

Spatiotemporal Dynamic Evolution of Population and Economy in Chongqing

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Abstract: Population change and economic development are closely related and interact. The coordinated development of population and economy has increasingly become a hot topic in modern society. Based on the data of resident population and GDP of 38 districts and counties in Chongqing from 2010 to 2019, this paper uses ArcGIS and GeoDa, adopts gravity center method, geographic concentration, inconsistency index, spatial autocorrelation and other research methods to systematically analyze the change of gravity center of population and economy in Chongqing, the spatial distribution and agglomeration degree of population and economy, the coordinated development of population and economy, and the spatial correlation of population and economy. The results show that: (1) Chongqing's population and economic center of gravity show signs of migration to the main urban area of Chongqing; (2) The geographical concentration of population and economy shows that the population and economy of Chongqing are mainly concentrated in the main urban area and its surrounding counties; (3) The inconsistency index between population and economy shows that population agglomeration and economic agglomeration are coordinated in half districts and counties of Chongqing; (4) The spatial autocorrelation analysis shows that the spatial distribution of Chongqing's population and economy has a relatively obvious positive spatial correlation, and areas with similar population and economic coordination tend to congregate in space.

1 INTRODUCTION

Population and economy are two key factors that determine whether a region can develop rapidly. They interact with each other. The growth, agglomeration and flow of population can affect the economic development of a region to a great extent. Whether the economy of a region is prosperous, whether the economy is developing rapidly, and whether the market is prosperous will in turn play an important role in the distribution and change of population. The interaction, connection and restriction between population and regional economy is an important topic in the study of regional social development. Population and economy are also two important indicators reflecting the differences between regions. Studying the relationship between population and regional economy is helpful to promote the development of regional economy and society, construct a good pattern of regional economic development, and realize the coordinated development between regions. To explore the

relationship between regional population growth and regional economic growth is of great practical significance for the population development and economic development of a region.

In recent years, many scholars at home and abroad have done a lot of research on the relationship between population and economy. Wesley E and Klaus P analyzed the role of population growth in economic growth (Wesley, 2017, Peterson, 2017, Klaus, 2014); Oliver M studied the impact of population aging on Japanese economy and the role of population aging in economic growth (Mikiko, 2015); Luca S analyzed the economic problems caused by population growth and the relationship between population growth and economic crisis (Luca, 2016, Luca, 2018). Domestic research on the population and economy of provinces is mainly based on the analysis of the dynamic evolution of population and economy in time and space. (Huang 2016, Zhao 2016), (Liu, 2017, Zhang, 2017, Liu, 2017) and (Xu, 2013, Tang, 2013, Wei, 2013) analyzed the change of population and economic

gravity center in Guizhou Province, Liaoning Province and Xi'an city by using regional population and economic gravity center; (Cai, 2016, Lu, 2016, Hua, 2016), (Ren, 2016, Zhu, 2016, Shou, 2016) and (Wang, 2013, Qin, 2013) analyzed the coupling relationship between population and economy in Guangxi Province, Ningxia urban agglomeration along the Yellow River and Shanxi Province by using geographic concentration and inconsistency index; (Bin 2018, Tang 2018, Li 2018), (Liu, 2013, Zheng, 2013) and (Ding, 2014, Gao, 2014, Gao, 2014) used exploratory spatial data analysis and other methods to study the spatial correlation between population and economy in Hunan Province, Henan Province and Qinghai Tibet Plateau; (Lian, 2018, Wu, 2018) and (Zhang, 2018, Run, 2018) used the growth elasticity of population and economy to analyze the impact of economic growth on population size in northeast China and Yangtze River Delta; Based on Cobb Douglas function, (Chen, 2018, Li, 2018, Yao, 2018) analyzed the impact of population agglomeration on China's urban economic growth. Some scholars have also studied the mutual development of population and economy in Chongqing (Guan, 2017, Tan, 2017, Zhang, 2017, Zhou, 2011, Tu, 2011, Lu, 2011, Liu, 2013, Su, 2013, Guan, 2013), but some of them have been studied for a long time, and there are few studies on the change of Chongqing's population and economic gravity center.

This paper mainly uses the method of barycenter, geographic concentration, inconsistency index and spatial autocorrelation, and uses Moran statistics, Moran scatter diagram and LISA cluster diagram, analyzes the change of the center of gravity of population and economy in Chongqing, the spatial distribution and agglomeration degree of population and economy in different districts and counties, the coordinated development of population and economy, and the spatial correlation of population and economy, and reveals the aggregation and coupling law of population and economy in Chongqing in recent years, which has practical significance for the coordinated development of population and economy in all districts and counties of Chongqing.

2 RESEARCH METHODS AND DATA SOURCES

2.1 Research Methods

2.1.1 Barycentre Method

The center of gravity of population and economy is the point to maintain regional balance and coordination. Suppose that a region is composed of n subunits, then the calculation formula of the barycenter coordinate $Q(X, Y)$ is as follows:

$$Q(X, Y) = \left(X = \frac{\sum_{i=1}^n r_i x_i}{\sum_{i=1}^n r_i}, Y = \frac{\sum_{i=1}^n r_i y_i}{\sum_{i=1}^n r_i} \right) \quad (1)$$

In equation (1), $Q(X, Y)$ represents the center of gravity coordinates of Chongqing's population or GDP; (x_i, y_i) represents the longitude and latitude coordinates of the geometric centers of all regions in Chongqing; r_i represents a certain attribute value of the statistical unit, that is, population or GDP.

2.1.2 Geographical Concentration

Geographical concentration is the data reflecting the concentration degree of a certain factor in a certain area, including population geographical concentration and economic geographical concentration, reflecting the spatial distribution of population and economy.

$$R_{pop_i} = \frac{pop_i / \sum pop_i}{S_i / \sum S_i} \quad (2)$$

$$R_{GDP_i} = \frac{GDP_i / \sum GDP_i}{S_i / \sum S_i} \quad (3)$$

In formulas (2) and (3), R_{pop_i} and R_{GDP_i} respectively represent the geographical concentration of population and economy in the i th region, pop_i and GDP_i respectively represent the population and GDP in the i th region, $\sum pop_i$ and $\sum GDP_i$ respectively represent the total population and total economy in Chongqing, and S_i and $\sum S_i$ respectively represent the area of the i th region and the total area of Chongqing.

2.1.3 Inconsistency Index of Population and Economy

The inconsistency index of population and economy is an important parameter to examine whether the distribution of population and economy is balanced in a region. The calculation formula is:

$$I = R_{pop_i} / R_{GDP_i} \quad (4)$$

Where I is the inconsistency index, the closer I is to 1, the more coordinated the population and economic development of a region; the smaller I is, the stronger the spatial aggregation ability of a region's economy is; the greater I is, the greater the agglomeration degree of population is.

2.1.4 Global Spatial Autocorrelation

We can use global Moran statistics to analyze the autocorrelation and spatial agglomeration of population and economy in Chongqing. Spatial agglomeration means that the population and economy between adjacent regions do not exist independently, but show typical characteristics of spatial spillover and spatial diffusion (Yang, 2021, Zhang, 2021, Zhang, 2021). According to Moran's research in 1948 (Moran, 1948), the calculation formula is as follows:

$$I_G = \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i=1}^n \sum_{j=1}^n w_{ij}} \quad (5)$$

Where I_G is the global Moran statistics, x_i and x_j represent the population or GDP of district i and district j respectively, w_{ij} is the adjacent weight of spatial units. In the spatial correlation analysis part of this paper, the queen adjacency matrix is used as the spatial weight matrix. $S^2 = \frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2$ is the

variance of population or GDP. The value range of I_G is between -1 and 1, greater than 0 means that the spatial distribution of population or GDP is positively correlated; less than 0 means that the population or GDP is negatively correlated in space; equal to 0 means that the population or GDP is not spatially related.

2.1.5 Local Spatial Autocorrelation

The method of local spatial autocorrelation can be used to analyze the spatial difference degree and significance of population or economy between an

area and its adjacent areas (Anselin, 1995). The definition of local Moran statistics is as follows:

$$I_i = z_i \sum_{j=1}^n w_{ij} z_j \quad (6)$$

Among them, z_i and z_j are the deviation of the number of permanent residents or GDP of the i and j area from the mean, that is, $z_i = (x_i - \bar{x})$, $z_j = (x_j - \bar{x})$, if $I_i > 0$, it means that there is a positive correlation between the population or economy of the adjacent districts and counties; $I_i < 0$, it means that there is a negative correlation. Moran scatter plot depicts the relationship between the population or economy of each region and its spatial lag term, and makes a visual two-dimensional display of it, reflecting the spatial autocorrelation of the investigated variables in the local region. Moran scatter are divided into four types: high-high, low-low, low-high and high-low. The point falling into a high-high or low-low region indicates that the population or economic agglomeration degree of a region is high (low) and the population or economic agglomeration degree of its adjacent regions is high (low), with small spatial difference, which belongs to spatial positive correlation; the point falling into a low-high or high-low region indicates that the population or economic agglomeration degree of a region is low (high) and the population or economic agglomeration degree of its adjacent regions is high (low), large spatial difference, belonging to spatial negative correlation.

2.2 Interpretation of Data

The resident population and GDP data of Chongqing from 2010 to 2019 are all from Chongqing statistical yearbook (Chongqing Statistics Bureau). Before analyzing the data, the relevant data are standardized.

3 RESULTS AND DISCUSSION

3.1 Analysis on the Migration of Gravity Center of Population and Economy in Chongqing

3.1.1 Population Distribution Gravity Center and Migration Change in Chongqing

According to the resident population data of various regions of Chongqing from 2010 to 2019, the

population distribution center of gravity ($107.2088^{\circ}E$ - $107.2898^{\circ}E$, $29.8694^{\circ}N$ - $29.8984^{\circ}N$) and geometric center coordinates ($107.8744^{\circ}E$, $30.0572^{\circ}N$) are calculated, and the migration map of population distribution center of gravity in Chongqing is generated (Fig. 1)

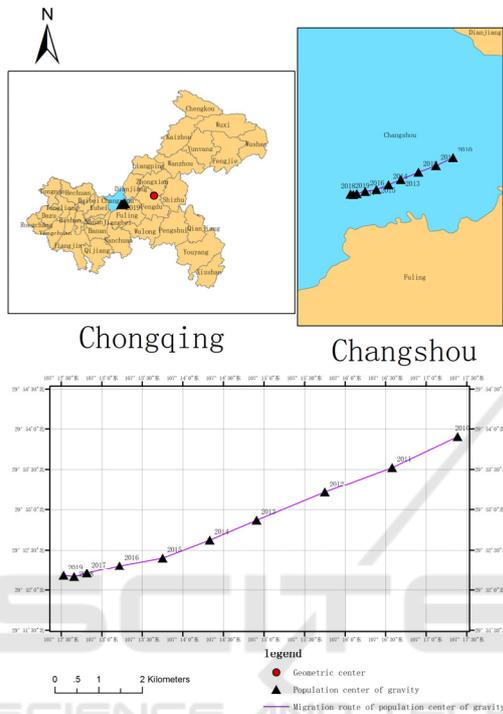


Figure 1: Migration map of population distribution gravity center in Chongqing.

From the migration map of population distribution center of gravity, it can be seen that from 2010 to 2019, Chongqing’s population center of gravity is distributed in Changshou District, which has a large deviation from the geometric center of Chongqing. In the past ten years, the population gravity center of Chongqing has been distributed in the southwest of the geometric center of Chongqing, and it has moved from northeast to southwest, and is farther and farther away from the geometric center of Chongqing, and keep the trend of migration to the southwest. This may be related to the good economic development and high population attraction of the main urban area in the southwest of Chongqing geometric center. In 2010, the total population of Chongqing main urban area is 7.4576 million, accounting for 25.85% of the total population; in 2019, the total population of Chongqing main urban area is 8.8439 million, accounting for 28.31% of the total population of Chongqing. In the past ten years,

the proportion of population in the main urban area has increased by nearly 3 percentage points, which is enough to see the trend of population gravity center moving to the southwest.

3.1.2 The Gravity Center of Economic Distribution and Its Change in Chongqing

According to the GDP data of each district and county in Chongqing from 2010 to 2019, the annual economic distribution gravity center ($106.9095^{\circ}E$ - $106.9345^{\circ}E$, $29.7498^{\circ}N$ - $29.7660^{\circ}N$) from 2010 to 2019 is calculated, and the economic distribution gravity center migration map of Chongqing is generated (Fig 2).

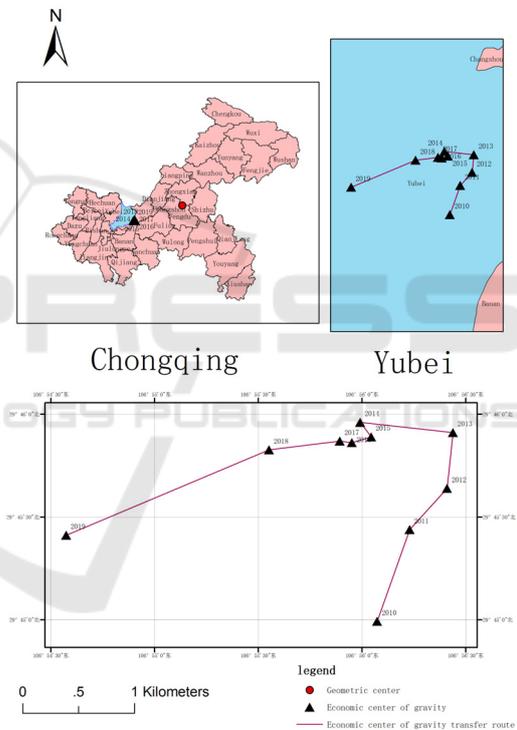


Figure 2: Chongqing economic distribution center of gravity transfer map.

It can be seen from the transfer chart of economic gravity center that the economic gravity center of Chongqing is distributed in Yubei District from 2010 to 2019, which is quite different from the geometric center of Chongqing. In the past ten years, Chongqing’s economic center of gravity is located in the southwest of Chongqing’s geometric center. From 2010 to 2013, Chongqing’s economic center of gravity moved from south to north. From 2013 to

2019, Chongqing’s economic center of gravity moved from northeast to southwest. From 2010 to 2013, Yubei District’s GDP increased greatly. In 2010, Yubei District’s GDP accounted for 7.14% of Chongqing’s GDP, while in 2013, Yubei district’s GDP accounted for 8.1%. Over the past few years, it has increased by 1 percentage point, which is the largest increase among all districts and counties in Chongqing. Therefore, from 2010 to 2013, Chongqing’s economic gravity center has been moving northward. From 2013, the proportion of GDP in Yubei District began to decrease, and the GDP of Hechuan, Rongchang, Tongliang and other districts and counties in southwest Chongqing began to increase significantly. From 2017 to 2019, the proportion of GDP in Hechuan, Rongchang, Tongliang increased by 0.63%, 0.53% and 0.53% respectively. Therefore, from 2013, the economic distribution gravity center of Chongqing began to move to the southwest.

3.2 Geographical Concentration Analysis of Chongqing’s Population and Economy

3.2.1 Analysis of Geographical Concentration of Population in Chongqing

Based on the data of resident population in 2010 and 2019, the geographic concentration index of Chongqing’s population can be calculated according to equation (2). The geographic concentration can be divided into five grades. The higher the level is, the more concentrated the population is. The classification results are shown in Table 1.

Table 1: Classification of geographical concentration of population in Chongqing in 2010 and 2019.

Geographical concentration of population		
Grades	2010	2019
Level 1	Kaizhou, Chengkou, Wuxi, Yunyang, Fengjie, Wushan, Shizhu, Fengdu, Nanchuan, Wulong, Pengshui, Qianjiang, Youyang, Xiushan	Kaizhou, Chengkou, Wuxi, Yunyang, Fengjie, Wushan, Shizhu, Fengdu, Nanchuan, Wulong, Pengshui, Qianjiang, Youyang, Xiushan
Level 2	Tongnan, Hechuan, Tongliang, Dazu, Jiangjin, Banan, Qijiang, Fuling, Changshou, Dianjiang, Liangping, Zhongxian, Wanzhou	Tongnan, Hechuan, Tongliang, Dazu, Jiangjin, Banan, Qijiang, Fuling, Changshou, Dianjiang, Liangping, Zhongxian, Wanzhou, Rongchang, Yongchuan
Level 3	Rongchang, Yongchuan,	Bishan, Beibei, Yubei

	Bishan, Beibei, Yubei	
Level 4	Shapingba, Dadukou, Jiulongpo, Jiangbei, Nan'an	Shapingba, Dadukou, Jiulongpo, Jiangbei, Nan'an
Level 5	Yuzhong	Yuzhong

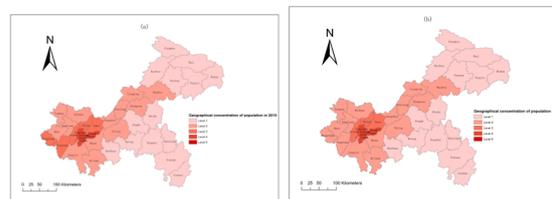


Figure 3: Geographical concentration distribution of Chongqing’s population in 2010(a) and 2019(b).

Fig 3 shows the distribution of population geographical concentration in Chongqing in 2010 and 2019. As can be seen from Fig 3, the population geographical concentration of Chongqing in 2010 showed a pattern of high in the West and low in the East. The population geographical concentration index decreases from the main city to the surrounding districts and counties. In terms of the degree of agglomeration, the main urban area has the most dense population, among which Yuzhong has the highest degree of population agglomeration, and the population geographical concentration index is 75.97, which is much larger than other regions. It is the only one of the level 5 of agglomeration areas. The population of the Nan’an and Jiangbei are also highly concentrated, with an index greater than 7.18, which are all areas of the fourth aggregation level. Some areas in the north and west of the main urban area, such as Bishan and Yongchuan, also have high population density, with an index between 1.57 and 2.65. They belong to the third aggregation level. Some areas south of the main urban area have relatively small population aggregation, such as Qijiang. Their indexes are between 0.84 and 1.57, which is the second aggregation level area. However, some areas in southeast and northeast Chongqing, which are far away from the main urban area, have a low degree of population aggregation, and the index is below 0.84. By 2019, the population geographical concentration of Chongqing has not changed much. Only the population concentration in Rongchang and Yongchuan has decreased, and the population concentration in the main urban area is still very high. Generally speaking, from 2010 to 2019, the main urban area has always been the most densely populated place in Chongqing, the degree of aggregation is increasing year by year, and the area with high population concentration tends to narrow. The population geographical concentration in Northeast and Southeast Chongqing remains at a low

level, and the population concentration is gradually weakening.

3.2.2 Analysis of Economic Geographical Concentration in Chongqing

Based on the GDP data of Chongqing in 2010 and 2019, the economic geographical concentration index in 2010 and 2019 is calculated. According to the economic geographical concentration index, each district and county is divided into five grades. The higher the grade, the more concentrated the economy is. The classification results are shown in Table 2.

Table 2: Classification of economic geographical concentration degree of Chongqing in 2010 and 2019.

Economic geographical concentration		
Grades	2010	2019
Level 1	Kaizhou, Chengkou, Wuxi, Yunyang, Fengjie, Wushan, Qijiang, Shizhu, Dianjiang, Liangping, Zhongxian, Tongnan, Fengdu, Nanchuan, Wulong, Pengshui, Qianjiang, Youyang, Xiushan	Kaizhou, Chengkou, Wuxi, Yunyang, Fengjie, Wushan, Shizhu, Wulong, Fengdu, Nanchuan, Xiushan, Youyang, Pengshui, Qianjiang, Zhongxian
Level 2	Hechuan, Banan, Tongliang, Dazu, Jiangjin, Fuling, Changshou, Bishan, Wanzhou, Rongchang, Yongchuan	Banan, Wanzhou, Changshou, Dazu, Jiangjin, Dianjiang, Liangping, Tongnan, Hechuan, Tongliang, Fuling, Qijiang
Level 3	Beibei, Yubei	Bishan, Beibei, Yubei, Rongchang, Yongchuan
Level 4	Shapingba, Dadukou, Jiulongpo, Jiangbei, Nan'an	Shapingba, Dadukou, Jiulongpo, Jiangbei, Nan'an
Level 5	Yuzhong	Yuzhong

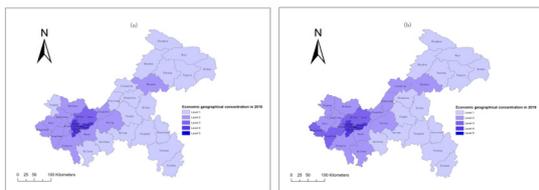


Figure 4: Distribution of economic geographical concentration of Chongqing in 2010(a) and 2019(b).

Fig 4 shows the distribution of economic geographical concentration of Chongqing in 2010 and 2019. In terms of the degree of agglomeration, in 2010, the economic distribution in the main urban area was the most intensive, among which Yuzhong District had the highest degree of economic concentration, and the economic geographical concentration index was 239.44, which was the area

with the strongest degree of economic agglomeration. The index of Jiangbei, Nan'an and other regions is greater than 13.70, belonging to the fourth level of economic agglomeration. The index of Yubei and Beibei are 4.06 and 3.16 respectively, belonging to the third-class economic agglomeration area. Bishan, Tongliang and other regional around the main urban area index are between 0.81 and 1.95, belonging to the second level economic agglomeration area. The index of Southeast Chongqing and Northeast Chongqing, which are far away from the main urban area, are less than 0.81, belonging to the area with the weakest degree of economic agglomeration. By 2019, Yuzhong District will still maintain the highest degree of economic agglomeration, and the degree of economic agglomeration in Bishan, Rongchang and other regions has increased. On the whole, the economic geographical concentration of Chongqing, like the population geographical concentration, shows an unbalanced pattern of high in the West and low in the East. The trend of economic geographical concentration decreasing from the main city to the surrounding districts and counties is very obvious. The main urban area has always been the most concentrated place of economic agglomeration in Chongqing, and the degree of economic agglomeration is becoming stronger and stronger. However, in the area far away from the main urban area with sparse population and vast area, the concentration of economic geography is very small. It can be seen that the economic development of Chongqing is mainly concentrated in the main urban area and its surrounding areas, while the economic development of some districts and counties on the edge of Chongqing is relatively slow, and the economic gap is gradually expanding.

3.3 Analysis on the Inconsistent Index of Population and Economy in Chongqing

In order to analyze whether the distribution of population and economy in various regions of Chongqing is consistent, According to formula (4), the inconsistency index of population and economy in Chongqing in 2010 and 2019 can be calculated, and the coordinated development of population and economy in various regions can be divided into three types: first, second and third, which respectively represent that the degree of population agglomeration is less than the degree of economic agglomeration, the degree of population agglomeration is consistent with the degree of economic agglomeration, and the

degree of population agglomeration is greater than the degree of economic agglomeration.

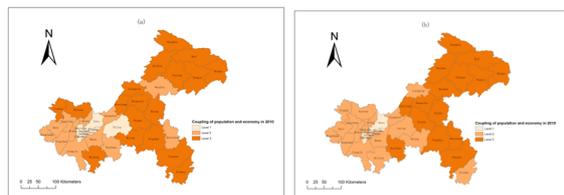


Figure 5: Spatial consistency pattern of population and economic distribution in Chongqing in 2010(a) and 2019(b).

As can be seen from Figure 5, the areas where population agglomeration was greater than economic agglomeration in 2010 were mainly concentrated in Northeast Chongqing and Southeast Chongqing. The degree of population and economic agglomeration in Changshou, Wanzhou and other regions is relatively consistent. In the main urban area, Bishan and Fuling, there is a trend that population agglomeration lags behind economic agglomeration. By 2019, population agglomeration and economic agglomeration in Tongnan, Hechuan and other regions tend to be coordinated. The degree of population agglomeration in most areas of Southeast and Northeast Chongqing is still higher than that of economic agglomeration. In general, only some areas of the main urban area have higher economic agglomeration than population agglomeration, and most other areas have greater population agglomeration than economic agglomeration or population agglomeration is consistent with economic agglomeration. From 2010 to 2019, the spatial differentiation pattern of the relationship between population and economic distribution in Chongqing has changed significantly, indicating that the economy of Chongqing has developed rapidly in recent years, and the GDP of many regions has increased rapidly, which has promoted the concentration of economy, thus promoting the coordinated development of population and economy in places with excessive population agglomeration.

3.4 Spatial Autocorrelation Analysis of Population and Economy in Chongqing

3.4.1 Spatial Autocorrelation Analysis of Chongqing's Population

In order to effectively measure the spatial correlation of Chongqing's population distribution, the global Moran statistics of Chongqing's population from

2010 to 2019 are calculated and tested, as shown in Table 3.

Table 3: Global Moran statistics of Chongqing's population.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
I_G	0.194	0.202	0.222	0.222	0.232	0.246	0.256	0.266	0.266	0.266
Z	2.4	2.5	2.9	2.9	3.1	3.2	3.3	3.4	3.4	3.4
P value	0.019	0.016	0.009	0.006	0.005	0.004	0.004	0.004	0.004	0.003

In Table 3, I_G values are greater than zero, indicating that the population distribution in Chongqing has a spatial positive correlation globally. The Moran scatter map of Chongqing's population in 2010, 2013, 2016 and 2019 is drawn, as shown in Fig 6.

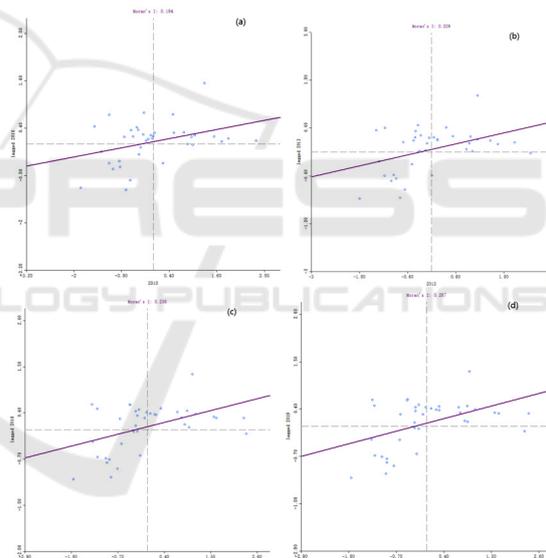


Figure 6: Moran scatter of Chongqing population in 2010(a), 2013(b), 2016(c), 2019(d).

As can be seen from Fig 6, the global Moran statistical value is greater than zero, indicating that there is a significant global spatial positive correlation between the population in various regions of Chongqing, and the population basically presents the characteristics of relatively stable spatial agglomeration, that is, the population in the surrounding areas is also more concentrated, where the population is more concentrated, and vice versa. But the global Moran statistics is low, which indicates that the agglomeration characteristics of population

distribution in Chongqing is not very strong and the correlation is relatively weak. From the Moran scatter diagram, we can see that most districts and counties in Chongqing are located in the first, second and third quadrants, and the distribution is relatively average, which indicates that the distribution of population does not show a very obvious high-high distribution or low-low distribution. It further shows that although there is a positive spatial autocorrelation between the population in various regions of Chongqing, the agglomeration trend is not strong and the positive correlation is weak. In Fig 6, since 2010, the global Moran statistics of the population in all districts and counties of Chongqing has been gradually increasing, which indicates that the spatial agglomeration of Chongqing's population is becoming more and more significant, and the polarization effect is increasing.

Lisa agglomeration map can be used to analyze the local spatial agglomeration characteristics of Chongqing population. Fig 7 shows the local spatial agglomeration of population in different years.

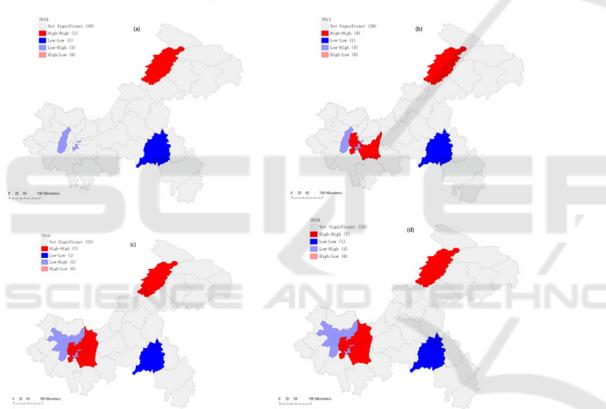


Figure 7. Local spatial autocorrelation agglomeration map of Chongqing's population in 2010(a), 2013(b), 2016(c), 2019(d).

It can be seen from Fig 7 that the population distribution of Chongqing has no obvious spatial agglomeration characteristics, and only a few areas belong to high-high type and low-low type. In general, the distribution pattern of population spatial agglomeration in Chongqing has changed to some extent. The number of high-high type areas of population spatial distribution has been increasing, from one in 2010 to seven in 2019; similarly, the number of low-high type areas of population spatial distribution is also increasing, from three in 2010 to five in 2019. It can be seen that the agglomeration characteristics of Chongqing's population spatial distribution are more and more strong, especially in the main urban area. Six of the seven high-high type

areas are in the main urban area, which indicates that the population growth of the main urban area is fast and the population is relatively dense in recent ten years. With the economic development, the main urban area can attract more people to immigrate.

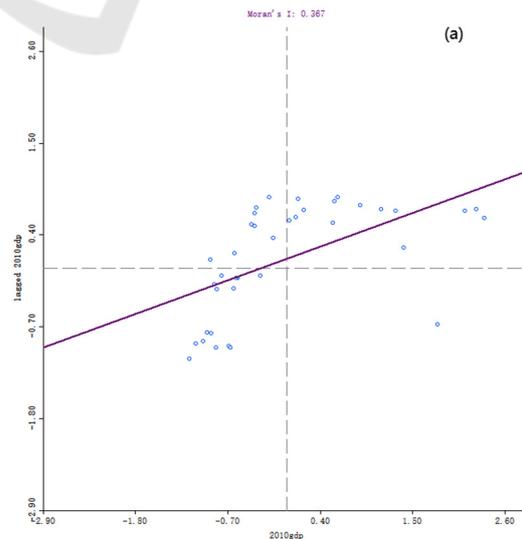
3.4.2 Spatial Autocorrelation Analysis of Chongqing's Economy

In order to effectively measure the spatial correlation of Chongqing's economic distribution, Moran statistics of Chongqing's economy are calculated, as shown in Table 4. It can be seen from table 4 that the Moran statistics of the economies of all districts in Chongqing from 2010 to 2019 passed the significance test at the confidence level of 0.01, and the global Moran statistics are greater than zero, indicating that the economic distribution of Chongqing has obvious positive spatial correlation in the world.

Table 4: Global Moran statistics of Chongqing's economy.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
I_G	0.367	0.367	0.352	0.367	0.371	0.371	0.382	0.387	0.411	0.451
Z	3.726	3.686	3.611	3.759	3.842	3.863	3.946	3.993	4.267	4.715
P	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
lu	2	2	2	1	1	1	1	1	1	1

In Fig 8, the GDP of most districts and counties in Chongqing is distributed in the first quadrant and the third quadrant, indicating that the GDP distribution of each district and county presents a relatively obvious high-high or low-low distribution.



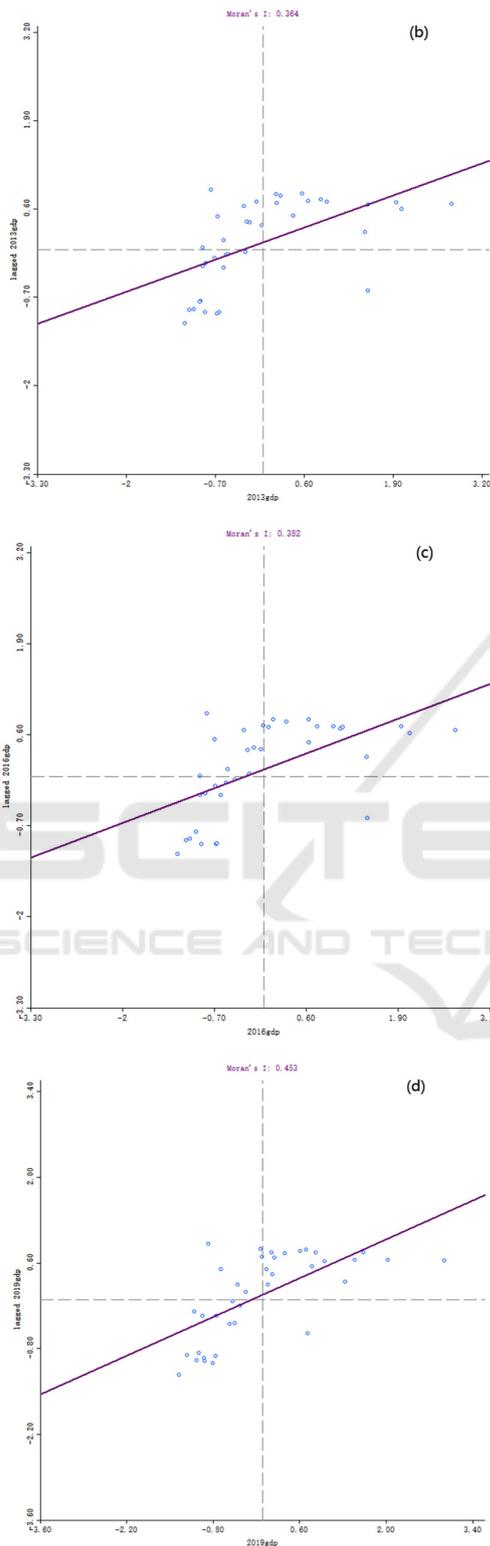


Figure 8. Moran scatter diagram of Chongqing's economy in 2010(a), 2013(b), 2016(c), 2019(d).

From 2010 to 2013, the overall Moran index of Chongqing's GDP has slightly decreased, but Chongqing's GDP is increasing every year. The reason for the decrease of Moran index may be that the regional economic development policies have a certain impact on the differences of economic spatial distribution. Since 2013, the overall Moran index of the economy of Chongqing has been gradually increasing, which indicates that the spatial agglomeration of Chongqing's economy is becoming more and more significant, and the polarization effect is increasing.

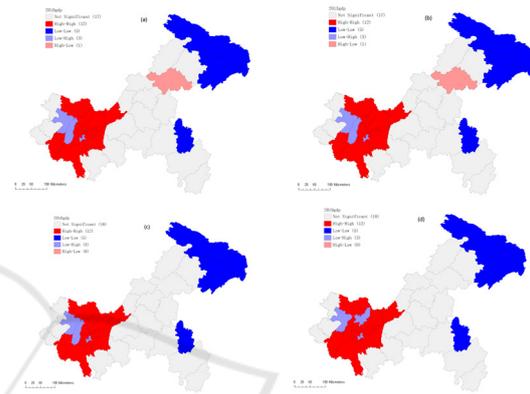


Figure 9: Local spatial autocorrelation agglomeration map of Chongqing's economy in 2010(a), 2013(b), 2016(c), 2019(d).

Fig 9 is the LISA spatial agglomeration map of economy in 2010, 2013, 2016 and 2019. It can be seen from Fig 9 that the spatial agglomeration characteristics of Chongqing economy are obvious, showing the basic pattern of high-high agglomeration in the main urban area and its surrounding areas, and low-low agglomeration in northeast Chongqing. Among them, the districts and counties with significant high-high type are Yubei, Jiangbei, Yuzhong and Nan'an in the main urban area, Hechuan, Changshou in the north of the main urban area, and Jiangjin, Yongchuan in the south of the main urban area. The main urban area is the economic center of Chongqing, with rapid economic development and strong spatial agglomeration. The significant low-low types of districts and counties are mainly Chengkou, Wuxi, Wushan and Fengjie in northeast Chongqing and Qianjiang in southeast Chongqing. Most of these areas are mountainous areas. Due to the poor geographical conditions, the economic development of these areas is relatively slow, and the overall level belongs to the less developed areas of the city. The significant low-high type areas are Dadukou district and Tongliang district

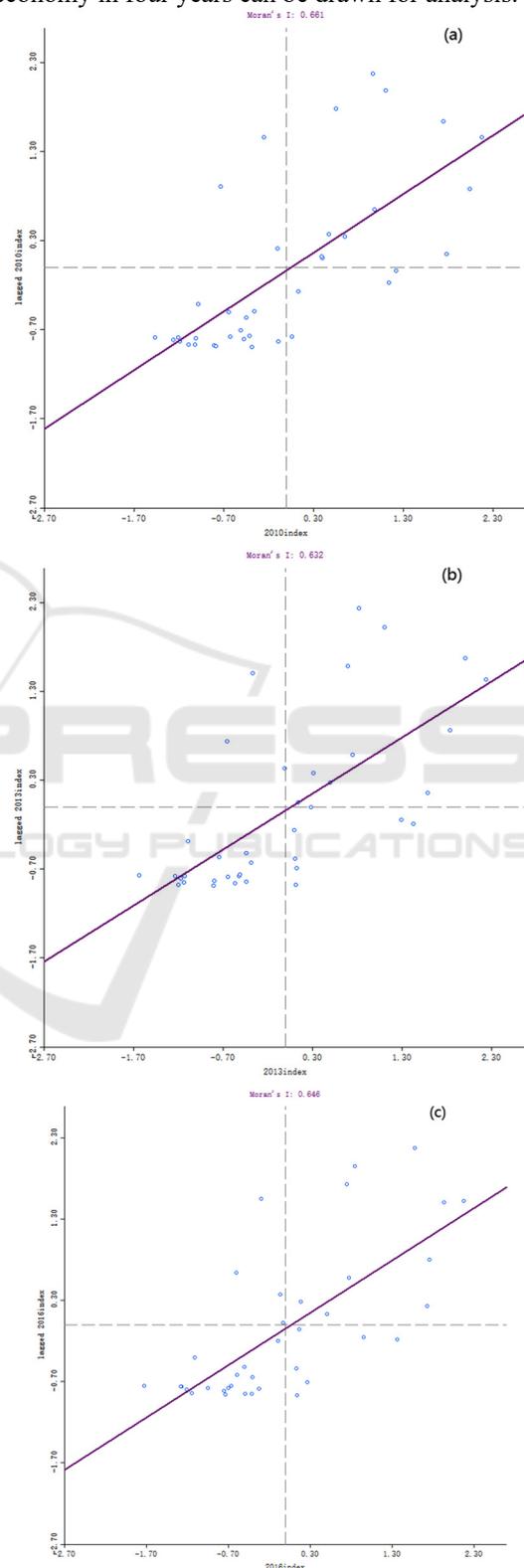
in the west of the main urban area, which shows that there is a relatively large spatial difference between the economic development of these two areas and the surrounding districts and counties, and there is a relatively strong negative spatial correlation. Although Dadukou District belongs to the main urban area, the population of Dadukou District is the least among the nine main urban areas, and the GDP is also the least among the nine main urban areas, which is several times lower than the other eight areas. Therefore, although Dadukou District belongs to the main urban area, the economic spatial distribution of Dadukou District does not show obvious high-high distribution, but low-high distribution. In general, the change of economic spatial agglomeration characteristics of Chongqing's districts and counties is not particularly large. From 2010 to 2019, the number of high-high type areas has remained stable at 12. Moreover, the basic pattern of high-high agglomeration in the main urban area and its surrounding areas and low-low agglomeration in the northeast of Chongqing has not changed much, which indicates that the change of economic agglomeration characteristics in various regions of Chongqing is basically stable.

3.4.3 Spatial Autocorrelation Analysis of Coordinated Development of Population and Economy in Chongqing

Based on the inconsistent index data of Chongqing in 2010, 2013, 2016 and 2019, this paper analyzes the spatial correlation between the coordinated development of population and economy in Chongqing. Use 10eode to draw the global Moran scatter diagram, as shown in Fig 10.

As can be seen from Fig 10, the global Moran autocorrelation coefficient of the inconsistency index within four years is significantly greater than zero, and most areas are located in the first quadrant and the third quadrant. The results show that there is a significant positive correlation between the population and economic disharmony index in Chongqing, showing obvious high-high distribution and low-low distribution. The regions with similar degree of population and economic coordination tend to gather in spatial distribution. Since 2013, the Moran value has been rising, which indicates that the spatial agglomeration degree of areas with similar population and economic coordination in Chongqing has become higher. In order to more intuitively reflect the difference and change process of the inconsistency index of local population and economic

spatial distribution in Chongqing, the Lisa cluster diagram of the inconsistency index of population and economy in four years can be drawn for analysis.



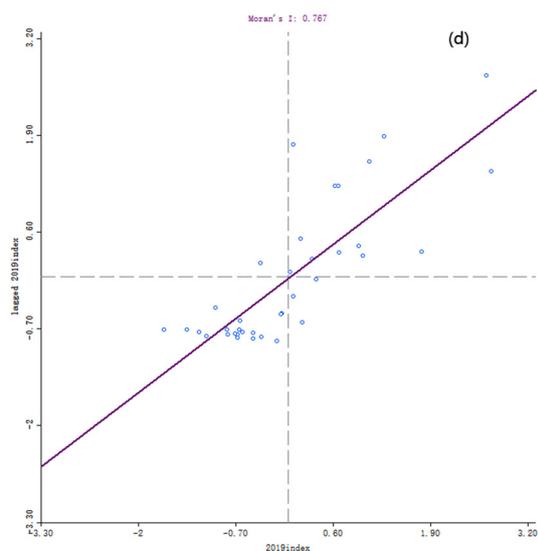


Figure 10: Moran scatter of inconsistency index of Chongqing in 2010(a), 2013(b), 2016(c), 2019(d).

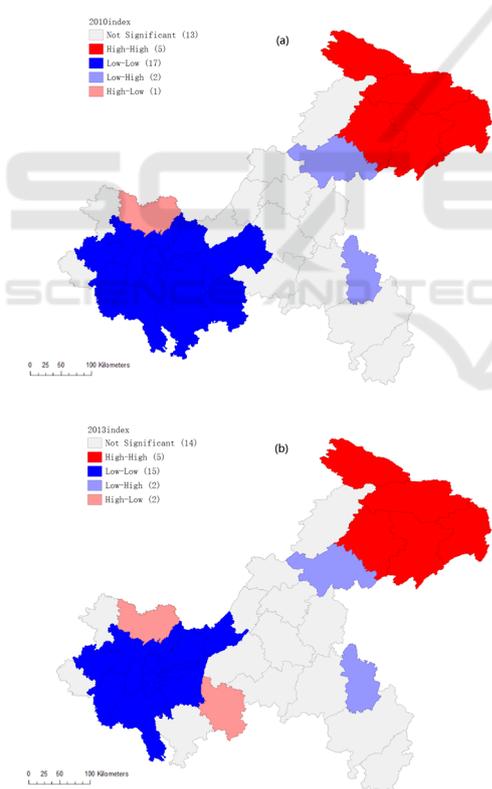


Figure 11: LISA cluster diagram of the inconsistency index in 2010(a), 2013(b), 2016(c), 2019(d).

Fig 11 is the LISA clustering map of the inconsistency index of population and economy. It can be seen from the map that in 2010, the main urban area and its surrounding areas were low-low agglomeration areas in the spatial distribution of population and economic inconsistency index; Wushan, Wuxi, Chengkou in northeast Chongqing are the regions with high-high agglomeration type of inconsistency index; Wanzhou and Qianjiang belong to low-high agglomeration type; Hechuan belongs to high-low agglomeration type. In 2019, the spatial agglomeration characteristics of Chongqing's population and economic inconsistency index did not change much. Generally speaking, the regions with low-low distribution of the inconsistency index are mainly concentrated in the main urban areas with better economic development and some areas around the main urban areas. The regions with obvious high-high distribution of inconsistency index are mainly concentrated in the remote areas and counties of northeast Chongqing where the economic development conditions are poor. It can be seen that Chongqing's population and economic development situation has obvious regional imbalance. The main urban area and its surrounding areas have a very good development foundation and conditions, and they are also in a relatively obvious advantage in the

economic competition of various regions in Chongqing, which promotes the economic agglomeration of the main urban area and its surrounding counties to be higher than the population agglomeration, and the inconsistency index of population and economy is significantly less than 1. Because of the terrain, the economic development of northeast Chongqing is relatively slow, and the natural resources and labor resources are not rich enough, which leads to the backward economy. The economic agglomeration lags behind the population agglomeration, and the inconsistency index of population and economy is significantly greater than 1.

4 CONCLUSIONS

Through the analysis of the development pattern and spatial relationship between population and economic distribution in Chongqing, the following conclusions can be drawn: (1) The population and economic center of gravity has moved to the main urban area; (2) The population and economy are mainly concentrated in the main urban area and its surrounding counties; (3) Population agglomeration and economic agglomeration are coordinated in half of Chongqing; (4) The spatial distribution of Chongqing's population and economy has a relatively obvious positive spatial correlation.

First of all, from the perspective of the gravity center and migration route of Chongqing's population and economy, the gravity center of Chongqing's population and economy is located in the southwest of Chongqing's geometric center, which is consistent with the fact that the main urban area of Chongqing is located in the southwest of Chongqing. From 2010 to 2019, Chongqing's population gravity center has been located in Changshou District, and it is moving to the southwest every year. The economic center of gravity has always been located in Yubei district. From 2010 to 2013, the economic center of gravity has the trend of moving northward, but from 2013, the economic center of gravity has gradually moved to the southwest. On the whole, the population and economic center of Chongqing is gradually moving to the main urban area of Chongqing.

Secondly, from the spatial agglomeration degree and distribution of Chongqing's population and economy, the geographical concentration degree of population and economic show that the spatial distribution of Chongqing's population and economy presents a significant unbalanced distribution pattern of high agglomeration degree in "one circle" and low

agglomeration degree in "two wings". "One circle" refers to the "one hour economic circle" in the main urban area and surrounding areas of Chongqing, and "two wings" refers to the remote areas in the southeast and northeast of Chongqing from the main urban area. The main urban area of Chongqing is the political, economic, cultural and financial center of the city. Due to the terrain, the main urban area of Chongqing and its surrounding areas are mainly low mountains and hills. It is rich in natural resources and has strong carrying capacity of resources and environment, which can attract more foreign population to the main urban area for development and further promote the economic development of the main urban area. As a result, the population and economy of the main urban area are highly concentrated, and the distribution density of population and economy is also very high. The "two wings" of southeast Chongqing and northeast Chongqing are located in Wuling mountain area and Daba mountain area, with steep and complex terrain, low environmental carrying capacity of resources, and poor economic development, which leads to the outflow of population. Therefore, the degree of population and economy aggregation in this part of the area is not obvious, and the distribution density of population and economy is relatively low.

Thirdly, from the perspective of the coordination of Chongqing's population and economic development, with the economic growth of all districts and counties in Chongqing, there are some changes in the coordinated development of Chongqing's population and economy from 2010 to 2019. For example, Tongnan and Hechuan to the north of the main urban area and Qijiang to the south of the main urban area have changed from the area where population concentration is ahead of economic concentration to the area where population concentration and economic concentration are coordinated. On the whole, population agglomeration and economic agglomeration are coordinated in half of Chongqing, while only a few areas have economic agglomeration ahead of population agglomeration.

Finally, from the perspective of spatial correlation of Chongqing's population and economy, the Moran global scatter diagram shows that the spatial distribution of Chongqing's population and economy shows a relatively obvious positive correlation, and the correlation is becoming stronger and stronger. LISA cluster diagram shows that the spatial agglomeration of Chongqing's population and economy in the "one circle" presents an obvious high-high distribution, and the low-low distribution is mainly concentrated in the "two wings" area. The

global Moran scatter diagram and LISA cluster diagram of the inconsistency index of population and economic distribution in Chongqing show that the inconsistency index has a significant positive spatial correlation, and regions with similar population and economic coordination tend to cluster in space. The specific performance is that the low-low agglomeration distribution of population and economic inconsistency index is always in the main urban area and some surrounding areas, while the high-high spatial agglomeration distribution area is always in northeast Chongqing, and has not changed much in the past decade.

The coupling development of population and economy is a complex and continuous evolution process. Due to the limitation of data source and quality, it is obviously limited to conduct in-depth research on the population and economic development of Chongqing only based on the population and GDP data of Chongqing from 2010 to 2019. However, in view of the certain characteristics of population migration and economic development in Chongqing, although this paper is a preliminary study, based on the research ideas and conclusions of this paper, it can provide an important basis for further in-depth analysis in the future. In future research, in-depth analysis and research can be carried out from the following aspects: (1) Select the data with longer time span and the latest data to deeply grasp the development law and latest development of population and economic in Chongqing; (2) Deeply analyze the impact of the differences of human capital structure and age structure on the migration of gravity center of population and economic growth in Chongqing; (3) Construct the index of influencing factors of GDP, and analyze the influencing factors of economic differences among regions in Chongqing and the spatial spillover effect of economic development.

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