



A Comparative Study on the Spatial-Temporal Evolution and Influencing Factors of Population Ageing in Urban Agglomerations-Taking Chengdu-Chongqing Urban Agglomeration and Yangtze River Delta Urban Agglomeration as Examples

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Abstract. The increasing degree of population aging level in urban agglomerations poses a great challenge to their development in all aspects. Based on the fifth, sixth and seventh national census data, this paper takes the Chengdu-Chongqing Urban Agglomeration and Yangtze River Delta Urban Agglomeration districts and counties as the spatial research units, and adopts the time-series comparative method, Moran's I index, the Theil coefficient and the geographic detector research method, and the results show that: 1) compared with the Yangtze River Delta Urban Agglomeration, the Chengdu-Chongqing Urban Agglomeration enters into the aging society later, and has a short development time and speed; 2) the aging population in the counties of the two city clusters show the spatial distribution characteristics of similar types of aggregation; 3) the differences in population aging between the two city clusters show a tendency to expand; there are obvious intra-regional differences in population aging in the city clusters; 4) from 2010 to 2020, the most important influencing factor on population aging in the two city clusters is population migration, followed by social and economic factors. This indicates that there is a certain spatial compression phenomenon of population aging between Chengdu-Chongqing Urban Agglomeration and Yangtze River Delta Urban Agglomeration, i.e., the Yangtze River Delta city cluster can provide some ideas on how to solve the problem of population aging for the Chengdu-Chongqing Urban Agglomeration which is a city cluster with rapid development of population aging.

Keywords: urban agglomerations; population ageing; Moran's I index; Theil coefficient; GeoDetectors

1 Introduction

Population ageing is a global and strategic issue facing China. According to estimates, it is expected that during the 14th Five-Year Plan period, the proportion of elderly people aged 60 and above will exceed 20 per cent of the total population, entering a stage of moderate ageing, and by 2035, the proportion of elderly people aged 60 and above in the total population will exceed 30 per cent, entering a stage of severe ageing. Urban agglomerations are the most promising and dynamic areas for China's future economic development. With the deepening of population ageing in China, population ageing in urban agglomerations and the problems it creates are the focus of geography and other related disciplines.

In recent years, geography scholars have conducted many studies on the phenomenon of population ageing from different perspectives, with different focuses. Domestic scholars have also studied population ageing from different perspectives, such as demography and geography, with demography mainly focusing on population forecasting [1-2], old age and old age resources [3-4]. Geography scholars mainly study the spatial and temporal characteristics of population ageing [5-6], regional differences [7-9], and influencing factors [10-12] from the perspectives of multi-scale, etc., and explore the changing rules of spatial and temporal population ageing at different scales, such as provincial [13], municipal [6], county [9], and urban agglomerations [10, 14].

In summary, existing studies on urban agglomerations have mainly analysed multiple urban agglomerations as a whole, and there is a relative lack of studies on comparative analyses of different types of urban agglomerations. Based on the above discussion, this study intends to take the Chengdu-Chongqing Urban Agglomeration and the Yangtze River Delta Urban Agglomeration as case comparisons, and start from the county level, and by exploring the regional differences of population aging in the Yangtze River Delta and the Pearl River Delta, reveal the characteristics of the current situation of population aging in the two Urban Agglomerations, the changes in the rules of change and the changes in the factors affecting it, and come up with a certain law of development of population aging in the Urban Agglomerations to provide a certain basis of policy and measures for the slower-developing This will provide a basis for policies and measures for the less developed urban agglomerations to cope with the problem of population ageing.

2 Research Methodology

2.1 Data Sources and Pre-Processing

This paper defines the aging coefficient (over 65 years old) by international standards, and the data of the aging coefficient comes from the data of the Fifth to Seventh National Population Censuses, and the statistical caliber of the data is the permanent resident population. The corresponding indicators of the impact factor come from the China County Statistical Yearbook and the statistical yearbooks of provinces, cities and counties, and other missing data are filled in from the statistical yearbooks of each region.

Since the administrative divisions of some cities changed from 2000 to 2020, this paper consolidates and unifies the administrative divisions of 2000, 2010, and 2020 according to the standard of 2019 to ensure the consistency of the administrative boundaries of the study units.

2.2 Theil Coefficient

The Theil coefficient is carried out to measure regional differences in aging, and the Theil index is widely used for difference measurement. The relevant formulae are used to calculate the indicators related to the overall regional differences, intra-regional differences and inter-regional differences in the study area, as follows.

Overall regional differences:

$$R = \sum_i \frac{X_i}{X} \ln \left(\frac{\frac{X_i}{P_i}}{\frac{X}{P}} \right) \quad (1)$$

Interregional differences:

$$R_a = \sum_j \frac{X_j}{X} R_{aj} \quad (2)$$

Intra-regional variations:

$$R_a = \sum_j \frac{X_j}{X} \ln \left(\frac{\frac{X_j}{P_j}}{\frac{X}{P}} \right) \quad (3)$$

2.3 GeoDetector

In this paper, we mainly use factor probes in GeoDetector to detect the explanatory power of the independent variables for the spatial divergence of the dependent variable, which is expressed in terms of q-values with the expression.

$$q = 1 - \frac{\sum_{h=1}^L N_h \sigma_h^2}{N \sigma^2} \quad (4)$$

Where, the value of q is in the range of [0,1], and the value of q is positively correlated with the explanatory power of the independent variable for the spatial differentiation of the dependent variable; N denotes the number of samples in the region under study, and N_h is the number of samples in the sub-region ($h = 1, 2, 3, \dots, L$); σ^2 is the dispersion variance of the population aging in the whole region, and σ_h^2 is the dispersion variance of the aging in the population in the sub region h.

3 Spatial-Temporal Evolution of Population Ageing and Regional Differences

3.1 Spatial-Temporal Evolution in Population Ageing in Urban Agglomerations

Calculations based on county-level population aging data show that the population aging levels of both the nation as a whole and the Chengdu-Chongqing Urban Agglomeration and the Yangtze River Delta Urban Agglomeration are on a growing trend, and the growth rate in 2010-2020 is significantly higher than that in the period 2000-2010, reflecting the accelerated and deepening trend of population aging in China as a whole. In different years, the Chengdu-Chongqing Urban Agglomeration and the Yangtze River Delta Urban Agglomeration are both higher than the overall national aging level. Compared with the growth rate of population ageing, the ten-year growth of population ageing rate in Chengdu-Chongqing Urban Agglomeration from 2000 to 2010 and from 2010 to 2020 is 3.58% and 6.17% respectively; and the ten-year growth of population ageing rate in Yangtze River Delta Urban Agglomeration from 2000 to 2010 is 1.66% and 5.55% respectively. Compared with the Yangtze River Delta Urban Agglomeration, the aging process in the Chengdu-Chongqing Urban Agglomeration is gradually accelerating. In 2000, the degree of population aging in the Chengdu-Chongqing urban agglomeration was lower than that of the Yangtze River Delta Urban Agglomeration (Fig. 1), and around 2004, the population aging rate of the Chengdu-Chongqing urban agglomeration exceeded that of the Yangtze River Delta urban agglomeration, and the difference is gradually widening over time until 2020.

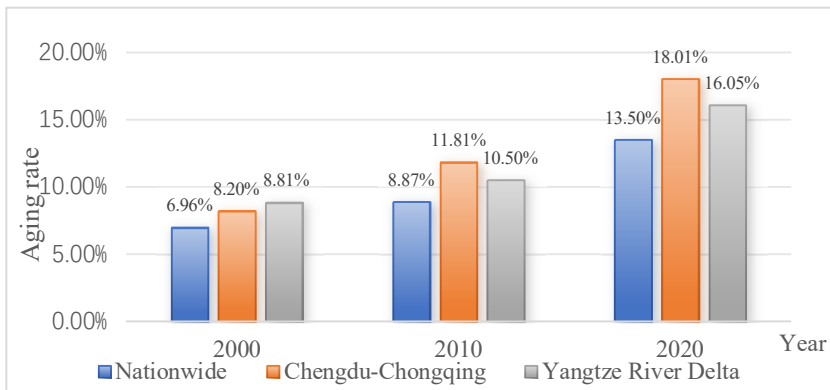


Fig. 1. Population ageing rate in Chengdu-Chongqing and Yangtze River Delta Urban Agglomeration.

Taking the population ageing coefficients of the two urban agglomerations in 2000, 2010 and 2020 as samples, linear regression is carried out to predict their population ageing coefficients in 1995-2030, resulting in the equation for the prediction of population ageing coefficients, which is $y = -973.264 + 0.49076x$ for the Chengdu-Chongqing urban agglomeration; $y = -715.896 + 0.36240x$ for the Yangtze River Delta urban

agglomeration. Calculating the development of the time series of population aging in the two Urban Agglomerations can be seen that the development stage of population aging in the Chengdu-Chongqing Urban Agglomeration from 2000 to 2020 (8.20%-18.01%) corresponds to the development stage of population aging in the Yangtze River Delta Urban Agglomeration from 1998 to 2026 (8.18%-18.33%), which indicates that the Chengdu-Chongqing Urban Agglomeration has a late start and a fast pace of development compared with the Yangtze River Delta Urban Agglomeration.

Of the 144 counties and cities in the Chengdu-Chongqing Urban Agglomeration in 2000 (Fig. 2), 17 counties, including Tianquan County, Pingwu County, and Jinkouhe District, were light, accounting for 11.81%, light ageing for 77.78%, and moderate ageing for 10.42%. In 2010, the Chengdu-Chongqing Urban Agglomeration had all entered the stage of population ageing, with light ageing accounting for 9.03%, moderate ageing for 86.81%, and deep ageing accounted for 4.17%. In 2020, the aging process of the Urban Agglomeration will be further deepened, with moderate ageing accounting for 15.28%, deep ageing accounting for 48.61%, and super-ageing accounting for 36.11%. Comparing the aging process of the population in Chengdu-Chongqing Urban Agglomeration from 2000 to 2010 with that of the population from 2010 to 2020, the speed of aging accelerates, and the overall situation shows homogeneity, and the number of super-ageing accounts for an increase in the proportion of the super-ageing in 2020. The number of aging accounts for an increase in the proportion, the high value of the aging coefficient area to the Urban Agglomeration central collapse zone cities in some districts and counties to concentrate.

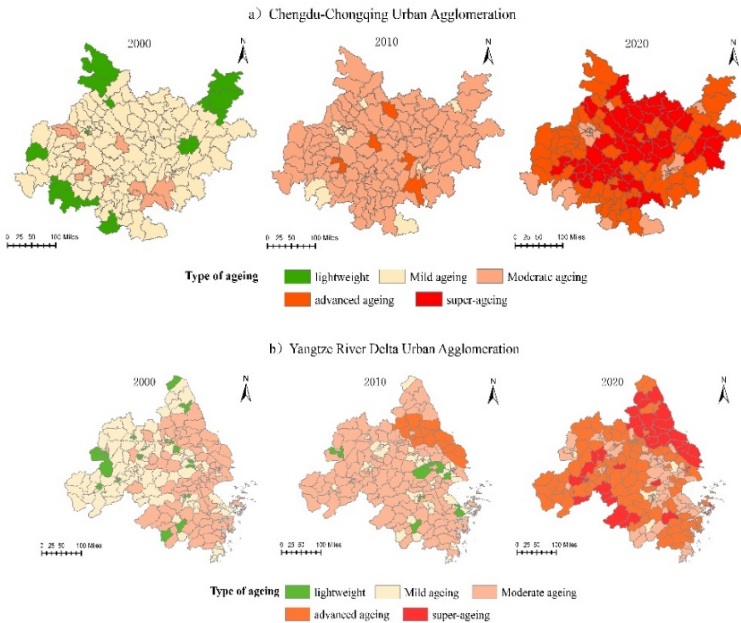


Fig. 2. Chengdu-Chongqing Urban Agglomeration and Yangtze River Delta Urban Agglomeration Ageing Type Map.

3.2 Regional Differences in Ageing

This study further uses the Theil Index to visual the inter-city differences in population ageing.

Table 1. Chengdu-Chongqing Urban Agglomeration and Yangtze River Delta Urban Agglomeration Theil Index Situation.

Region	2000			2010			2020		
	re-gio-nal (%)	intra-re-gional (%)	Coeffi-cient of ageing (%)	re-gio-nal (%)	intra-re-gional (%)	Coeffi-cient of ageing (%)	re-gio-nal (%)	intra-re-gional (%)	Coeffi-cient of ageing (%)
Chengdu-Chongqing	8.1206	0.8096	8.9302	6.5869	0.6978	7.2847	10.3752	1.0742	11.4494
Yangtze River Delta	6.1574	0.3072	6.4646	9.1311	1.2472	10.3783	9.5516	2.3382	11.8897

Comparison found (Table 1), the two Urban Agglomerations present different regional differences in population aging, the overall aging differences in the Yangtze River Delta Urban Agglomeration show an expanding trend, and the overall differences in the Chengdu-Chongqing Urban Agglomeration show a fluctuating development. According to the analysis of the Theil index of the Chengdu-Chongqing Urban Agglomeration as a whole and the four regions [15], it can be seen that the fluctuation shows an expanding trend. The inter-regional Theil coefficient fluctuates from 0.8096% to 1.0742%, and the intra-regional Theil coefficient fluctuates from 8.1206% to 10.3752%, which indicates that the differences in population aging within and between their regions show an enlarging trend, and that there are obvious intra-regional differences in population aging. The Theil index of the population aging coefficient of the Yangtze River Delta Urban Agglomeration for the period of 2000-2020 increases from 6.4646% to 11.8897%. Although the differences in population ageing among the four provinces and cities in the Yangtze River Delta region and within the region are expanding, the growth rate of its intra-regional and population ageing coefficients in 2000-2010 is slowing down compared with that in 2010-2020, and the growth rate of the inter-regional coefficient has changed from 0.92% from 2000 to 2010 to 1.091% from 2010 to 2020. The inter-regional growth rate changes from 0.92% from 2000 to 2010 to 1.091% from 2010 to 2020, indicating that there are obvious intra-regional differences in population ageing in the Yangtze River Delta Urban Agglomeration. Further calculating the Theil index of the aging coefficient of Jiangsu, Zhejiang and Anhui, it can be concluded that the Theil index of the aging coefficient of Jiangsu Province is significantly higher than that of Zhejiang Province and Anhui, and there are obvious differences in the degree of population aging among the cities in Jiangsu Province, and to a certain extent, the population is flowing from the central part of Jiangsu to the

southern part of Jiangsu Province, resulting in the decrease of the population in the three cities in the central part of Jiangsu Province, and the formation of the population collapse zone in the northern wing of the Yangtze River Delta.

In summary, it can be seen that the differences in population ageing within the above two urban agglomerations show a fluctuating increase, and the differences are widening.

3.3 Analysis of Factors Affecting Population Ageing

In this paper, the population aging coefficient in 2010 and 2020 is taken as the detected factor, and 10 indicators in five dimensions, namely, population change factors, economic development level, medical and health care level, social development level and culture and education level, are selected as the driving factors of population aging in the two urban agglomerations (Table 2).

Table 2. Description of factors and indicators.

factor	Indicator name	calculation method
Population change factors	migration rate (%) / X1	(household population - resident population) / resident population
	birth rate (‰) / X2	birth population / Average annual population
	Population mortality rate (‰) / X3	deaths / Average annual population
	population density (Persons/km ²) / X4	resident population / Administrative area
Level of economic development	GDP per capita (yuan) / X5	GDP / Area resident population
	Per capita disposable income (yuan) / X6	disposable income / resident population
	Total retail sales of consumer goods (ten thousand yuan) / X7	Summing up the sales data collected for each retail unit
Level of health care	Number of beds in health-care facilities per 10,000 population / X8	Total number of beds / resident population * 10000
Level of social development	urbanization rate (%) / X9	urban population / total population
Cultural and educational level	illiteracy rate (%) / X10	Number of illiterate persons aged 12 (or 15) and over / total population aged 12 (or 15) and over * 100 percent

Based on the results of the one-way probe (Table 3), it can be seen that

1. Chengdu-Chongqing Urban Agglomeration in 2010, the determinants of population aging from large to small, respectively, for the population migration rate, illiteracy rate, per capita disposable income, its determining power of 0.5914, 0.5798, 0.5077; 2020 population aging determinants from large to small, respectively, for the urbanization rate, population migration, per capita disposable income, the determinants of its determinants of 0.6793, 0.6618, 0.6548, 0.6618, 0.6548. Sichuan and Chongqing as a

large population province, from the population age structure of the migrant population is generally young adults, a large number of working-age population outflow exacerbated the degree of population aging. With the development of time, the urban agglomeration is influenced by national policy support and economic development level, attracting more young adults to work and live in such big cities as Chengdu and Chongqing, the level of urbanization continues to rise, the population density continues to increase, so that the aging rate of its population decreases, while the outflow of population presents a serious phenomenon of aging.

2. Table 3 shows that in 2010, population ageing in the Yangtze River Delta Urban Agglomeration is mainly affected by population migration, per capita disposable income and accelerated urbanization; in 2020, the first major determinant of population ageing will still be population migration, and the second and third major determinants will be the mortality rate of the population and the retail sales of consumer goods, which indicates that population migration is the major influencing factor of the Yangtze River Delta Urban Agglomeration, and the average values of population migration rate are 12.42% and 16.80% respectively, and the influence is increasing, The average value of population migration rate of the urban agglomeration in 2020 is 12.42% and 16.80% respectively, and the size of the determining force is 0.4462 and 0.6512 respectively, and the influence is increasing; while the urbanization process was further accelerated in 2010, the urban agglomeration of the Yangtze River Delta is located in the eastern developed region, with higher income levels and greater attraction to the foreign population, making the change of the aging level of the population relatively slower. By 2020, the improvement in medical care and the decline in population mortality will, to a certain extent, result in an increase in the number of elderly people, but the influx of a large number of migrant workers due to the level of the economy has also eased the ageing of the population of the urban agglomerations to a certain extent.

In summary, it can be seen that the Chengdu-Chongqing Urban Agglomeration and the Yangtze River Delta Urban Agglomeration population aging factors to a certain extent are affected by population migration factors, which is caused by the differences in the level of socio-economic development.

Table 3. Single-factor detection results for Chengdu-Chongqing and Yangtze River Delta Urban Agglomeration.

Region determinant	Chengdu-Chongqing			Yangtze River Delta		
	First	Second	Third	First	Second	Third
2010	X1	X10	X6	X1	X6	X9
2020	X9	X1	X6	X1	X3	X7

4 Conclusions

In this paper, through a comparative study of the spatial and temporal variation of population ageing and influencing factors in the Chengdu-Chongqing Urban Agglomeration and the Yangtze River Delta Urban Agglomeration, it is concluded that: 1) the

Chengdu-Chongqing Urban Agglomeration enters into the ageing society later compared with the Yangtze River Delta Urban Agglomeration and develops in a short period of time at a fast speed, which has exceeded the Yangtze River Delta Urban Agglomeration. 2) the population ageing of the Chengdu-Chongqing Urban Agglomeration, the Yangtze River Delta Urban Agglomeration and the counties and cities under its jurisdiction show positive spatial correlation in the space. High-high (H-H) and low-low (L-L) types of agglomeration in the two city clusters are the main manifestations of spatial correlation. 3. The difference in the coefficients of population aging in the Yangtze River Delta Urban Agglomeration shows an increasing trend, and the difference in population aging in the Chengdu-Chongqing Urban Agglomeration as a whole shows a decreasing and then increasing trend. From the viewpoint of intra-regional and inter-regional Thiel coefficients, the differences in population ageing within the region are still obvious and are on a widening trend. 4. The population ageing of the Chengdu-Chongqing Urban Agglomeration and the Yangtze River Delta Urban Agglomeration in the period of 2010-2020 will be mainly affected by the external factor of population migration, and to a lesser extent, by the level of economic and social development, which is caused by the differences in the level of socio-economic development.

In summary, there is a certain spatial compression of population ageing between the Chengdu-Chongqing Urban Agglomeration and the Yangtze River Delta Urban Agglomeration. In other words, the Chengdu-Chongqing Urban Agglomeration can learn from the policies and measures of the Yangtze River Delta Urban Agglomeration in dealing with the problem of population ageing. Subsequent studies can be carried out in a number of urban agglomerations for in-depth research, to more comprehensively explore and discover the developmental patterns of population ageing in different urban agglomerations, so as to prevent and effectively deal with the emergence of population ageing problems in urban agglomerations with a lower degree of ageing.

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