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RESEARCH

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Spatial equity and factors that influence the distribution of elderly care institutions in China

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Abstract

Background With China becoming an aging society, the number of elderly care institutions (ECIs) is continuously increasing in response to the growing population of older persons. However, regional disparities may lead to an uneven distribution of ECIs, which could affect equity in care. This study identified the limiting factors in the development of ECIs across different regions, thereby promoting equity in accessing care for the older population.

Methods This study utilised point-of-interest data on ECIs in China from 2018 to 2022. The spatiotemporal distribution of ECIs and the causes of disparities were assessed along four dimensions—economy, population, society, and environment—using research methods such as the standard deviation ellipse, rank-size rule, and multiscale geographically weighted regression.

Results There were significant differences between the ECIs of the eastern and western regions in China. The eastern region had a denser distribution and higher concentrations in primary cities. The proportion of the older population, regional economic development, and household income are crucial for a balanced distribution of ECIs, whereas the environmental impact is relatively minor.

Conclusions The number of ECIs in China continues to increase, but improvements in regional disparities remain insignificant. The construction of ECIs is influenced by various factors; in underdeveloped regions, government initiatives are crucial for promoting equity in care for older persons.

Keywords Aging population, Elderly care institutions, Spatial equity, Influencing factors, China

Introduction

With the increasingly severe phenomenon of an aging population, many countries are committed to optimising and enhancing elderly care institutions (ECIs) to meet the growing demand for such care. Among the global trends in aging, the Chinese situation is the most prominent; not only does China have the largest population of older people in the world, but its population aging process has also been exceptionally rapid. Since the onset of the aging trend in 2000, the proportion of the population over 60 years old in China has exceeded 20%. [1] According to the United Nations' 'World Population Prospects 2022', by 2050, approximately one in four older people globally will be from China. [2] The proportion of older persons with dependency in China has also increased rapidly in recent years. Past stringent population policies have accelerated changes in Chinese family structures, with the traditional extended family model (a couple with more than two children) gradually giving way to the new Chinese small family model (a couple with one child). Although the state has implemented new relaxed fertility policies, the declining birth rate trend has not been effectively reversed. [3] Against this backdrop, the traditional Chinese cultural concept of 'raising children for old age'

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and the family-based care model for older persons have gradually been disrupted. Faced with a heavy burden of support, an increasing number of Chinese families are beginning to accept and choose ECIs as a new method of care for aging family members. [4]

ECIs, as a type of public service facility, were expected to align with the theoretical requirements of public service equalization. Every older person deserved equal rights to elderly care. Therefore, the planning and distribution of ECIs needed to address the needs of different groups or regions, striving to achieve a fair spatial distribution. From the perspective of spatial equity, measures such as economic improvements across cities, optimization of resource allocation, and increased insurance coverage supported enhanced accessibility to elderly care. Regardless of regional location, economic conditions, or other factors, older persons were expected to have access to high-quality elderly care services.

Compared to ECIs in developed countries, ECIs in China require further improvement. Previously, ECIs were primarily nursing homes, but this model has struggled to meet the diverse care needs of older persons. [5] Drawing on the experiences of developed countries, the Chinese government has begun to build a nationwide network of ECIs. [6] This ECIs network includes medical nursing homes with long-term care functions, senior apartments with general care functions, community care centres with day-care functions, and service centres for older persons, which have recreational functions. This initiative aims to ensure that every older person enjoys a high quality of life through diversified and comprehensive services.

By improving ECIs, China hopes to achieve equity in care for all senior citizens. However, the process presents several challenges. First, the distribution of the older population in China shows significant regional disparities: dense in the east, sparse in the west, more in the north, and fewer in the south. The development of ECIs must be flexible to adapt to these dynamic changes. [7] Second, there are many constraints on the development of ECIs. [8–10] Economic development is a major influence on the distribution of ECIs, with more facilities concentrated in economically advantaged areas. [11, 12] The development of ECIs in urban and rural areas is unbalanced, with rural residents finding it more difficult to access quality ECIs. [13, 14] Demographic factors also have a significant impact, as population distribution and ethnic differences pose challenges to balanced development. [15–18] The care needs and preferences of older persons have both active and passive impacts on the distribution of ECIs. [19–22] These factors require further examination regarding their influence on Chinese development.

To promote further improvement in the equity of elderly care across different regions, existing research has conducted quantitative studies at two different scales: prefecture-level cities and provincial regions. At the prefecture-level city scale, studies primarily focus on two key aspects: spatial planning and spatial accessibility. [23, 24] These studies describe the impact of factors such as population distribution within cities, economic zoning, transportation infrastructure, and preference selection. [25, 26] Methods such as the two-step floating catchment area method, network analysis, and buffer analysis are used to explain the issue of equity in the distribution of ECIs at the urban scale. [27, 28] At the provincial scale, constrained by the historical development of ECIs in China, existing studies mainly focus on a single type of institution, such as nursing homes or care centers [29, 30]. Spatial analysis tools such as the Theil index, spatial mismatch index, and Gini coefficient are utilized, and through visualization techniques, the spatial distribution of ECIs across large provincial areas is demonstrated [31–33].

Overall, in terms of research scale, analyzing individual cities allows for a better explanation of elderly care issues within urban areas. However, the varying sizes and development levels of different cities make it difficult to use a uniform standard for measurement. It is necessary to compare different types of cities across the country and illustrate the agglomeration or diffusion effects resulting from the scale differences in ECIs. In terms of research subjects, different types of institutions can achieve functional complementarity, as there is a common demand for various types of ECIs in the preferences of the elderly. Based on different types of elderly care facilities, a comprehensive consideration of their spatial distribution and the impact of various factors is required.

Therefore, in this study, our objective was to assess the overall ECIs in China using data from various types of institutions such as nursing homes, community care centres, and service centres for older persons. Additionally, we explored the spatial distribution of elderly care institutions and their impacts across cities of different sizes nationwide, providing insights that may assist other developing countries in achieving equity in elderly care. Section 2 describes the dataset and research methods employed in this study. Section 3 describes the analysis of the spatiotemporal distribution disparities of ECIs using standard deviation ellipses (SDE) and rank-size rules, the use of multiscale geographically weighted regression (MGWR) to investigate factors that constrain balanced development. Finally, Sect. 4 summarises the findings and proposes directions for future research.

Methods

The research approach adopted in this study is illustrated in Fig. 1 and is divided into three steps: 'Spatial Equity Analysis,' 'Constructing an Evaluation System for the Factors Influencing ECIs,' and 'Impact Evaluation.'

Study site

This study included point-of-interest (POI) data of ECIs from 334 prefecture-level cities and municipalities in China for 2018 and 2022. Conducting research at the national level enables better coverage of regions at different levels of development, leading to more comprehensive and scientifically grounded conclusions. The data were sourced from Amap API (https://lbs.amap.com); the types of ECIs included nursing homes, care centres, and community service stations for older persons. After removing duplicate entries, the study obtained 30,760 valid data points in 2018 and 43,013 in 2022, which closely align with the publicly reported ECI numbers in China (28,671 and 40,587). The bias might have stemmed from two aspects. First, to comprehensively collect ECIs data, the data in this study were gathered from January of the year following the time point, which might have led to an overestimation compared to official statistics. Second, POI data relied on information uploaded by users or institutions. During data collection, it was found that some ECIs had been uploaded multiple times or listed under different names. Although coordinate screening and manual name verification were performed, this might still have resulted in a higher count compared to official statistics. The data were compared with official statistics by city, and the credibility of the data was relatively high. Due to data availability constraints, the study did not include data from Taiwan Province, Hong Kong Special Administrative Region, Macau Special Administrative Region, Sansha City in Hainan Province, Ali Prefecture in the Tibet Autonomous Region, or Diqing Tibetan Autonomous Prefecture in Yunnan Province.

Step 1: spatial equity analysis

First, the original data were processed using 'Min–Max Normalization.' Second, the SDE method was employed to analyze large-scale changes in the development direction of ECIs, with analysis and visualization conducted using ArcGIS 10.8. Then, to demonstrate the impact of different city sizes on the development of elderly care institutions, the Rank Size Rule was used to assess the agglomeration and diffusion effects. The SDE method helped analyze the concentration of ECIs distribution, identified areas with concentrated distribution, and better promoted the enhancement of spatial equity.

SDE were proposed in 1926 by D. Welty Lefever, a sociology professor at the University of Southern California. [34] Key parameters and calculation steps include

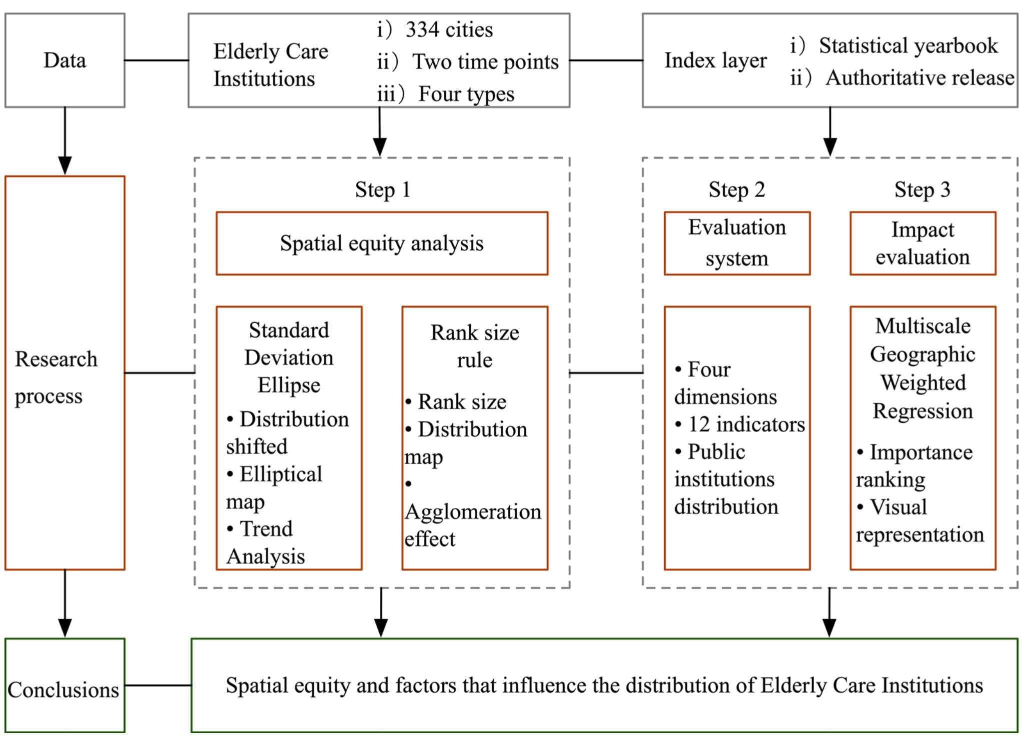

Fig. 1 Methodological framework

determining the centre, rotation angle, and X, Y axes of the ellipse. Here, x_i and y_i represent spatial coordinates, and X and Y denote the arithmetic mean centre. θ represents the orientation angle of the ellipse, $\widetilde{x_i}$ and $\widetilde{y_i}$ denote the coordinate differences of the research objects from the mean centre, whereas σ_x and σ_y denote the standard deviations along the x-axis and y-axis, respectively.

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{X})^2}{n}} \tag{1}$$

$$SDE_y = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \overline{Y})^2}{n}} \tag{2}$$

$$A = \left(\sum\nolimits_{i=1}^{n} \tilde{x}_i^2 - \sum\nolimits_{i=1}^{n} \tilde{y}_i^2\right) \tag{3}$$

$$tan\,\theta = \frac{A + \sqrt{A^2 + 4\left(\sum_{i=1}^{n} \tilde{x}_i\tilde{y}_i\right)^2}}{2\sum_{i=1}^{n} \tilde{x}_i\tilde{y}_i} \tag{4}$$

$$\sigma_x = \sqrt{2}\sqrt{\frac{\sum_{i=1}^{n}\left(\tilde{x}_i cos\theta - \tilde{y}_i sin\theta\right)^2}{n}} \tag{5}$$

$$\sigma_y = \sqrt{2}\sqrt{\frac{\left(\sum_{i=1}^{n}\tilde{x}_i sin\theta + \tilde{y}_i cos\theta\right)^2}{n}} \tag{6}$$

The rank-size rule was implemented using the Zipf index formula. The relationship between size and rank is described by a linear regression in a scale-free space. The Zipf index q characterises the internal differentiation state. When q approaches 1, it indicates an ideal rank-size structure. A value greater than one suggests a dominant distribution characteristic that is significantly influenced by the largest city. A value of less than 1 indicates greater overall organisational dispersion. P_i represents the number of ECIs at rank I, P_1 denotes the highest number of ECIs in a city, R denotes the rank, and q represents Zipf's index. Python software was used to process the data and generate the plots.

$$lnP_i = lnP_1 - qlnR \tag{7}$$

Step 2: constructing an evaluation system for the factors influencing ECIs

To measure the factors that influence the development of ECIs, this study drew upon international research on facilities and key aspects of public facility construction. From the economic, population, societal, and environmental dimensions, a set of 12 indicators was selected to construct an evaluation framework for the factors that influence the development (Table 1).

Step 3: impact evaluation

To further explore the factors that influence the distribution of ECIs, MGWR was used to measure the impacts of the 12 indicators across four dimensions.

MGWR was introduced by Fotheringham in 2017, building upon the classic geographically weighted regression (GWR). [35] Through continuous refinement and development, this method has become widely applicable to empirical studies. (u_i,v_i) denotes the coordinates of city i, β_0 represents the intercept, β_{bwm} signifies the regression coefficient of the mth factor that influences city i, and ε_i is an error term. MGWR for MacOS software was used to analyze the 2022 data on various influencing factors, with ArcGIS 10.8 employed for visualization [36].

$$Y_i = \beta_0(u_i, v_i) + \sum\nolimits_m \beta_{bwm}(u_i, v_i)x_{im} + \varepsilon_i \tag{8}$$

The model reliability was tested. First, a spatial autocorrelation analysis was performed on the 12 indicators across the four dimensions. The results indicated strong spatial autocorrelation for all indicators, with each variable having a variance inflation factor (VIF) of less than 7.5. Subsequently, GWR and MGWR models were established to compare the simulation results. The GWR model assumes that the regression coefficients for all spatial points change uniformly across the same scale, while the MGWR model allows the regression coefficients to vary at different spatial scales. The models were evaluated based on AICc, R-squared (R^2), and adjusted R-squared (Adj. R^2). Lower AICc values and higher R^2 and Adj. R^2 values indicate better model fit. As compared with the GWR model, the MGWR model exhibited a decrease in AICc by 188.537, with increases in R^2 and Adj. R^2 of 0.155 and 0.139, respectively. This indicates that the MGWR model better explained the spatial heterogeneity and nonstationarity of the variables. Therefore, this study adopted the MGWR model for further analyses (Table 2).

Results

Strong influence of head cities

Providing a comprehensive perspective of cities across China, the number of ECIs exhibited a growing trend, with significant increases primarily concentrated in the eastern regions of Central and South. Only the northeastern region presented a declining trend (Fig. 2a, b).

From the perspective of the ECIs distribution range, the ellipse representing the distribution noticeably reduced over the sample period. The area of the ellipse decreased from 248.989 million km^2 in 2018 to 209.993 million km^2 in 2022, a decrease of 15.6% (Fig. 2c). The

Table 1 Factors used in the framework for evaluating the development of ECIs

Target layer	Index layer	Data sources	Index interpretation	References
Economy	Gross Domestic Product (GDP)	Statistical Communique of City (Autonomous Prefecture) on the 2023 Economic and Social Development	GDP refers to the final products produced by all resident units in a country during a certain period	[33, 38]
	Per Capita Disposable Income of Households (DI)	Statistical Communique of City (Autonomous Prefecture) on the 2023 Economic and Social Development	Disposable income of the population refers to the sum of final consumption expenditure and savings available to the population (i.e. the income available to the population for discretionary spending)	[12]
	Percentage of Three Industries (TI)	Statistical Communique of City (Autonomous Prefecture) on the 2023 Economic and Social Development	Tertiary industry (i.e. the service industry) refers to the proportion of industries other than the primary and secondary industries	
Population	Percentage of People Aged 65 + (65 +)	The Seventh National Population Census of China (2020)	Ratio of persons aged 65 and over to total population for the same period	[33]
	Elderly Dependency Ratio (EDR)	The Seventh National Population Census of China (2020)	$EDR = \frac{P_{65+}}{P_{15-64}} * 100\%$ P_{65+}: Number of persons aged 65 and over $P_{15\text{-}64}$: Population of working age (15–64 years)	[37, 46]
	Natural Population Growth Rate (NPGR)	The Seventh National Population Census of China (2020)	NPGR refers to the ratio of the number of deaths to the average population (or mid-year population) during a certain period	[19, 46]
Society	General Public Budget Expenditure (GPBE)	Statistical Communique of City (Autonomous Prefecture) on the 2023 Economic and Social Development	GPBE refers to the distribution and use of the funds that the government has raised, to meet the need for economic construction and other issues	[16, 36]
	Basic Endowment Insurance for Urban Workers (UWBEI)	Statistical Communique of City (Autonomous Prefecture) on the 2023 Economic and Social Development	UWBEI refers to staff and workers participating in the basic endowment insurance for urban workers at the end of the reference period, who already have payment records in social security management agencies	[33, 47]
	Urbanisation Rate (UR)	Statistical Communique of City (Autonomous Prefecture) on the 2023 Economic and Social Development	Urban population as a proportion of total population (both agricultural and non-agricultural)	[11]
Environment	Air Quality Index (AQI)	China National Environmental Monitoring Centre (2022)	Based on the ambient air quality standards and the impact of each pollutant on human health, ecology, and the environment, the routinely monitored concentrations of several air pollutants were simplified into the form of a single conceptual index value	
	Average Temperature and Annual Precipitation (TP)	China National Meteorological Centre (2022)	$TP = \frac{\lvert T_i - T_a \rvert + \lvert P_i - P_a \rvert}{2}$ T_a, P_a: Average temperature and precipitation of the top five major cities in the China Meteorological Administration's evaluation of human climate comfort in major cities $\lvert T_i - T_a \rvert$ and $\lvert P_i - P_a \rvert$ represent normalisation in calculations	[41]
	Height Above Sea Level (ASL)	Natural Overview 2022 of the Websites of City (Autonomous Prefecture)	Vertical distance between the centres of municipalities and sea level	

Table 2 Comparison of Model Fit Between GWR and MGWR Models

Year	2022	
Model	GWR	MGWR
AICc	505.350	316.813
R^2	0.753	0.908
Adj. R^2	0.746	0.885
Bandwidths	123	[30,332]

minor axis of the ellipse, representing the distribution decreased by 11.7%, measuring 996.2 km, whereas the major axis decreased by 4.4%, measuring 671 km. The centroid of the distribution shifted south-westward by 120 km, although this shift was relatively minor.

From the perspective of ECIs types, the distribution of nursing homes showed relatively small changes, while other types of ECIs grew significantly in the eastern regions. The distribution changes of different types better illustrated the distribution characteristics of various institutions, in Fig. 3. The number of nursing homes increased in most cities across China, but the growth rate was not significant, with a decline in the number of cities in the Northeast. The number in the western regions was relatively low, while cities in the eastern regions, most of which were large or central cities, had a higher number. Other types of ECIs experienced significant growth. In North and East China, the growth of other types was particularly notable around large cities. In the western regions, the growth was relatively weaker, mainly concentrated in provincial capital cities within the region.

According to the Jenks classification, based on the number of ECIs in cities, the fitted curve was divided into three segments: head, middle, and tail (Fig. 4c). The Jenks classification method better reflected the characteristics of data distribution by considering the distribution features of the reference data. This method was widely used in spatial analysis and offered strong interpretability. Cities with more than 600 ECIs were considered head cities. The number of cities with more than 600 increased from four in 2018 to eight in 2022, with the median rising from 50 to 67 (Fig. 4a, b). The calculated Zipf index was 1.18, indicating a strong spatial impact and clustering effect of large cities. The head cities had a lower proportion, with the majority concentrated in the tail, highlighting the significant spatial distribution differences in medium and small cities.

Analysis of influences

Table 3 shows the regression results of the MGWR model, categorised into five classes according to Jenks' classification (Fig. 5). The impact of the older population and resident income was more pronounced, with higher explanatory power for the societal dimension indicators. Specifically, from an economic perspective, all indicators positively influenced the development of ECIs. DI and GDP exhibited more pronounced effects (0.491 and 0.413, respectively) with high explanatory power. Their impact gradually decreased from southeast to northwest (Fig. 5a, b). The bandwidth of GDP was close to the total sample size, indicating its global homogeneity in influencing the distribution of ECIs. TI had lower explanatory power (22.8%) and smaller impact (0.181).

From a societal perspective, both UWBEI and GPBE had positive impacts, whereas UR had a negative impact. All three indicators demonstrated high explanatory power. The bandwidth of GPBE was 332, nearly on a global scale, indicating weak spatial heterogeneity. The number of UWBEI was the most influential indicator in the social dimension (0.460), with its impact decreasing from northeast to southwest (Fig. 5e). GPBE decreased from north to south (Fig. 5d).

From an environment perspective, all three indicators positively influenced the development of ECIs, albeit to a moderate extent (0.120–0.123). ASL and TP exhibited strong spatial heterogeneity (52, 88). AQI and TP demonstrated higher explanatory power, whereas ASL significantly affected only the central coastal regions (Fig. 5i). The impact of TP decreased gradually from southeast to northwest, whereas AQI showed the opposite trend (Fig. 5g and h).

From a population perspective, 65 + years was the most influential indicator (0.530) affecting ECI development. The distribution of the older population had the most significant impact. EDR and NPGR indicators also had a positive effect, but to a lesser extent (0.164, 0.079) and exhibited strong spatial heterogeneity (128, 44, 62) with relatively lower explanatory power (43.3%, 29.9%). The population growth rate primarily manifested in Northeast China, decreasing from north to south (Fig. 5j–l).

Discussion

Our study reveals that from 2018 to 2022, the number of ECIs in China continued to grow, although regional disparities persist. This growth was more pronounced in urban areas of the eastern region, with development increasingly concentrated in areas surrounding head cities. Among the four dimensions of economy, society, population, and environment, the influence of environmental factors was weaker, while regional development levels and the number of elderly individuals had a more significant impact. In less developed regions, government initiatives play a critical role in promoting fairness in elderly care.

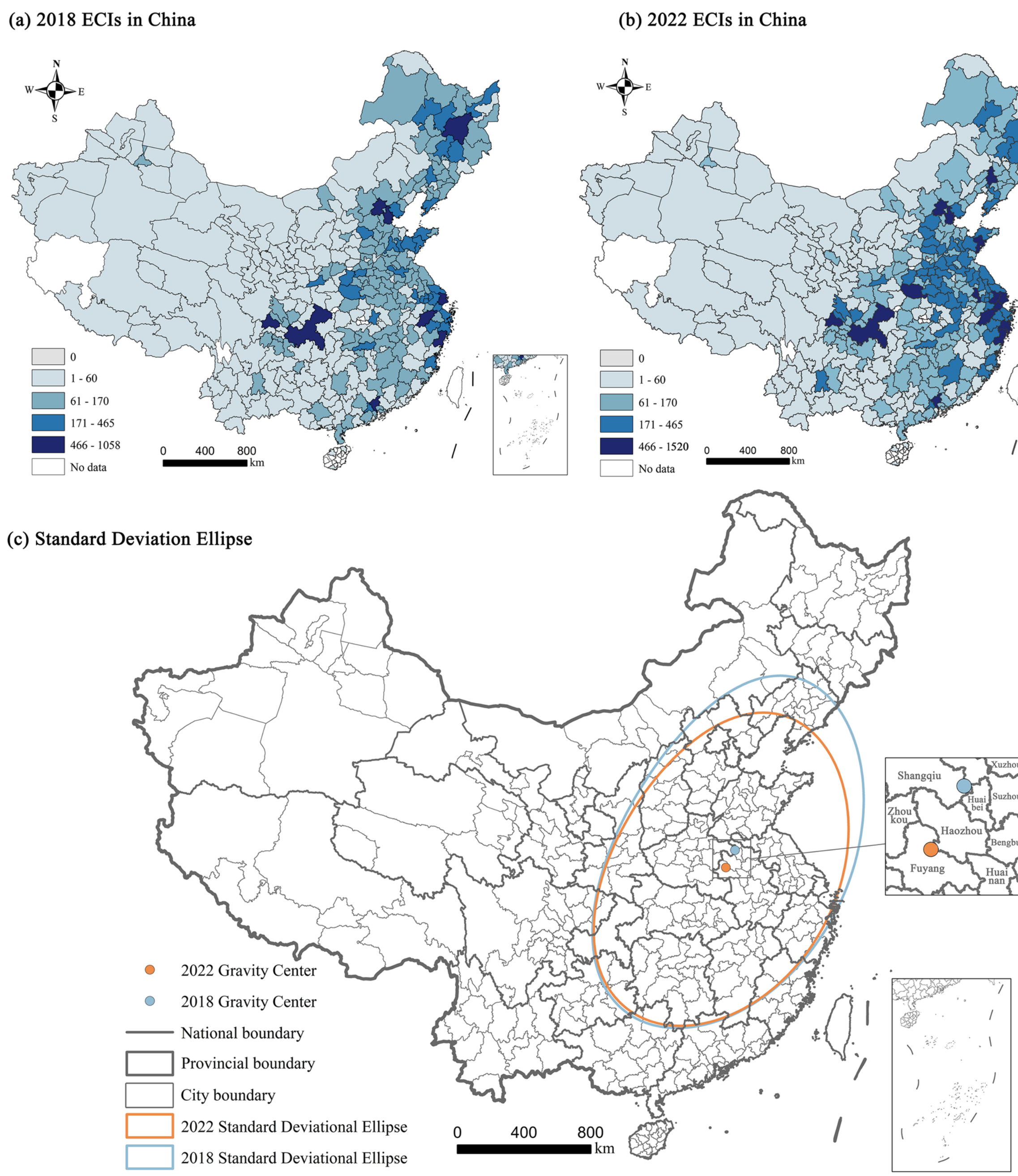

Fig. 2 Spatial and temporal differences in the distribution of ECIs in China

Previous studies have identified a distinct east–west disparity in Chinese nursing homes. [33, 37] After considering different types of institutions, our research found that this disparity still exists in the distribution of ECIs. This study demonstrated the overall changes in the distribution. The most significant growth was observed in Central and South China, whereas a decline was noted in the northeast. Nationally, the spatial distribution has become more concentrated. Although the development focus of ECIs has shifted southwest, improvements in regional disparities have not been significant. Notably, this phenomenon of distribution concentration in well-developed areas has been observed in multiple countries, [29] with China manifesting an agglomeration effect of head cities. Due to the limited mobility of older persons, most are unable or unwilling to relocate, making it

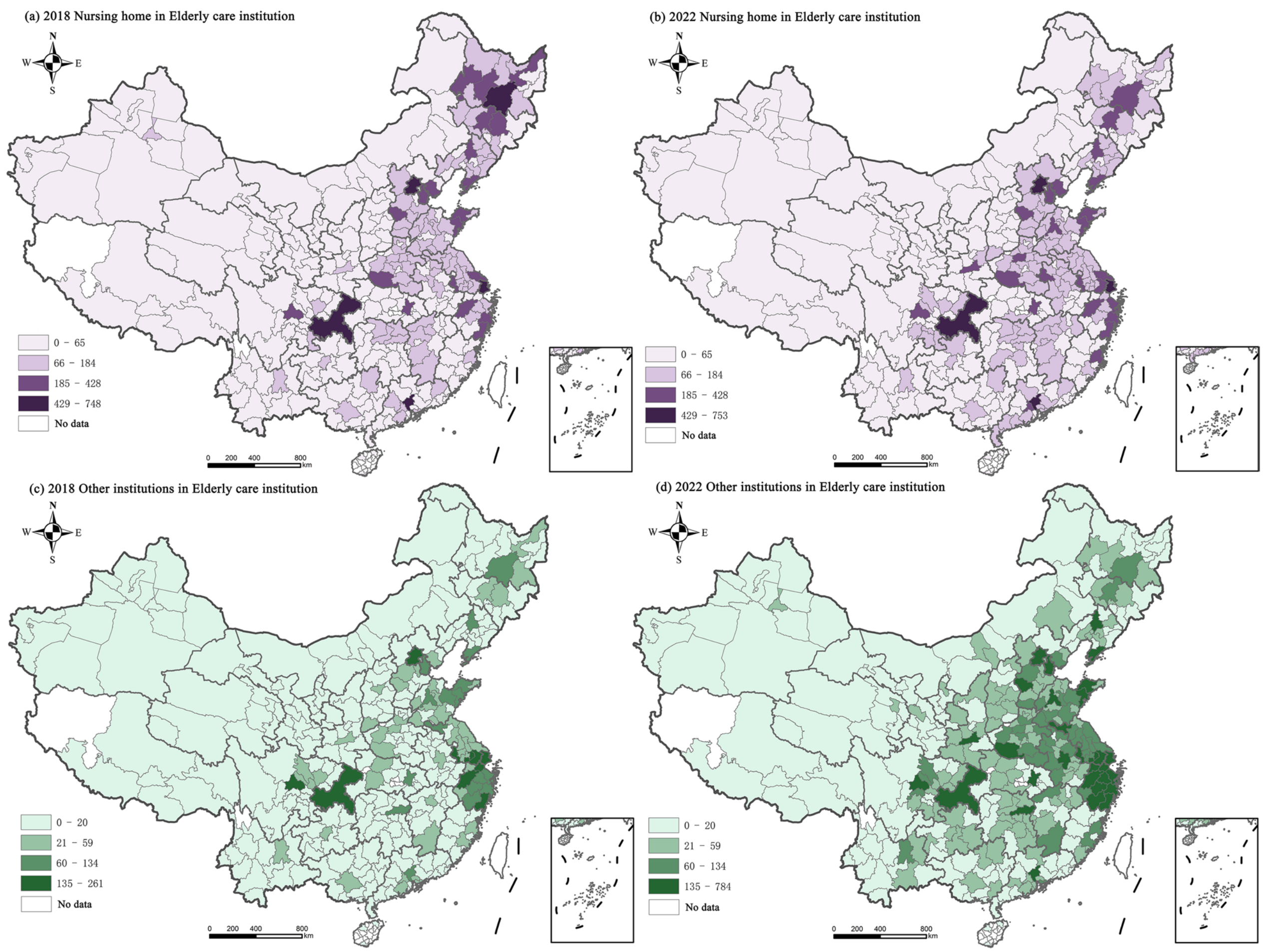

Fig. 3 Spatial–temporal differences of different types of elderly care institutions

a common challenge for China and many other countries to balance the distribution disparities of ECIs in less-developed areas.

To explore the factors that influence spatial disparities, this study introduced MGWR to analyse the multidimensional influences. The most significant factors were in the economic, societal, and population domains. In the economic domain, DI and GDP positively affected the development. With continuous improvements in living standards, aside from the basic ECIs provided by the government, many high-quality ECIs have emerged. The costs are higher than those of home care; therefore, using the former requires older persons to have substantial pensions, or their children to have considerable economic capabilities. Therefore, economic indicators significantly influence the distribution. [12, 38, 39] Historically, Eastern China, the first region to implement economic reforms, had benefitted from a strong economic foundation, fostering more comprehensive elderly care facilities. This economic advantage was projected to become even more prominent in the coming years. In the near future, the economic development advantage of the eastern region is expected to become even more pronounced. [40]

In the societal domain, GPBE, as a government-led fiscal budget, effectively supplements the lack of commercial capital in less-developed areas. In northern regions such as Inner Mongolia and Xinjiang, where the older population is relatively scattered, basic public ECIs are the primary providers of services for older persons. Therefore, the positive impact of government budgets is more evident in these regions. In the future, increasing support for ECIs in underdeveloped western regions could favourably influence the balanced development of ECIs. [41] UWBEI had the most significant positive impact in the northeast. An increase in the number of insured employees leads to higher regional pensions, promoting the development in these areas. However, in recent years, the northeast has experienced significant population loss, explaining the decline in the number

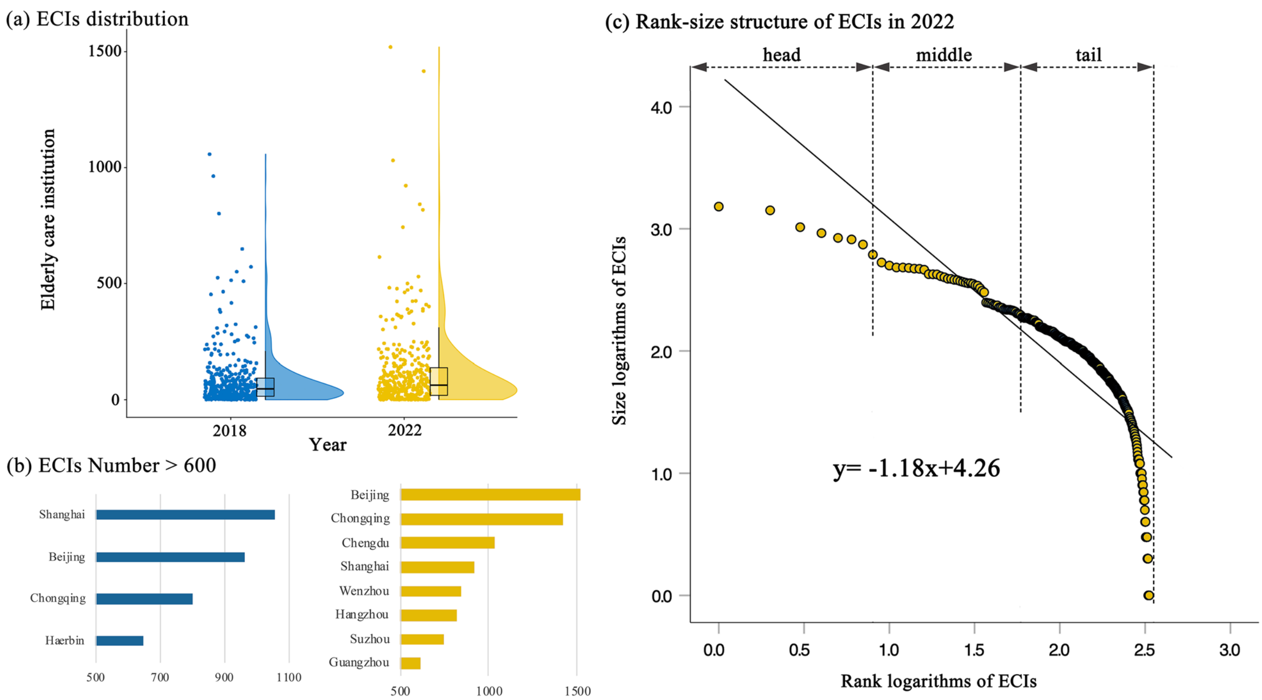

Fig. 4 Chinese overall rank-size structure of ECIs

Table 3 Regression results of the MGWR model

Index	Mean	Min	Max	Standard Deviation	P < 0.05 (%)	bandwidths
GDP	0.413	0.004	0.712	0.184	95.8	30
DI	0.491	0.333	0.617	0.098	100	168
TI	0.181	0.099	0.328	0.062	22.8	48
65 +	0.530	0.222	0.776	0.183	100	128
EDR	0.164	− 0.584	0.383	0.214	43.4	44
NPGR	0.079	0.027	0.091	0.014	29.9	62
GPBE	0.255	0.250	0.259	0.002	100	332
UWBEI	0.460	0.079	0.622	0.099	83.2	168
UR	− 0.304	− 0.470	− 0.176	0.093	100	156
AQI	0.120	0.057	0.128	0.013	98.5	282
TP	0.120	0.071	0.150	0.019	94.1	88
ASL	0.123	0.097	0.138	0.012	17.9	52

of ECIs. The rise in urbanisation rates means that more people are concentrated in cities and core towns, facilitating the government's construction of larger-scale nursing homes to accommodate older persons centrally. This reduces the need to build nursing homes in remote areas, thereby explaining the negative correlation.

In terms of the population, the proportion of older people significantly affects the development of ECIs. The proportion of the population that is older is the fundamental reason for the changes in the number of ECIs. The goal of promoting the balanced development is to meet the care needs of older adults in various regions. A higher proportion of older people indicates more significant demand, suggesting a larger market space in the future. The population growth rate had a more significant impact on the northeastern region of China, which is closely related to local population loss. The maritime climate of the southeastern coastal areas provides favourable conditions for the development. More liveable temperature and humidity conditions are beneficial for older

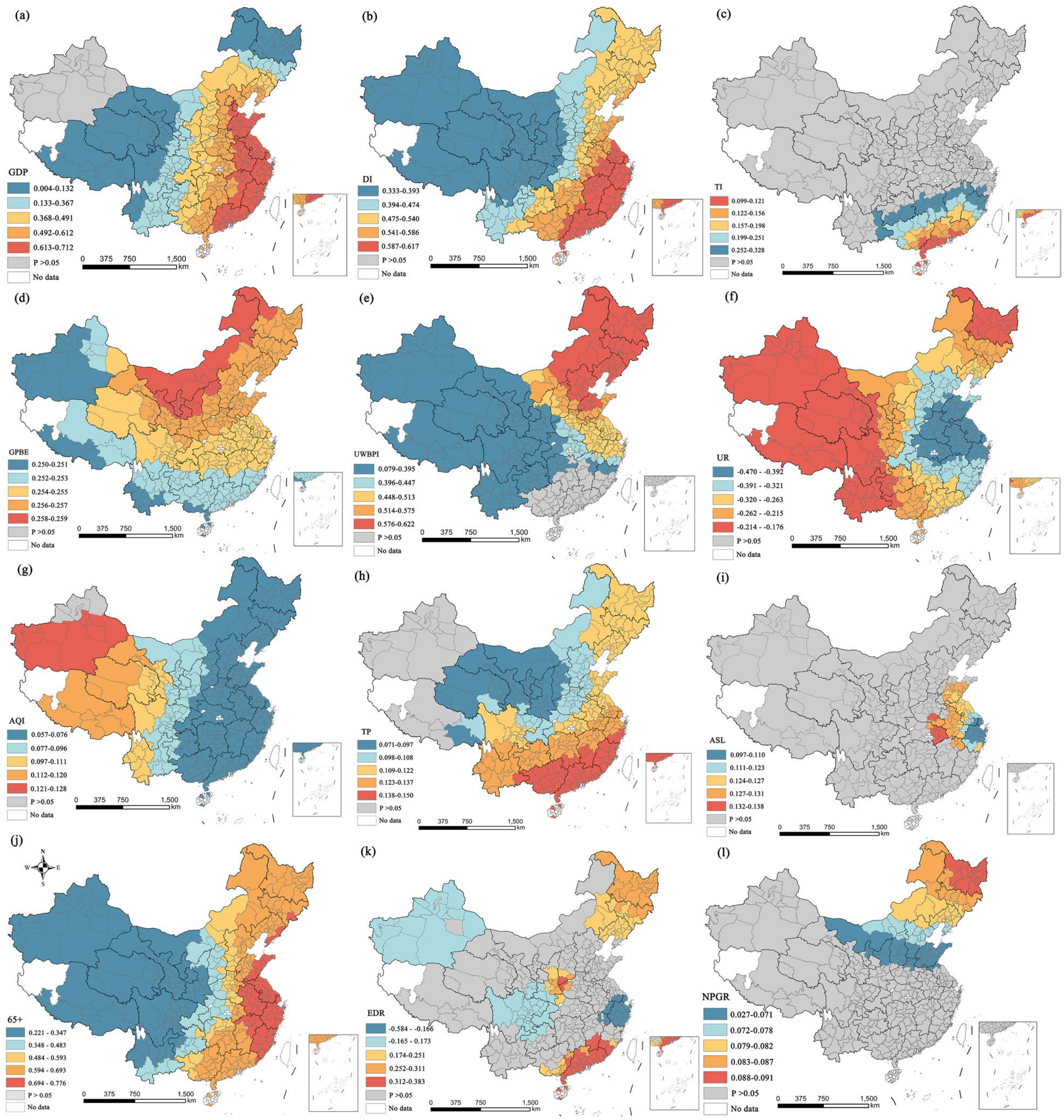

Fig. 5 Spatial differentiation patterns of factors that influence the development of ECIs in China. Economy (**a** GDP; **b** DI; **c** TI); Society (**d** GPBE; **e** UWBEI; **f** UR); Environment (**g** AQI; **h** TP; **i** ASL); Population (**j** 65 +; **k** EDR; **l** NPGR). Northeast Region: Liaoning Province, Jilin Province, Heilongjiang Province. North China Region: Beijing, Tianjin, Hebei Province, Shanxi Province, Inner Mongolia Autonomous Region. East China Region: Shanghai, Jiangsu Province, Zhejiang Province, Anhui Province, Fujian Province, Jiangxi Province, Shandong Province. Central-South Region: Henan Province, Hubei Province, Hunan Province, Guangdong Province, Guangxi Zhuang Autonomous Region, Hainan Province. Southwest Region: Chongqing, Sichuan Province, Guizhou Province, Yunnan Province, Tibet Autonomous Region. Northwest Region: Shaanxi Province, Gansu Province, Qinghai Province, Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous Region

residents and attract them to these areas. For example, in the northeastern region of China, low temperatures in autumn and winter lead many older people to migrate to other regions for care. Existing studies have also found that climatic factors are an important reason for the migration behaviour of older persons. [42] The elderly welfare in China remained closely tied to the household registration (hukou) system, which weakened the overall influence of environmental factors on the development of ECIs. Retirement migration was primarily an option for older people with better economic means. Furthermore, improvements in building conditions—such as enhanced winter heating facilities and upgraded exterior insulation—effectively mitigated the adverse impacts of environmental challenges.

Our study has limitations in terms of data quantity and the design of the framework for assessing the influencing factors. First, this study only obtained the locations of various types of ECIs in China but did not identify newly established or temporarily closed ECIs. Although the data were generally consistent with relevant statistics provided by the Chinese government, there is still the possibility of missing data. Second, although the study established a multidimensional framework of influencing factors, it could not measure the specific impact of cultural and habitual changes on the development of ECIs.

China is a country with a long history, during which many cultural norms and conventional theories have emerged, including the concept of 'filial piety'. For a long time, sending one's parents to an ECIs was considered a 'shameful' act. The saying, 'You raised me, I will care for you in your old age', reflects the traditional Chinese way of expressing love by providing home-based care for parents. [43–45] Today, with the continuous development of medical care methods, more people, especially those with higher education, are prepared to choose ECIs. However, it may be challenging to encourage parents to change their beliefs. A further challenge is how such cultural changes may be reflected in data. In future research, our team will conduct nationwide surveys in China to understand the specific impact of the increased demand for ECIs resulting from this cultural shift. Future research will further subdivide advantageous and disadvantaged regions for elderly care to conduct a more in-depth analysis. It will explore the differences in the accessibility of various types of ECIs within advantageous regions, aiming to unlock the operational potential of these institutions further.

Despite these limitations, we identified disparities in the development of ECIs between Eastern and Western China. In underdeveloped areas, especially in small- and medium-sized cities, there is a need for further optimisation of the quantity and distribution. Future planning efforts should not only focus on increasing the number of ECIs but also explore the use of internet-based models by introducing remote elderly care platforms. Online services, such as psychological counselling, could enhance the care experience for older people. In cities with abundant elderly care resources in Eastern China, efforts should go beyond meeting basic care needs by introducing high-end ECIs. Establishing a multi-level and specialized elderly care system could better address the diverse needs of various groups.

This study suggests that while the economic domain plays a significant role, government support for ECIs in less-developed regions can promote a more balanced distribution, particularly through the expansion of public institutions. Such government intervention could mitigate the disadvantages in economically weaker areas. Setting aside differences in political systems and management approaches, we hope that government-led ECIs will be promoted in more countries. This is particularly relevant for nations with lower per-capita income and greater social stratification.

Conclusion

Our study found that from 2018 to 2022, the number of ECIs in China continued to grow, but regional disparities persisted. The growth of ECIs was more pronounced in cities in the eastern regions of China, with development being more heavily skewed towards the head cities. Across the four dimensions of economy, society, population, and environment, environmental factors had a weaker impact, with more significant influences being derived from local development levels and the number of older people. Government initiatives in less-developed regions are crucial to promote equitable care for older persons.

Abbreviations

ECIs	Elderly Care Institutions
POI	Point-of-interest
SDE	Standard Deviation Ellipse
GWR	Geographically weighted regression
MGWR	Multiscale Geographic Weighted Regression
GDP	Gross Domestic Product
DI	Per Capita Disposable Income of Households
TI	Percentage of Three Industries
65+	Percentage of People Aged 65+
EDR	Elderly Dependency Ratio
NPGR	Natural Population Growth Rate
GPBE	General Public Budget Expenditure
UWBEI	Basic Endowment Insurance for Urban Workers
UR	Urbanisation Rate
AQI	Air Quality Index
TP	Average Temperature and Annual Precipitation
ASL	Height Above Sea Level

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Author contributions
X. Li. contributed to conceptualization, data curation, formal analysis, visualization, and writing the original article. W. Qin. contributed to formal analysis, visualization, resources, supervision, methodology, and funding acquisition. H. Jiang. contributed to conceptualization, data curation, and visualization. F. Qi contributed to data curation, review and editing the article. Z. Han contributed to review and editing the article. All authors gave final approval and

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This research was ethically approved by Ludong University.

Consent for publication
Participants consented to their data to be published.

Competing interests
The authors declare no competing interests.

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