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Study on Population-Innovation Coordination and Spatial Layout Based on the Context of Aging

-- A Case Study of Guangdong, Hong Kong and Macao Greater Bay Area

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Abstract: As a major area for the docking and integration of China's 21st Century Maritime Silk Road, the innovation-driven development of the Bay Area city cluster can provide support for the continuous enhancement of China's economic innovation and competitiveness. Population vitality is the prerequisite and foundation of the country's innovative development, but China is facing a very serious aging situation. The process of population aging in the Guangdong-Hong Kong-Macao Greater Bay Area has also become an important factor limiting its rapid development. This study intends to analyze the aging population data and urban innovation and other related indices of the Greater Bay Area urban agglomerations through OLS, entropy method and Moran index, and use ArcGIS to visualize the trends, laws and characteristics of urban development, so as to provide scientific and reasonable data reference and support for the upper-level decision of urban planning.

Keywords: Population-Innovation, Coordination Spatial Layout, Aging Population.

1. Introduction

Due to the strict implementation of the family planning policy and the increase in the cost of raising children in the last century, people's fertility concept is changing from "having more babies and raising more children" to "fewer and better children", China is facing a very serious aging situation—the scale of the elderly population is expanding, the growth rate is accelerating, and there are problems such as the old age before the rich, and the burden of old age is increasing. Guangdong-Hong Kong-Macao Greater Bay Area is a typical region that reflects the aging population in China.Urban population dynamics is an important factor in determining the success of urban technological innovation. In the discussion of population and urban economy, Yang Weining et al. analyzed the coupling relationship between population migration, technological innovation and industrial upgrading to compare and analyze the degree of synergy and evolution of China's economic and social development in the context of the "new normal"[1]. Zhang Yu used the least squares (OLS) method to quantitatively investigate the driving mechanisms affecting the spatial and temporal changes of the coupling coordination between population and economic development in the Pan-YRD, and corresponding countermeasures were proposed for regions with different degrees of coupling coordination according to the regional development conditions and driving mechanisms[2]. Zhang Yaojun et al. used spatial analysis to calculate the changes of population and the center of gravity of each industry in the Beijing-Tianjin-Hebei region from 2000 to 2014, and the local spatial autocorrelation of population and each industry in 2014[3]. In the specific regional scope of Guangdong, Hong Kong and Macao, Chen Tingting et al, used the empirical analysis method to build a model based on panel data, and analyzed that the stronger the interaction between industrial agglomeration and cities, the more developed its regional economy[4]. Wang Yingying et al, by finding that the existing literature ignored the stage characteristics of the development of population aging and its impact on economic growth, concluded that the different stages of the development of population aging on economic growth The impact of different stages of population aging development on economic growth has a U-shaped relationship[5]. Scholars have mostly explored the relationship between "population" and "innovation" as a single factor through linear regression of two-dimensional functions, without unifying the two or three into a single dimension for spatial exploration. In addition, in terms of population, domestic and foreign studies mainly focus on the overall population composition, age structure, and population migration, but lack data on aging, which is less relevant. Regarding the regional economy-related studies in the Greater Bay Area, scholars have mostly focused on exploring the impact of single factors - population, industry, innovation, etc. - on the urban economy, and studies on the coordinated analysis of multiple factors are relatively lacking. Research on the impact of population aging in the Guangdong-Hong Kong-Macao Greater Bay Area, for example, has mostly focused on the correlation between population, culture and senior care industry and senior care facilities, but there is a lack of research on the combination of aging and urban innovation, and most of the research lacks visualization and visualization.

Hence, based on the existing studies, this study intends to investigate and calculate the data related to the aging population and innovation indexes of 11 cities in the Guangdong-Hong Kong-Macao Bay Area, establish a coupling model between population aging and urban technology innovation, attempt to reveal the coupling relationship, coordination degree and regional differences between the two, and use ArcGIS to visually present the balanced development degree of urban clusters in the form of spatial layout on a map. In order to make up for the lack of research in this area, and to provide a basis for policy decisions to reasonably guide technological innovation and population migration to achieve balanced and scientific development among regions.

2. Population and Innovation in the Guangdong-Hong Kong-Macao Greater Bay Area

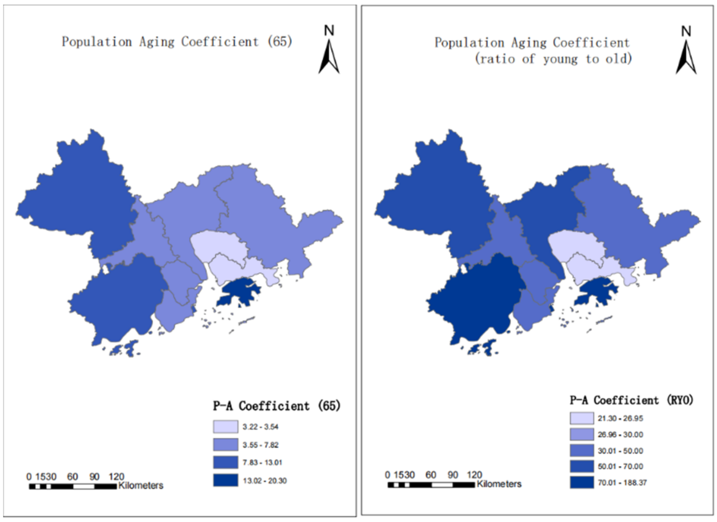
2.1. Population Aging Index

The aging population is an important part that affects the vitality of urban population. Population aging refers to the dynamics of a decrease in the number of young people and an increase in the number of older people in the total population due to a decrease in fertility and an increase in life expectancy, and is the result of a shift in the way the population is reproduced as a result of economic and social progress. The degree of population aging is usually reflected by the coefficient of aging indicator. In this study, the coefficient of aging is calculated using the following two main formulas.

$$\text{Aging coefficient (\%)} = \text{population over 65/total population} \times 100 \quad (1)$$

$$\text{Child aged ratio (\%)} = \text{number of elderly people aged 65 / number of young people aged 0-14} \times 100 \quad (2)$$

According to international standards, an aging society is defined as one in which the proportion of the population aged 65 years or older reaches 7%. Also in formula (2), cities with coefficients < 15% are judged as young cities, those with coefficients between 15% and 30% are mature cities, and those with coefficients > 30% are aged cities[6]. This study uses these two formulas to make a distinction between the degree of population aging in 11 cities in the Greater Bay Area, and to determine the degree of aging in different cities by calculating the proportion of the population aged 65 years or older in each city.



(a) (b)

Figure 1. Greater Bay Area aging coefficient map

The aging process of cities in the Greater Bay Area has entered an accelerated period, and the overall degree of aging in the region is high, among which Guangzhou, Foshan, Jiangmen, Zhaoqing, Hong Kong and Macao have entered the aging society, and the degree of Hong Kong is the deepest. There are currently no young cities in the Greater Bay Area, Shenzhen and Dongguan are adult-type cities with high vitality, and the rest are old-type. For a better differentiation of different types of aged cities and a more scientific analysis of the reasons, this study classifies the aged city data into three levels of aging based on the percentage of child aged ratio.

Table 1. Greater Bay Area Urban Aging Classification Table

City Type	Aging class	City Name
Mature Cities (15%-30%)	/	Shenzhen and Dongguan
	I level	Hong Kong and Macao
Aged Cities (>30%)	II level	Jiangmen and Zhaoqing
	III level	Zhuhai, Zhongshan, Guangzhou, Foshan and Huizhou

2.2. City Innovation Index

2.2.1. Innovation Indicators

There is no unified standard for measuring the level of technological innovation in a region. This study extracts a total of six relevant indicators based on the four dimensions of the system: innovation environment, innovation input, innovation output, and innovation effectiveness, which are the number of R&D employees, the number of patents granted, the number of people enrolled in college or above, the number of cell phone subscribers, the percentage of high-tech product exports, and the added value of advanced manufacturing industry, and imports SPSS will assign weights to the relevant indicators, and finally calculate the innovation index of each city according to the weighting of the weights.

Table 2. Table of urban innovation indicators

Tier 1	Tier 2	Tier 3
Chinese Innovation Index	Innovative Environment	Number of students enrolled in specialized courses or above (persons/100,000)
		Number of cell phone subscribers (million)
	Innovation Inputs	Number of R&D employees (people)
	Innovative Output	Number of patents granted (pieces)
	Innovation Effect	Percentage of exports of high-tech products (%)
		Value added of advanced manufacturing industry (billion yuan)

2.2.2. Entropy method and innovation index

The common assignment methods are hierarchical analysis, entropy method and principal component analysis. The hierarchical analysis method is a subjective method, while the entropy method and the principal component analysis are objective methods. To avoid the interference of subjective factors, this paper considers the objective method of assigning weights. Since the main function of principal component analysis is to exclude the indicators with weak correlation, and the indicators selected in this paper are all strongly correlated in the calculation of technology innovation comprehensive index, and the difference of correlation degree is not very significant, so the entropy method is finally adopted in this paper[7].Thus m is the number of 11 cities in the Bay Area examined; j is the number of indicators in each city's technological innovation index system; x_{ij} is the j^{th} indicator of the i^{th} city. As a result, Guangzhou and Shenzhen have the strongest innovation capability; Foshan, Dongguan, and Hong Kong are the next; Zhaoqing has the weakest innovation capability.

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{3}$$

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{4}$$

$$g_j = 1 - e_j; 0 \le g_j \le 1 \tag{5}$$

$$w_j = \frac{g_j}{\sum_{i=1}^{m} g_j}, 0 \le g_j \le 1, w_1 + w_2 + \cdots + w_j = 1 \tag{6}$$

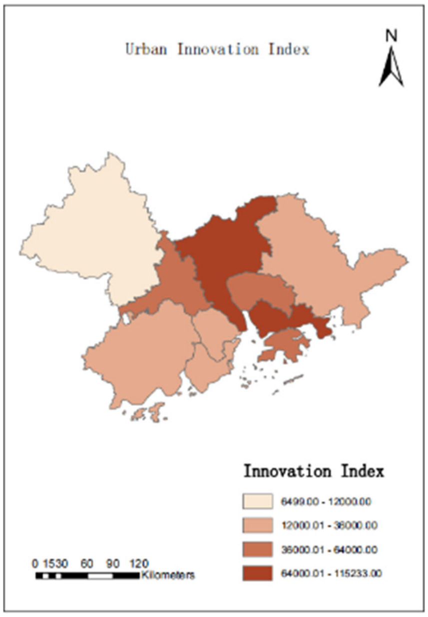


Figure 2. Greater Bay Area Innovation Index Map

2.3. Coupling Coordination of Population Aging Coefficient and Urban Innovation Index

In order to ensure the rigor of the study, the classical OLS regression model is used to predict the amount of change in one variable (the explanatory variable) or to determine the relationship between two or more variables. In this model, the innovation index is set as the dependent variable, and OLS (ordinary least squares) regression analysis is performed with the proportion of population aged 60 and over to the total population, the proportion of population aged 65 and over to the total population, and the proportion of population aged 65 and over to the population aged 0-14 as independent variables, and is performed using Robust standard error regression methods.

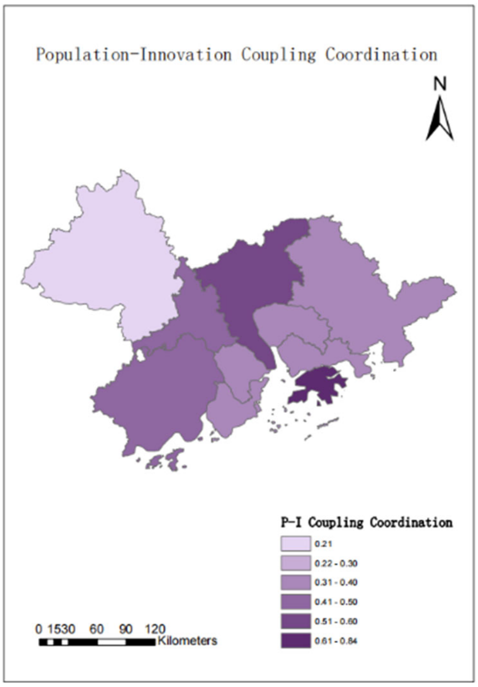


Figure 3. Greater Bay Area urban coupling coordination map

The results present that the proportion of population aged 65 and above to the population aged 0-14 has a significant positive influence relationship on the innovation index. Therefore, the proportion of population aged 65 and above to the population aged 0-14 was imported into SPSS for coupled coordination calculation to investigate whether the population and innovation in the 11 cities in the Greater Bay Area develop in a coordinated manner, and the extent to which population aging affects innovation in this urban cluster.

$$D = \sqrt{C \cdot T}$$

$$C = 2 \cdot \sqrt{(U_1 \cdot U_2)/(U_1 + U_2)^2} \quad (8)$$

D is the coupling coordination degree, taking the value of [0,1], the larger the D, the more coordinated the development level of the two systems, and vice versa, the lower the degree of synergy between the two systems; C is the coupling degree, taking the value of [0,1], the larger the C, the better the coupling state of the two systems, and the smaller the C, the worse the coupling state of the two systems, and will tend to disorderly development.

Table 3. Urban coupling coordination in the Greater Bay Area

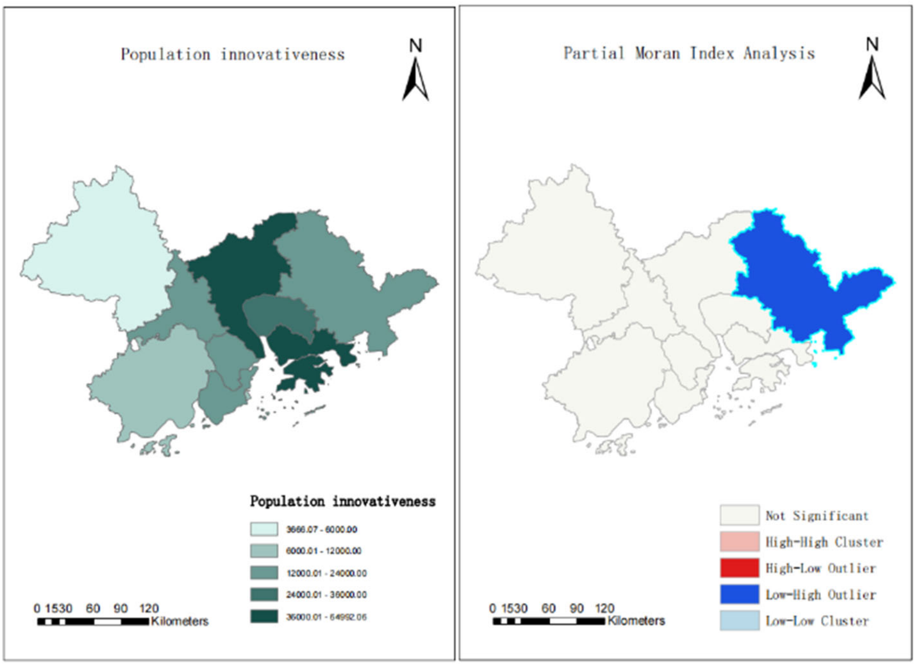
City Name	D-value	C-value	Coupling coordination state
Hong Kong	0.842	0.947	Excellent coordination
Guangzhou	0.582	0.906	Reluctant coordination
Foshan	0.471	0.966	On the verge of disorder
Jiangmen	0.453	0.859	On the verge of disorder
Shenzhen	0.315	0.199	Mild disorder
Zhuhai	0.375	0.997	Mild disorder
Huizhou	0.331	0.944	Mild disorder
Zhongshan	0.355	0.989	Mild disorder
Dongguan	0.368	0.579	Mild disorder
Macau	0.388	0.690	Mild disorder
Zhaoqing	0.211	0.428	Moderate disorder

3. Demographic Innovativeness Index and Spatial Layout

Population is an important factor in determining the success of innovation[8]. In this study, referring to the concept of population innovativeness in the book "Population Innovativeness - Opportunities and Pitfalls of the Rise of Great Powers" by Liang Jianzhang and Huang Wenzheng, which briefly summarize the contribution and influence degree of population on innovation within cities, and use the entropy value method (same as Equation 5-7) to obtain the weight value from the weighted value of innovation and the ratio of old to young for each city, and calculate the spatial layout of population innovation in the region is presented by using the Moran index formula of ArcGIS to calculate this comprehensive index.

$$I_i = \frac{Z_i}{S^2} \sum_{j \neq i}^{n} w_{ij} Z_{ij} \quad (9)$$

Where $Z_i = y_i - \bar{y}$, $Z_j = y_j - \bar{y}$, $S^2 = \frac{1}{n} \sum (y_i - \bar{y})^2$, w_{ij} is the spatial weight value, $y_{i(j)}$ represents the population innovativeness of region i(j), n is the total number of all regions on the study area, and I_i represents the local Moran index of region i. In summary, with Huizhou as the center, the surrounding cities show low-high clustering spatially, like Guangzhou, Dongguan, and Shenzhen, which are bordering Huizhou, have stronger population innovativeness and show clustering trends. In contrast, the population innovation power in the area west of Guangzhou shows a low trend and no significant spatial clustering.



(a) (b)

Figure 4. (a) Greater Bay Area population innovation map; (b) Moran index distribution map

4. Conclusions

The ratio of old to young produces a significant positive influence relationship on the innovation index. For the national level, the aging of the population will have a positive impact on the future development of technological innovation in China. At the same time, in the development process of China's modern society, population aging has become an inevitable trend, and the scope of aging cities will slowly expand in the near future and eventually become a senior society. It can be mitigated by continuous economic development, providing social security and childcare benefits, extending the retirement age, improving medical care, and promoting good living habits, so that the benefits outweigh the disadvantages.

4.1. Urban "Population-Innovation" Coordination

The "population-innovation" coordination of cities in the Guangdong-Hong Kong-Macao Greater Bay Area is summarized in two dimensions: adult cities and older cities. Adult cities (Shenzhen and Dongguan) have a lower degree of aging, higher population vitality, and higher innovation index, and the population and innovation are relatively coordinated in general, with some slight dissonance. The innovation index of this type of cities is influenced by the demographic structure to the greatest extent and is in a state of being developed at a high speed, with strong favorable policies for young and highly skilled talents and high prospects for urban development, but attention should be paid to sustainable development.

The aging cities exist in the following three situations depending on the three levels of classification: (1)The aging degree is at level I, with high innovation index and good coordination between population and innovation, such as Hong Kong. However, the deepening aging in recent years has led to a downward slope of innovation, and the government should pay attention to talent introduction and urban renewal. (2)The aging degree is at level II, the innovation index is low, and the population and innovation are in a moderate disorder, such as Jiangmen and Zhaoqing. This type of city region is less developed economically, and when the first type of city develops, the population loss is serious, mostly left behind by the elderly, and the innovation degree is low. The government needs to retain talents, develop basic education and higher education, improve the quality of education in the city, and vigorously introduce innovation, talents, technology, and capital to develop the regional economy. (3)The aging degree is at level III, with a high innovation index, relatively coordinated overall, and some slight disorders, such as Guangzhou. This category of cities, with Guangzhou as the core, seizes the opportunity, the city was built early, supported by the government, and has driven the radiation development of the surrounding cities such as Foshan in recent years. Although it has entered the aging society, there is a more significant situation of population flow affecting the innovation index[9]because there is still room for development in the new urban area, with a thick foundation of economy, innovation and education, and a strong urban attractiveness.

4.2. Spatial Agglomeration of Urban Agglomerations

The spatial agglomeration of urban agglomerations is found in the external spatial extensibility of core cities. In terms of the local Moran index, the population innovation in Guangzhou and its eastern region is coordinated, with significant agglomeration in developed cities, while the population innovation in the region west of Guangzhou is low, with the western-most Zhaoqing as a typical example, with no significant agglomeration, and the overall biased agglomeration in the urban agglomeration of the Greater Bay Area is obvious. Combining the above urban innovation index and "population-innovation" coordination data, the analysis shows that the population and capital of Guangzhou and cities to the east of Guangzhou have a stronger direct effect on economic growth and a more positive spatial external effect on economic growth. "Guangzhou-Shenzhen-Hong Kong" three core cities drive the development of Dongguan, Foshan, Huizhou and other cities, but such growth externality with the distance increases and decreases; while the core cities to the west of Guangzhou have not yet developed, still belong to the Greater Bay Area city circle layer of the population innovation and vitality of the lower cities, so need to focus on and vigorously support The cities in the region should focus on talent innovation and economic development, pay attention to talent introduction policies, create innovative industrial parks and research environment, and form a sustainable economic innovation new city with "Zhuhai-Zhongshan" as the core, and radiation drive the development of Jiangmen and Zhaoqing. The level of development of cities in the Greater Bay Area is uneven, and the future should strengthen the flow of resources between regions, improve infrastructure sharing, break the barriers between the Pearl River Delta and Hong Kong and Macao, and accelerate regional economic development.

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