-Zhu-Tan Urban Agglomeration as well as its formation mechanism was analyzed. The basic principles of these three processes are stated as follows:

2.2.1 Global spatial autocorrelation

The global spatial autocorrelation quantitatively describes the spatial characteristics of a property value in the whole region. The major indexes of global spatial autocorrelation include Global Moran′s *I* (Bivand *et al*, 2009), Geary′s *C* (Jong *et al*., 1984) and Geits-ord General *G* (Getis and Ord, 1992). The calculation of Global Moran′s *I* can be expressed as:

$$I = \frac{n}{S^2} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \quad (1)$$

$$S^2 = \sum_{i=1}^{n}(x_i - \bar{x}) \big/ n \quad (2)$$

where n is equal to the total number of units; x_i is the observed value of spatial unit i; $\bar{x}$ is the mean value of x_i; W_{ij} is the spatial weight matrix; S^2 is the sum of all elements of the spatial weight matrix which is the core of ESDA-based spatial analysis (Liu and Wang, 2002). A binary-symmetric spatial weight matrix ($W_{n \times n}$) is determined based on either the adjacency standard or the distance standard. In this study, the adjacency standard is adopted. That is, when there is a shared side between two adjacent units i and j, then $W_{ij} = 1$, otherwise $W_{ij} = 0$. Generally, the standardized Moran′s *I* is tested through *Z* statistics. The range of Global Moran′s *I* is between –1 and 1. Given a specific significance level, the closer the Global Moran′s *I* gets to 1, the higher the spatial autocorrelation exhibits in the region, which corresponds to significant spatial clustering of zones with higher (or lower) economic level. However, a region with Global Moran′s *I* closer to –1 generally represents a negative correlation, indicating a significant disparity in economy development among the units. When Global Moran′s *I* is close to its expected value ′$-1/(n-1)$′, the economy level among these units follows a random distribution without any spatial autocorrelations.

2.2.2 Local spatial autocorrelation

While the global spatial autocorrelation assumes that the spatial trend is only applicable to the whole region, local autocorrelation analysis can more accurately reveal the spatial heterogeneity and cluster characteristics inside the region (Li *et al*., 2010). Common indexes of local spatial autocorrelation include local Moran′s *I* (Anselin, 1995) and local Getis-Ord G_i^* (Ord and Getis, 1995). Research has demonstrated the advantages of local Getis-Ord G_i^* over local Moran′s *I* in revealing more accurate results of local spatial agglomeration, especially for intensive clusters (Zhang and Zhang, 2007). Therefore, local Getis-Ord G_i^* was applied in this study to detect the local spatial clusters with high or low economic level in the study region.

(1) Moran scatterplot

Moran scatterplot has been widely used to study local spatial heterogeneity (Pu *et al*., 2005). In a Moran scatterplot, the horizontal axis represents the standardized property value of units and the vertical axis denotes the mean property value of adjacent units that are determined by the spatial weight matrix. The slope of the oblique line in Moran scatterplot is the value of Global Moran′s *I*. The first quadrant (upper right) and the third quadrant (bottom left) of the Moran scatterplot represent the regions covered by the unit and its surrounding units with higher and lower economic levels, respectively. Therefore, their economic levels share a same correlation value. The second quadrant (upper left) covers high value units whose surrounding units have lower economic level. The fourth quadrant (bottom right) just shows the result contrary to the second quadrant. Therefore, economic levels in the second quadrant and the fourth quadrant represent different negative correlations.

(2) Getis-Ord G_i^* exponent can be expressed as:

$$G_i^* = \frac{\sum_{j=1}^{n} W_{ij}x_j - \bar{x}\sum_{j=1}^{n} W_{ij}}{\left[\sqrt{\sum_{j=1}^{n} x_j^2 \Big/ n - (\bar{x})^2}\right] \times \sqrt{\left[n\sum_{j=1}^{n} W_{ij}^2 - \left(\sum_{j=1}^{n} W_{ij}\right)^2\right] \Big/ (n-1)}} \quad (3)$$

where G_i^* is the Getis-Ord local statistic; x_j is the observed value of spatial unit j; W_{ij} is the spatial weight matrix between units i and j; and n is the sum of all elements of the spatial weight matrix. In order to standardize G_i^* for the convenience of comparison, it can be transformed into:

$$Z\left(G_i^*\right) = \frac{G_i^* - E\left(G_i^*\right)}{\sqrt{Var\left(G_i^*\right)}} \quad (4)$$

where $E(G_i^*)$ is the mathematical expectation of G_i^* (i.e., the Getis-Ord local statistic); $Var(G_i^*)$ is the variance of G_i^*. If the $Z(G_i^*)$ values in unit i and its surrounding units are positively high (i.e., greater than the mean value), the spatial cluster forms a hotspot zone.

2.2.3 Spatial variation function

The spatial variation function, also known as the semivariable function, represents the randomness and constitutive property of a regional variable through strict mathematical analyses as illustrated in Equation (5). In addition, spatial variation functions can be used to represent the spatial variability and correlation of geographical variables (Garrigues *et al.*, 2006).

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[L(x_i) - L(x_i + h) \right]^2 \quad (5)$$

where $\gamma(h)$ is the spatial variation function; h is the distance between sample points of regional variable $L(x)$ at locations of x ($L(x)$) and $x + h$ ($L(x + h)$), that is, lag. $N(h)$ is the sample size of h lag. It should be pointed out that the spatial variation function only makes sense within 1/2 maximum distance of sample points (Jin and Lu, 2009), which means that $h \times N(h)$ should be no larger than 1/2 maximum distance between sample points. $L(x_i)$ is the observed value of regional variable $L(x)$ at unit i.

Additionally, as stated by Garrigues *et al.* (2006), the spatial variation function curve would not theoretically pass through the origin and should have a minimum spatial heterogeneity 'nugget' in y-axes which is caused by the local randomness of variables. A stable spatial variation would be achieved when the variable increase to a certain size with the increased distance in x-axes, which is called the 'still'. A larger 'still' indicates a stronger spatial heterogeneity, and vice versa. The 'nugget coefficient' is calculated as the nugget/still ratio. A large nugget coefficient demonstrates that the local spatial variation is mainly caused by random elements. Otherwise, the local spatial variation is mainly caused by geographical processes like local spatial autocorrelation. The 'spatial range', the distance between two points when the variation function reached the 'still', is used to measure the spatial autocorrelation scale. In this 'spatial range', closer distribution of sample points in the region will result in a stronger spatial correlation. However, no spatial correlation could be observed when the distance is beyond this spatial range.

3 Results

3.1 Global analysis of spatial economy pattern

The Global Moran's I of county level per capita GDP (Fig. 2) in the Chang-Zhu-Tan Urban Agglomeration from 2000 to 2010 was calculated using the software 'GeoDa'. The calculated Global Moran's I with significance Z statistic validation was determined through 999 spatial arrangements.

(1) During the time period, Global Moran's I is significantly positive with an overall increasing trend. This indicates a positive spatial correlation of county-level economy in the entire study region. In other words, county units with high economic level and those with low economic level in the Chang-Zhu-Tan Urban Agglomeration were observed to be spatially clustered.

(2) Evolution of economic clusters can be divided into three stages according to the trend curve of Global Moran's I. The first stage was from 2000 to 2003 when a region cluster was initialized in the Chang-Zhu-Tan Urban Agglomeration; the second stage was from 2003 to 2008 when the global autocorrelation of the urban agglomeration fluctuated within a small range, basically maintaining a stable clustering trend; the third stage was from 2008 to 2010 when the clustering effect increased suddenly and reached a higher level, thus resulting in a high correlation between adjacent units in the urban agglomeration.

3.2 Local analysis of spatial economy pattern

Due to the representativeness of 'transition years' for the entire period in terms of local spatial characteristics of economy, years 2000, 2003, 2008, and 2010 were screened out for the spatial evolution analysis. This analysis is also based on the Global Moran's I results

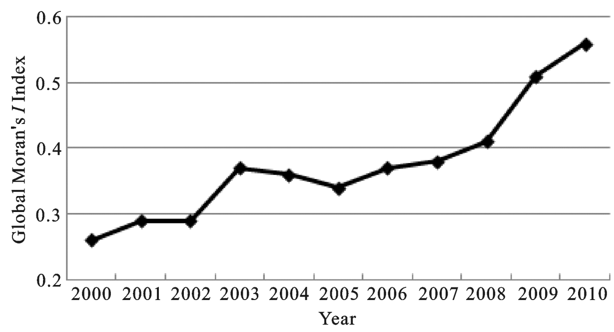

Fig. 2 Global Moran's I of county level per capita GDP in Changsha-Zhuzhou-Xiangtan Urban Agglomeration from 2000 to 2010

mentioned above. In this process, Moran′s *I* scatterplot was produced for per capita GDP (Fig. 3) in GeoDa. Furthermore, the evolution diagrams of county-level economic hotspots were created using ArcGIS 9.3 (Fig. 4).

3.2.1 Moran's I scatterplot

(1) As shown in Fig. 3, for the four transition years, almost all county units in the Chang-Zhu-Tan Urban Agglomeration were included in the first (Fig. 3a) and the third quadrants (Fig. 3b), which belong to high-high and low-low clusters with significant spatial autocorrelations, respectively. However, more counties fall into the third quadrant, denoting a significant disparity of economy development within the urban agglomeration. This finding suggests that further improvement is needed to promote an overall development of economy.

(2) As can be observed from Fig. 3, the first quadrant attracted more points, whereas the third quadrant lost points gradually. No significant variation was observed in the urban agglomeration from 2000 to 2003. However, from 2008 to 2010, the Wangcheng District and Liuyang City shifted from the fourth quadrant to the first quadrant, the cluster zone with high economic level, while Ningxiang County entered the second quadrant. This pattern variation suggests that the spatial correlation of county level economy in the Chang-Zhu-Tan Urban Agglomeration strengthened significantly since 2008. The economic development of units surrounding the core area of Changsha Proper has substantially benefited from its increasingly prominent radiation effect.

3.2.2 Evolution of economic hotspot zone

(1) Figure 4 shows the spatial pattern of county-level hotspot zone of per capita GDP in the Chang-Zhu-Tan Urban Agglomeration during the four transition years. It can be seen that the hotspot zone in the region diffused around the single core area centered at Changsha Proper since 2000. Meanwhile, the units beyond the core area fell into the coldspot or sub-coldspot zones.

(2) In terms of zone evolution, the hotspot zone with high economic level experienced a stable growth from 2000 to 2010. Although the hotspot zone in 2003 remained the same as that in 2000, it expanded to Wangcheng District and Liuyang City in 2008. In 2010, Ningxiang County, Shaoshan City, Xiangxiang City and Liling City withdrew from the coldspot zone, and Xiangtan County entered the sub-hotspot zone. With the largely boosted economy, the hotspot zone with high economic level in the northern county units changed significantly. However, units in the southern coldspot zones such as Youxian County, Chaling County and Yanling County which experienced little positive driving, still had to rely on themselves to a large extent.

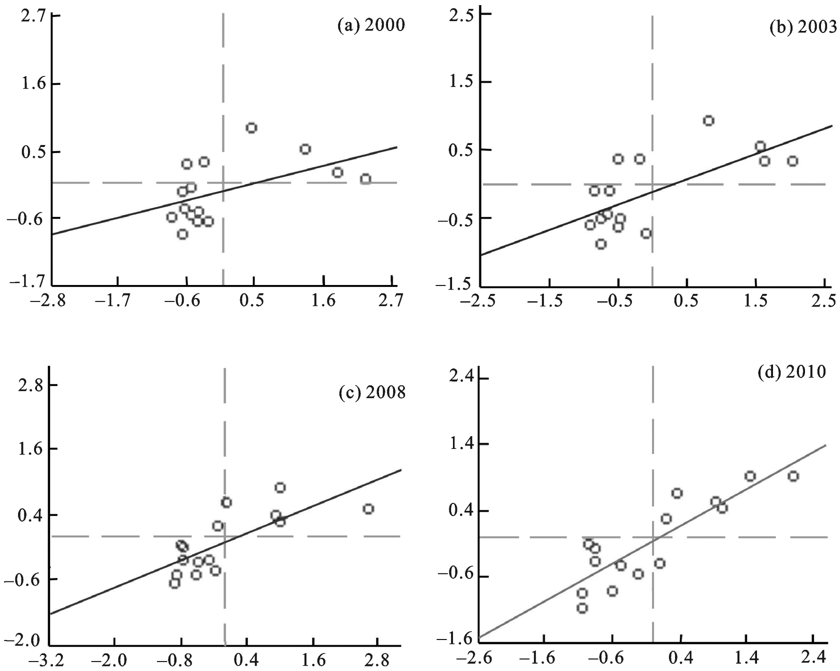

Fig. 3 Moran scatterplot of county level per capita GDP in Changsha-Zhuzhou-Xiangtan Urban Agglomeration

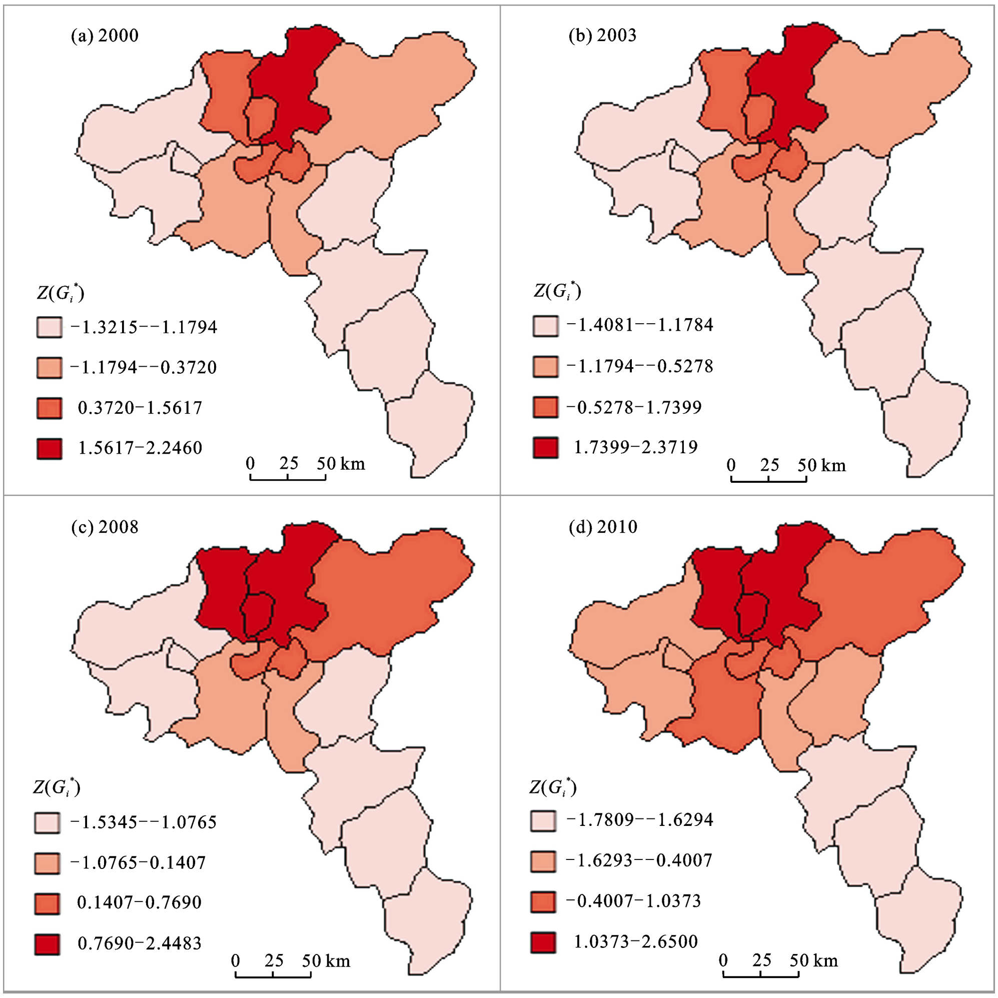

Fig. 4 Hotspot zone evolution of spatial economy pattern in Changsha-Zhuzhou-Xiangtan Urban Agglomeration based on Z score of Getis-Ord G_i^* ($Z(G_i^*)$)

3.3 Variation of spatial economy pattern

The evolution process of the spatial economy pattern during the four transition years in the Chang-Zhu-Tan Urban Agglomeration was further investigated by using the spatial variation function. According to Equation (5), the optimal fitting model (i.e., exponential) was obtained through the tests among different fitting models, such as spherical, exponential, Gaussian, linear, and circular. Variogram parameters determined for exponential models in different years are shown in Table 2. Furthermore, ordinary Kriging interpolation was carried out based on the fitting results to produce the 3D evolution map of the spatial economy pattern in the agglomeration area (Fig. 5).

(1) As shown in Table 2, there is an obvious pattern of spatial heterogeneity in economy among county units in the Chang-Zhu-Tan Urban Agglomeration. The nugget coefficient was generally close to 0, indicating the spatial heterogeneity was mainly caused by the spatial autocorrelation instead of random factors. Furthermore,

Table 2 Variogram parameters for modeling spatial economy pattern in Changsha-Zhuzhou-Xiangtan Urban Agglomeration

Year	Range (km)	Nugget (C_0)	Still (C+C_0)	C_0/(C+C_0)	Model	R^2
2000	10.49	0.0091	0.38	0.034	exponential	0.918
2003	11.96	0.0023	0.28	0.008	exponential	0.824
2008	23.98	0.0311	0.33	0.095	exponential	0.811
2010	35.34	0.0001	0.37	0.000	exponential	0.617

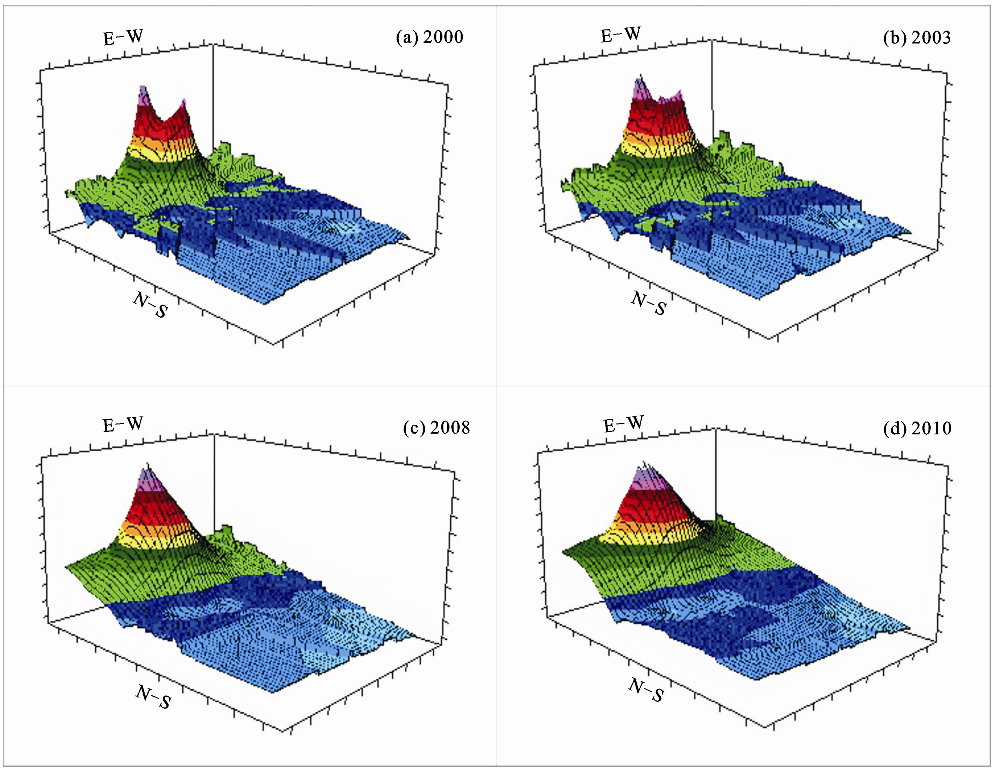

Fig. 5 3D evolution map of spatial economy pattern in Changsha-Zhuzhou-Xiangtan Urban Agglomeration

during the four transition years, the determination coefficient of the fitting models decreased from 0.918 to 0.617, indicating a weakening trend of self-organization of economy in the urban agglomeration.

(2) The spatial range generated from the model fitted under fixed lag exhibited an expanding trend. This suggests that the spatial autocorrelation effect caused by the structured spatial gradient of county-level economy is increasing. As a result, the radiation coverage of the core growth pole located in Changsha Proper increased correspondingly and the economic integration of the entire area has been accelerated since 2008.

(3) Figure 5 further illustrated that the spatial economy pattern in the Chang-Zhu-Tan Urban Agglomeration is continuous and follows a certain law. Since 2000, a wide single-peak upheaval centered at Changsha Proper has gradually developed into two small peaks (Changsha Proper and Zhuzhou Proper) in the urban agglomeration (Fig. 5a). This evolution significantly uplifted the economic level of northern county units with a diffusion trend and gradually expanded its radiation coverage. However, a plain structure with an economic slump at the same time period was also observed for county units in the southern part of the urban agglomeration. This obvious difference suggests increased disparities in economy development between the southern and northern county units.

4 Causal analysis

The above findings revealed that the Changsha 'upheaval' and its surrounding units have gradually become the core area of the Chang-Zhu-Tan Urban Agglomeration in terms of economic development, whereas the southern counties underwent a relatively slower development, leading to an obvious south-north disparity. While the results are consistent with previous studies that employed Gini coefficient and Thiel coefficient (Li, 2010), they disclose extra information about the spatial process of economic development and the hotspot and coldspot zones. This enables one to easily understand the difference of economic levels among county units in the Chang-Zhu-Tan Urban Agglomeration. Thus, based on the results from previous research (Zhu, 2012; Zhou and Peng, 2012; Tang and Zhou, 2013), in this section we analyzed the causes for difference of economic development among county units from the perspective of spatial pattern and its evolution.

4.1 Pattern contributors analysis

The economic development of a region generally relies on its resource affluence and economic position. The economy development disparities between the southern and northern county units in the Chang-Zhu-Tan Urban Agglomeration during 2000 to 2010 are of course a reflection of their economic positions. Changsha Proper, the capital of Hunan Province, is the political, economic and cultural center of the Province, as well as the hub of electronic engineering and transportation. Changsha Proper therefore enjoys the best location advantage for economic development which leads to its economic single-peak upheaval. Additionally, from the perspective of town density, Chang-Zhu-Tan Urban Agglomeration contains 15 town units among which 12 were distributed in the northern region and three (Youxian County, Yanling County and Chaling County) scattered in the long and narrow southern region. Consequently, the spatial diffusion effect of the economy development of Changsha 'upheaval' failed to reach these three units. On the contrary, the Changsha County and Wangcheng District adjacent to the Changsha economy 'upheaval' experienced a fast economic development due to the 'upheaval's radiation effect and evolved as a hotspot zone with high economic levels.

4.2 Evolution contributors analysis

4.2.1 Role of industrial 'pusher'

The development speed of the economy of a region absolutely depends on its three-industrials (Gao and Ma, 2008). Therefore, the correlation analysis between per capita GDP and three industrials could be useful for better understanding difference in economic development (measured by per capital GDP) among the northern and southern county units. Table 3 presents the global spatial autocorrelation results of the three Industries in the Chang-Zhu-Tan Urban Agglomeration from 2000 to 2010.

Comparing the results of Global Moran's *I* from three industrials' output (Table 3) and those of the per capita GDP (Fig. 2), it can be found that: 1) Due to the land restriction, the output of the primary industry in the Chang-Zhu-Tan Urban Agglomeration exhibited a negative spatial correlation with obvious differences among county units, indicating an adjacency tendency between relatively rich units and less-rich units. 2) The tertiary industry generally presents a spatial randomness pattern and fails to positively promote the economy development of the urban agglomeration. This phenomenon indicates a polarized distribution of tertiary industry in the study area. 3) The output of secondary industry was consistent with that of per capita GDP, both of which exhibited significantly positive spatial correlations and strengthening trends with time. This finding indicates the remarkable economic contributions of the secondary industry to the development of the Chang-Zhu-Tan Urban Agglomeration.

4.2.2 Guidance of macro-policy

Governmental macro-policy can dramatically drive a region's development and intensify regional relations (Wang and Fang, 2011). This rule is especially effective in China and has yielded to strong governmental dominance in developing the Chang-Zhu-Tan Urban Agglomeration.

Based on theoretical concepts and guidelines from the central and provincial governments, it can be understood that policies around the Chang-Zhu-Tan Urban Agglomeration before 2005 were still conceptual. These preliminary policies include the integral infrastructure construction planning, the 'Overall Planning for the Development and Construction of Xiangjiang River Eco-economic Belt' in 2002, and the 'Regional Planning of Chang-Zhu-Tan Urban Agglomeration' in 2005. This is also the most feasible reason why the economic spatial pattern of the Chang-Zhu-Tan Urban Agglomeration remains relatively stable before 2005. After that, as the national pilot area for constructing a resource-saving and environmental-friendly society, the Chang-Zhu-Tan Urban Agglomeration was approved by the State Council in December, 2007. Meanwhile, projects such as the High-Tech Industrial Park, the College Town and the Intercity Expressway were implemented in this area.

Table 3 Global Moran's *I* for county level three industries in Changsha-Zhuzhou-Xiangtan Urban Agglomeration from 2000 to 2010

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Primary Industry	–0.16	–0.15	–0.18	–0.14	–0.16	–0.16	–0.16	–0.19	–0.16	–0.17	–0.17
Secondary Industry	0.17	0.17	0.18	0.21	0.19	0.26	0.28	0.29	0.21	0.23	0.25
Tertiary Industry	0.01	0.02	0.01	0.02	0.02	0.01	–0.01	–0.01	–0.01	–0.01	–0.01

This symbolized a stage from which the whole integration construction of the Chang-Zhu-Tan Urban Agglomeration entered a substantial level. These progresses were echoed by our findings in this study, which revealed that the integration of Chang-Zhu-Tan Urban Agglomeration accelerated significantly from 2008 to 2010

In addition, from the spatial perspective, most policies concerning the Chang-Zhu-Tan Urban Agglomeration were preferential to its urban areas such as Changsha Proper, Zhuzhou Proper, and Xiangtan Proper. This reflects that decision-makers of the Chang-Zhu-Tan Urban Agglomeration were employing an imbalanced development mode to drive the whole urban agglomeration′s economy. In this way, it is reasonable to understand that the core status of Changsha Proper was intensified gradually and the economy development of the northern county units in the urban agglomeration exhibited a diffusion trend around the Changsha ′upheaval′. On the contrary, some southern units experienced an obvious economic slump.

5 Conclusions

In this study, the spatial economy pattern in the Chang-Zhu-Tan Urban Agglomeration from 2000 to 2010 and its county-level evolution are explored using ESDA tools. The results answer questions about whether or not the county units′ economy in the Chang-Zhu-Tan Urban Agglomeration progressed as planned by the ′integration′ policy. The results are important for making solutions to guide a reasonable economy development in the Chang-Zhu-Tan Urban Agglomeration. From this study, we conclude that:

(1) County-level economy in the Chang-Zhu-Tan Urban Agglomeration showed significantly strong spatial autocorrelations. In addition, the spatial cluster of economy intensified significantly and the economic integration accelerated greatly after 2008.

(2) The northern county units surrounding the core area of Changsha Proper form a hotspot zone that has high economic level, whereas those located in the southern part fall into a coldspot zone. Significant variations of economic development were observed in the Chang-Zhu-Tan Urban Agglomeration.

(3) In terms of space-time mechanism, the economy development disparities among county units in the Chang-Zhu-Tan Urban Agglomeration were mainly caused by spatial autocorrelation instead of random factors. The spatial economy pattern centered at Changsha ′upheaval′ drives the development of it surrounding units to a large extent.

(4) Town density, secondary industry, and integration policy are the major contributors driving the evolution of the spatial economy pattern in the Chang-Zhu-Tan Urban Agglomeration.

However, it should be pointed out that this study presents a preliminary application of ESDA in analyzing the form and evolution of the spatial economy pattern in the Chang-Zhu-Tan Urban Agglomeration. Further works should focus on comprehensive and systematic explorations on the selection of economic indicators, determination of research time span and key ′transition years′, and on overcoming the Modifiable Area Unit Problem (MAUP) in the study area. For example, the evolution of spatial economy pattern in the area and its driving factors could be further explored based on a longer time span, at a smaller spatial scale (i.e., town or village unit), and with multi-regional variables.

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References

Akita T, 2003. Decomposing regional income inequality in China and Indonesia using two-stage nested Theil decomposition method. *The Annals of Regional Science*, 37(1): 55–77. doi: 10.1007/s001680200107

Andrienko N, Andrienko G, 2006. *Exploratory Analysis of Spatial and Temporal Data*. Berlin, Germany: Springer.

Anselin L, 1995. Local indicators of spatial association: LISA. *Geographical Analysis*, 27(2): 93–115. doi: 10.1111/j.1538-4632.1995.tb00338.x

Arbia G, 2001. The role of spatial effects in the empirical analysis of regional concentration. *Journal of Geographical Systems*, 3: 271–281. doi: 10.1007/PL00011480

Bivand R, Müller W G, Reder M, 2009. Power calculations for global and local Moran's *I*. *Computational Statistics & Data Analysis*, 53(8): 2859–2872. doi: 10.1016/J.csda.2008.07.021

Carl G, Kùhn I, 2007. Analyzing spatial autocorrelation in species distributions using Gaussian and logit models. *Ecological Modeling*, 207: 159–170. doi: 10.1016/j.ecolmodel.2007.04.024

Dong Guanpeng, Guo Tengyun, Ma Jing, 2010. GIS based analysis on spatial disparity of economic growth in BTHMR.

Journal of Geo-information Science, 12(6): 797–805. (in Chinese)

Ellison G, Glaeser E L, 1997. Geographic concentration in U.S. manufacturing industries: A dartboard approach. *The Journal of Political Economy*, 105(5): 889–927.

Ertur C, Koch W, 2006. Regional disparities in the European Union and the enlargement process: An exploratory spatial data analy sis,1995–2000. *The Annals of Regional Science*, 40: 723–765. doi: 10.1007/s00168-006-0062x

Fishman R, 2000. The American metropolis at century′s end: Past and future influences. *Housing Policy Debate*, 11(1): 199–213. doi: 10.1080/10511482.2000.9521367

Gallo J, Ertur C, 2003. Exploratory spatial data analysis of the distribution of regional per capita GDP in Europe, 1980−1995. *Papers in Regional Science*, 82(2): 175–201. doi: 10. 1007/s101100300145

Gao Xiaona, Ma Yanji, 2008. Spatial pattern and influencing factor of county-level industrial development in Liaoning Province of China. *Chinese Geographical Science*, 18(1): 24–32. doi: 10. 1007/s11769-008-0024-6

Garrigues S, Allard D, Baret F *et al.*, 2006. Quantifying spatial heterogeneity at the landscape scale using variogram models. *Remote Sensing of Environment*, 103(1): 81–96. doi: 10. 1016/j.rse.2006.03.013

Getis A, Ord JK, 1992. The analysis of spatial association by use of distance statistics. *Geographical Analysis*, 24(3): 189–206. doi: 10.1111/j.1538-4632.1992.tb00261.x

Goodchild M, Anselin L, Applebaum R *et al.*, 2000. Towards a spatially integrated social science. *International Regional Science Review*, 23: 139–159. doi: 10.1177/01600176000230-0201

Goodchild M, Haining R, 1992. Integrating GIS and spatial data analysis: Problems and possibilities. *International Journal of Geographical Information Systems*, 6(5): 407–423. doi: 10.1080/0269379 9208901923

Guillain R, Le Gallo J, 2010. Agglomeration and dispersion of economic activities in and around Paris: An exploratory spatial data analysis. *Environment and Planning B*: *Planning and Design*, 37(6): 961–981. doi: 10.1068/b35038

Hunan Provincial Bureau of Statistics, 2001–2011. *Hunan Statistical Yearbook (2000–2010)*. Beijing: China Statistics Press. (in Chinese)

Jin Cheng, Lu Yuqi, 2009. Evolvement of spatial pattern of economy in Jiangsu Province at county level. *Acta Geographica Sinica*, 64(6): 714–724. (in Chinese)

Jong P, Sprenger C, Veen F, 1984. On extreme values of Moran's *I* and Geary's *c*. *Geographical Analysis*, 16(1): 17–24. doi: 10.1111/j.1538-4632.1984.tb00797.x

Li Tingting, Wu Shidai, Li Yongshi *et al.*, 2010. Spatial variability and evolutionary mechanism of economic growth in Fujian Province. *Scientia Geographica Sinica*, 30(6): 848–853. (in Chinese)

Li Tian, 2010. Regional economic disparities in Changzhutan Urban Agglomeration. Jinan: Shandong University. (in Chinese)

Liu Xuhua, Wang Jinfeng, 2002. Analysis and application on the specification methods of the spatial weight matrix. *Geo-information Science*, 4(2): 38–44. (in Chinese)

Murray A, McGuffog I, Western J *et al.*, 2001. Exploratory spatial data analysis techniques for examining urban crime implications for evaluating treatment. *British Journal of Criminology*, 41(2): 309–329. doi: 10.1093/bjc/41.2.309

Ord JK, Getis A, 1995. Local spatial autocorrelation statistics: Distributional issues and an application. *Geographical Analysis*, 27(4): 286–306. doi: 10.1111/j.1538-4632.1995.tb00912.x

Patacchini E, Rice P, 2007. Geography and economic performance: Exploratory spatial data analysis for Great Britain. *Regional Studies*, 41(4): 489–508. doi: 10.1080/0034340-0600928384

Pu Yingxia, Ge Ying, Ma Ronghua *et al.*, 2005. Analyzing regional economic disparities based on ESDA. *Geographical Research*, 24(6): 966–973. (in Chinese)

Qin Zhiqin, Zhang Pingyu, 2011. Simulation analysis on spatial pattern of urban population in Shenyang City, China in Late 20th century. *Chinese Geographical Science*, 21(1): 110–118. doi: 10. 1007/s11769-011-0444-6

Rosenthal S, Strange W C, 2004. Evidence on the nature and sources of agglomeration economies. *Handbook of Regional and Urban Economics*, 4: 2119–2171. doi: 10.1016/S1574008-0(04)80006-3

Tang Kai, Zhou Guohua, 2013. Analysis of spatial conflict measurement based on the perspective of economics: A case study of Changzhutan areas. *Journal of Natural Science of Hunan Normal University*, 36(3): 90–94. (in Chinese)

Wang Fazeng, Lu Jinrong, 2011. The evaluation and spatial-temporal evolvement of the city competitiveness of Zhongyuan Urban Agglomeration. *Geographical Research*, 30(1): 50–59. (in Chinese)

Wang Jing, Fang Chuanglin, 2011. New-type driving forces of urban agglomerations development in China. *Geographical Research,* 30(2): 336–347. (in Chinese)

Wang Yang, Fang Chuanglin, Xiu Chunliang *et al.*, 2012. A new approach to measurement of regional inequality in particular directions. *Chinese Geographical Science*, 22(6): 705–717. doi: 10.1007/s11769-012-0556-7

Wang Youqiang, Tsui Kaiyuan, 2000. Polarization ordering and new classes of plarization indices. *Journal of Public Economic Theory*, 3(2): 349–363. doi: 10.1111/1097-3923.00042

Zhou Guohua, Peng Jiajie, 2012. The evolution characteristics and influence effect of spatial conflict: A case study of Changsha-Zhuzhou-Xiangtan urban agglomeration. *Progress in Geography*, 31(6): 717–723. (in Chinese)

Zhang Songlin, Zhang Kun, 2007. Contrast study on Moran and Getis-Ord indexes of local spatial autocorrelation indices. *Journal of Geodesy and Geodynamics*, 27(3): 31–34. (in Chinese)

Zhu Shunjuan, 2012. Study on the spatial structure of Changzhutan urban agglomeration and its optimization. Changsha: Central South University. (in Chinese)