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SPATIAL DIFFERENTIATION OF URBAN ECONOMIC RESILIENCE AND ITS INFLUENCING FACTORS: EVIDENCE FROM BAIDU MIGRATION BIG DATA

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Abstract. Under the development pattern of the "double cycle", optimizing urban economic resilience is tremendously meaningful to improving a city's affordability and the adaptability of the economy and to promoting the Chinese economy to develop with high quality. Based on Baidu migration big data perspective, exploratory spatial data analysis (ESDA) and multi-scale geographical weighted regression (MGWR) model were used to analyze the spatial characteristics and driving factors of economic resilience in 287 Chinese cities in 2019. The results show that (1) the number of low-level economically resilient cities is the largest and distributed continuously, while the number of high-level economically resilient cities is the lowest and distributed in clusters and blocks; (2) compared with the Pearl River Delta and Yangtze River Delta, the population accumulation characteristic of the Beijing- Tianjin-Hebei region is relatively slow; (3) Both net inflow of population after spring festival and daily flow scale are significantly correlated with urban economic resilience, and the former will affect urban economic resilience; and (4) the spatial heterogeneity of each factor driving is significant, and they have different impact scales. The impact intensity is as follows: net population inflow > innovation ability > public financial expenditure > financial efficiency > urban size.

Keywords: economic resilience, population mobility, spatial difference, Multi-scale Geographical Weighted Regression (MGWR).

JEL Classification: J61, O15, P25, R11, R58.

Introduction

The development of urban economy is the result of the interaction of multiple factors (Chen et al., 2021b), which is characterized by uncertainty and vulnerability. Global economic growth, already weak since the 2008 financial crisis, was hit by the COVID-19 pandemic in 2020, which is still ongoing, and all countries experienced a precipitous decline in economic growth. In addition, due to the global economic environment is complex and changeable,

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and urban economic development will inevitable be impacted and disturbed by technological innovation (Chen et al., 2021b), market change (Du & Yang, 2015), foreign trade friction (Bao & Yang, 2019) and periodic economic recession (Smirnov et al., 2015). Whether it is in the form of fierce financial crises and industrial reform or chronic combustion such as energy depletion and population ageing, it may increase the uncertainty and vulnerability of economic development (Bailey et al., 2010). Data show that, affected by COVID-19, China's economy dropped by 6.8% compared with the same period in the first quarter of 2020: The added value of first industry decreased by 3.2% compared with the same period last year; that of the secondary industry decreased by 9.6%, while the tertiary industry decreased by 5.2%. The secondary industry decreased the most, which had much influence on the economy. Most manufacturing enterprises stopped production due to epidemic prevention and control, the supply chain was interrupted, and capital turnover was difficult. In the face of successive dangers and challenges, how to effectively improve the affordability and coping ability of the urban economy, make the urban economy adapt to the new environment faster, accelerate the speed of economic recovery and improve the resilience of the urban economy has attracted great attention from scholars and administrators, and there are an increasing number of discussions on "building a resilient regional economy" (Website of Central Government of the People's Republic of China, 2020).

Economic development is highly related to people's production and life. Population mobility can bring great growth potential for economic development in both urban and rural China. However, there are several factual issues that need to be clarified urgently, as: how does population mobility affect urban economic resilience? To what extent does it affect urban economic resilience? These problems need to be scientifically explained to explore the basic facts. Therefore, this paper, taking 287 prefecture-level cities in China in 2019 as the research object, constructs an evaluation index system from the three dimensions of crisis resistance, urban resilience and risk transformation to investigate the spatial differentiation pattern of China's urban economic resilience development and compares it with the spatial pattern of population flow. At the same time, this paper takes short-term population migration into consideration, uses a multiscale geographical weighted regression (MGWR) model to explore the driving factors of urban economic resilience and analyses the effect of influencing factors such as population flow and urban scale from different spatial scales to offer a reference that can promote the construction of differentiated urban economic resilience in China.

1. Literature review

1.1. Research on economic resilience

The term "resilience" originates from engineering mechanics and points to the ability of a material that can return to its original state after deformation under the action of external force (Alexander, 2013). In 1973, ecologist Holling (1973) first introduced resilience into the study of ecosystem carrying capacity, and then it was widely used in various research fields. Due to the diversity of research objects and purposes, academic circles have different definitions of the concept of resilience. The debate mainly focuses on the differences between the "equilibrium" and "stability" emphasized in the concept of resilience and the "disequilibrium" and "evolution" shown by the research object of real resilience (Klimanov et al., 2018; Martin, 2012). At present, the four dimensions of urban economic resilience proposed by Martin are widely recognized: First, risk-resistance, that is, the vulnerability and susceptibility of the urban economy when encountering external shocks; Second, resilience, that is, the speed and degree of recovery after the impact on the urban economy; Third, the ability of reorganization, that is, the ability of the urban economy to reintegrate internal resources and adjust the structure to adapt to the external environment after encountering external shocks; and fourth, the renewal power, that is, the ability of the urban economy to change the original growth path, open a new development model and make the economy regain its rebirth (Martin, 2012).

The evaluation of economic resilience is an important aspect of economic resilience research, mainly includes a development level evaluation model (Chen et al., 2021b), CGE model (Rose & Liao, 2005), etc. Among them, the development level evaluation model uses entropy method, coefficient of variation method, APH, Delphi and other comprehensive index methods to determine the weight of economic resilience index (Shi et al., 2022; Zhou et al., 2022); CGE model evaluates urban economic resilience through the analysis of input-output data among urban sectors; In addition, methods such as measuring the changes in the proportion of employment and unemployment in urban sectors (Diodato & Weterings, 2012) and assessing the urban economic resilience by assessing the changes in urban unemployment rate or GDP growth rate when the regional economy is impacted (Brown & Greenbaum, 2017) have also been widely used. In this paper, the index system is constructed by referring to Martin's four dimensions, and the entropy method is used to determine the weight. Compared with the rich assessment of economic resilience, the exploration of spatial characteristics of economic resilience is still lacking, and most of the existing studies focus on a specific region, lacking an overall discussion of economics in China. However, there is still a lack of targeted research on whether the influencing factors have spatial autocorrelation characteristics, to what extent they will affect the construction of urban economic resilience and whether they have the same effect in different cities.

1.2. Development strategy and path

The construction of urban economic resilience was noticed early by foreign scholars. Through evaluating urban economic resilience and discussing the factors affecting urban economic resilience, they put forward relevant constructive suggestions, such as strengthening the level of economic agglomeration and developing industrial policies according to urban location, to enrich the policy management means of economic macrocontrol. Due to the different economic systems and research stages between China and foreign countries, they also pay different attention to the development strategies and paths of economic resilience. Chinese scholars focus on the impact of cultural factors (Brown & Greenbaum, 2017), social capital (Crespo et al., 2014; Hauser et al., 2010), policy and institutional environment (Martin, 2012) on urban economic resilience. Foreign scholars tend to study the driving mechanism of urban economic resilience from the micro perspectives of industrial structure (Brown & Greenbaum, 2017) and market players (Martin et al., 2013). Population, as one of the productivity factors, can not only enrich the urban labour market but also stimulate the urban economic resilience factor and increase the urban internal economic development potential (Combes et al., 2008). According to endogenous economic growth theory, a highly skilled labour force usually has higher mobility than an ordinary labour force (Storper & Scott, 2009), and the inflow of a highly skilled population is more likely to bring innovation improvement to the city to enhance the city's ability to transform risks. In addition, some scholars have found that population mobility will affect economic convergence. Liberalizing the restrictions on population migration is conducive to economic convergence, achieving the purpose of balancing regional economic growth and contributing to the improvement of regional economic resilience (Kirdar & Saracoglu, 2008).

Due to the phenomenon of homogenization and differentiation in social space, namely the so-called boundary, it will have an impact on the uneven distribution of social economy. Therefore, for the same explanatory variable, its explanatory degree is likely to be different in different scales (Yu et al., 2020). McMaster and Sheppard (2004) regards scale as the essence of geographical search and Goodchild (2001) believes that scale is the most important content in the research related to geographic information science. However, the existence of heterogeneity scale is often ignored in the previous analysis of the influencing mechanism of urban economic resilience. Different cities in China have great differences in economic level, policy environment, resource endowment, lifestyle, industrial structure and functional positioning, which leads to differences in the allocation of economic resources among different cities. This spatial difference leads to the spatial heterogeneity and spatial scale difference of influencing factors of urban economic resilience. For example, some scholars have found that there is spatial non-stationarity between industrial structure, technology, wages and other characteristic factors and urban resilience (Zhou et al., 2021). Based on this, the following hypotheses are proposed:

H1. The spatial scales of different influencing factors of economic resilience are different.

H2. Due to the existence of spatial scale, the impact intensity of the same economic resilience factor on different cities is different.

H3. Due to the existence of spatial scale, the influence direction of the same influencing factor may be different in different cities.

1.3. Summary

Although the research on urban economic resilience has not formed a unified connotation within the discipline, it does not affect the establishment of a relevant theoretical framework and the development of research practice but does result in research that gradually extends from theoretical analysis to internal mechanisms. Most of the existing studies focus on the impact of industrial structure, social capital, social culture, systems and policies on economic resilience, and few articles take the population mobility factor into account. In contrast, articles on population and the economy are rich in the study of population mobility and economic growth, while there are relatively few articles on the relationship between population mobility and economic resilience. Compared with the existing literature, the marginal contributions of this paper are as follows: (1) This paper analyses the spatial differentiation and influencing factors of urban economic resilience by starting from the perspective of population migration. Independent variable processing avoids the census data with static characteristics selected by most studies, which is based on big data from Baidu migration, and more vividly depicts the population flow and daily large-scale flow in a continuous period of time. (2) Starting with spatial distribution, this paper conducts an in-depth study on the spatial dependence of urban economic resilience construction. Many economic resilience construction data come from spatial sampling and have spatial correlation. The combination of Exploratory spatial data analysis (ESDA) and MGWR are selected as spatial measurement methods, which solve the problems of sample independence and irrelevant assumptions followed in traditional econometric analysis to a certain extent. (3) The driving factors are analysed from different spatial scales by means of the MGWR model and other relevant variables are added to overcome the possible estimation errors to more accurately show the impact of population mobility on urban economic resilience.

2. Research area, research method, index construction and data source

2.1. Overview of the region

As the world's second largest economy, with a population of 1.4 billion, China has abundant labor resources and a vast market. The sudden outbreak of COVID-19 in 2020 hit the global economy with a major shock, but China's economy still maintained a growth rate of 2.3% in 2020, according to the National Bureau of Statistics, demonstrating its strong resilience. In addition, China has a huge flow of population. Statistics show that in 2020, the floating population has reached 376 million, and population migration has become a phenomenon that cannot be ignored in China's social development. Therefore, it is of great significance to take China as the research area and population migration as the entry point to analyze the factors influencing economic resilience. However, due to the lack of available data for Hong Kong, Macao and Taiwan, the administrative regions of Tibet Autonomous Region changed a lot, and some cities' data were seriously missing. After comprehensive consideration, 287 cities were taken as the research object, covering 30 provincial-level administrative regions.

2.2. Research method

2.2.1. Entropy method

Entropy method is one of the multi-dimensional comprehensive evaluation methods, which has the advantage of avoiding the interference of human factors in subjective evaluation and getting more objective results. In this paper, the entropy method is used to calculate the urban economic resilience index. For specific calculation steps, please refer to reference (Chen et al., 2021a).

2.2.2. Improved TOPSIS method

As a common method in multi-objective decision making, TOPSIS method is also known as the sorting method of ideal solutions. It divides ideal solution into positive ideal solution and negative ideal solution. By measuring the distance between the evaluation object and the two, the approximation degree of each evaluation object and the optimal scheme is obtained, and the relative ranking is based on the merits of the evaluation object. The optimal solution is close to the positive ideal solution and far away from the negative ideal solution. Compared with the traditional TOPSIS method, the advantage of the improved TOPSIS method is that the determined weight is introduced into the evaluation matrix, and the relative proximity is taken as the standard to evaluate economic resilience of 287 cities. It makes the evaluation results more scientific and reasonable. Due to limited space, detailed calculation steps will not be described here. Please refer to reference (Yan et al., 2022). According to the regional economic classification criteria of the World Bank, we take 50%, 100% and 150% of the mean value of urban economic resilience as the segmentation points. The economic resilience of each city is divided into four grades: low level, medium-low level, medium-high level and high level, as shown in Table 1, where M is the mean.

Table 1. Standard for the level of urban economic resilience

Relative proximity	[0.5, 0.5M)	[0.5M, M)	[M, 1.5M)	[1.5M, 1)
The level of urban economic resilience	Low	Medium-low	Medium-high	High

2.2.3. Exploratory spatial data analysis

ESDA is an ideal data-driven analysis method. It takes spatial correlation as the core and detects spatial agglomeration and spatial anomalies by descripting and visualizing spatial phenomena, thus revealing the spatial interaction mechanism between research objects. It usually includes global spatial autocorrelation and local spatial autocorrelation.

Global spatial autocorrelation reflects the spatial similarity of attribute values of adjacent or close regions of observations in the whole research area. The global Moran's I index is commonly used to calculate the correlation coefficient between observations and spatial lag variables.

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i - \overline{x}\right)\left(x_j - \overline{x}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}}. \tag{1}$$

In formula (1), I is the global Moran's I; n is the number of regions; X_i and X_j represent the urban economic resilience of region i and region j, respectively, and W_{ij} is the spatial weight matrix.

Local spatial autocorrelation mainly analyses whether there are similar or different aggregation characteristics between the local area and surrounding area. Generally, Local Moran's I, which is also local indicator spatial association (LISA), is used to show which areas have similar aggregation and which areas have different aggregation, thus indicating the significance of the spatial difference degree.

$$LISA = \frac{\left(x_i - \overline{x}\right)}{S_x^2} \sum_{i=1}^{n} [w_{ij}\left(x_i - \overline{x}\right)]. \tag{2}$$

In Formula (2): $S_x^2 = \frac{\sum\left(x_i - \overline{x}\right)^2}{n}$, a positive LISA, including H-H or L-L, indicates that the research unit is of high value and adjacent units are also of high value or that the research unit is of low value and adjacent units are also of low value. A negative LISA, including H-L or L-H, indicates that the research unit has a high value but the neighbouring unit has a low value or that the research unit has a low value but the neighbouring unit has a high value.

2.2.4. Multi-scale geographically weighted regression

Compared with the traditional geographical weighted regression (GWR) model, the MGWR model allows each variable to have different spatial smoothness levels, which solves the defect of the classical GWR that requires the same bandwidth for all variables. At the same time, the specific bandwidth of each variable can also be used as the spatial scale index of the action of each spatial process, which makes the spatial feature model generated by the multi-bandwidth method better fit reality. In this study, the MGWR model was used to explore the spatial differentiation and spatial scale differences of the driving factors of urban economic resilience in 287 prefecture-level cities in China in 2019. The formula is as follows:

$$y_i = \sum_{j=1}^{k} \beta_{bij}\left(u_i\ , v_i\right) x_{ij} + \varepsilon_i . \tag{3}$$

In Formula (3), β_{bij} represents the regression coefficient of the local variable; bij represents the bandwidth used by the regression coefficient of the variable *j*; (u_i, v_i) represents the spatial coordinates of the sample point *i*; X_{ij} is the observed value of the variable *j* at the sample point *i*, and ε_i is the random disturbance term.

2.3. Index construction

Urban economic resilience is a crucial component of urban resilience. This means that the urban economy can cope with the impact of various external interference factors encountered in the process of economic development by constantly adjusting its own state and can learn from the interference factors, further enhancing its own ability to deal with risks (Dawley et al., 2010; Shaw & Maythorne, 2013; Walker et al., 2006). Urban economic resilience includes the absorption, recovery and transformation of disturbance factors by the urban economy. It not only emphasizes the ability of the internal economic system to adapt to crises (Pike et al., 2010; Hudson, 2010) but also focuses more on the capacity to transform itself after absorbing external disturbances in the economic system (Shaw & Maythorne, 2013; Walker et al., 2006). Therefore, from the three dimensions of crisis resistance, urban resilience and risk transformation, this paper constructs a comprehensive evaluation index system for economic resilience (Table 2), including 9 corresponding indicators.

Crisis resistance points to the capacity to resist or absorb these unfavourable factors in an urban economic system when it encounters external disturbances, maintains its own equilibrium state and ensures normal operation of the urban economic system. The standard-level indicators include per capita GDP (Hu et al., 2018; Zheng et al., 2018), import and export trade volume (Jiang et al., 2022) and the proportion of secondary and tertiary industry output value in GDP (Burton, 2015; Chen et al., 2021b). Urban resilience refers to the ability of the urban economy to adapt to the new state quickly, resume production and construction and ensure that urban economic operation is not affected even though it has been damaged to a certain extent when it encounters the impact of external risks. The standard-level indicators select the per capita CNY deposit balance of financial institutions (Liu et al., 2021), per capita general public budget revenue (Hu et al., 2018; Zheng et al., 2018) and the proportion of employees in tertiary industry (Zhou et al., 2021). Risk transformation power refers to the ability to quickly switch from the previously broken equilibrium state to a more adaptive state when the urban economy is subject to greater external pressure and risk impact, the normal operation of the urban economy is hindered, and it is difficult to restore it to its original state. The urban economy can quickly switch from the previously damaged balance to a new balance that is more suitable for the current situation. The standard-level indicators include the proportion of expenditures on science and education (Bristow & Healy, 2018), the number of college students per 10,000 people (Shi et al., 2021) and the total retail sales of consumer goods per capita (Burton, 2015; Jiang et al., 2022).

Table 2. Urban Economic Resilience Index System

Target layer	Criterion layer	Domain layer	Index layer
Economic resilience	Crisis resistance	Economic strength	GDP per capita
		Economic extraversion	Import and export trade volume
		The industrial structure	The proportion of the output value of the secondary and tertiary industries in GDP
	Urban resilience	Social development	Per capita RMB deposit balance of financial institutions
		Financial strength	Per capita general public budget revenue
		Economic diversity	Proportion of employees in the tertiary industry
	Risk transformation	Investment in science and education	Spending on science and education as a percentage of GDP
		Talent pool	Number of college students per 10,000 people
		Level of consumption	Per capita total retail sales of consumer goods

2.4. Data source and processing

The data used in this study are mainly from the China City Statistical Yearbook and the statistical yearbook of provinces and cities and some missing index data were estimated by the linear regression method. In data processing, the spatial distribution map of the economic resilience index of 287 cities was drawn by ArcGIS10.2 software, and the differences in the spatial distribution of urban economic resilience were described in detail. The spatial correlation of the urban economic resilience index in each region is analysed by the global and local Moran's I index.

Spring Festival travel rush is a unique cultural phenomenon in China, which refers to a large-scale phenomenon of high transportation pressure around the Spring Festival. The Spring Festival is the most important festival for Chinese people, and it is also the day for family reunion. Most people choose to go back to their hometown in the first two weeks of the Spring Festival, and go out to work in the two weeks after the Spring Festival. China's population accounts for about 1/5 of the world's, with a huge flow of people, and the scale of population flow during the Spring Festival peak is a rare phenomenon in the world.

The population migration data selected for this study were collected from the Baidu migration website using Python software, which are called Baidu migration big data. The data based on Baidu LBS (location-based service) technology, reflect the temporal and spatial trajectory of daily population migration in a real-time, dynamic and visual way. If similar technology is available abroad, similar research can also be done.

Population migration was studied two weeks after the Spring Festival and two weeks in daily life. According to Baidu Map's smart eye big data platform, the migration scale index can reflect the scale of people moving in or out of cities of China and can be used for horizontal comparison between cities. Two weeks after the Spring Festival, from February 11, 2019 (the seventh day of the first lunar month), to February 24, 2019 (the 20th day of the first lunar month), is the peak period for migrant workers to return home. This period's allopatric employment is migrant workers who prepare to return to their workplaces and students away at college. Therefore, the scale of population migration in the two weeks after the Spring Festival can approximately reflect the inflow and outflow of population in each city in that year (Niu et al., 2021). Avoid days with Chinese statutory holidays and choose the corresponding dates of the following as the daily life period, i.e. from March 11, 2019, to March 24, 2019. The flow of people in daily life is mainly based on scientific, cultural and business exchanges between different cities, which can approximately reflect the division of cooperation and interconnection between cities (Tong et al., 2020).

The specific calculation procedures of population migration data in daily life and the two weeks after the Spring Festival as follows:

$$N_i^{in} = \sum_{j=1}^{14} P_{ij}^{in} - \sum_{j=1}^{14} P_{ij}^{out}; \tag{4}$$

$$N_i^{out} = \sum_{j=1}^{14} P_{ij}^{out} - \sum_{j=1}^{14} P_{ij}^{in}; \tag{5}$$

$$D_i^{sum} = \sum_{j=1}^{14} M_{ij}^{in} + \sum_{j=1}^{14} M_{ij}^{out}, \tag{6}$$

where, i represents the name of the city, j represents the jth day, and its value ranges from 1 to 14. P_{ij}^{in} represents the population inflow index of city i on the jth day after February 10; P_{ij}^{out} is the population outflow index of city i on the jth day; N_i^{in} is the population inflow scale index of city i after the Spring Festival; N_i^{out} is the population outflow scale index of city i after the Spring Festival. Similarly, M_{ij}^{in} represents the population inflow scale index of city i on the jth day after March 10; M_{ij}^{out} is the population outflow scale index of city i on the jth day; D_i^{sum} is the daily flow scale index of city i in daily life.

3. Spatial analysis

3.1. Spatial analysis of economic resilience

3.1.1. Spatial pattern analysis

The results show (Figure 1a) that urban economic resilience in China presents significant spatial heterogeneity, and urban economic resilience in central and western China is generally lower than that in eastern China. There are few regions with a high level of economic resilience, most of which are clustered in groups and bults in the Beijing-Tianjin-Hebei region, Shandong Peninsula, Yangtze River Delta and Pearl River Delta, and a small part are scattered

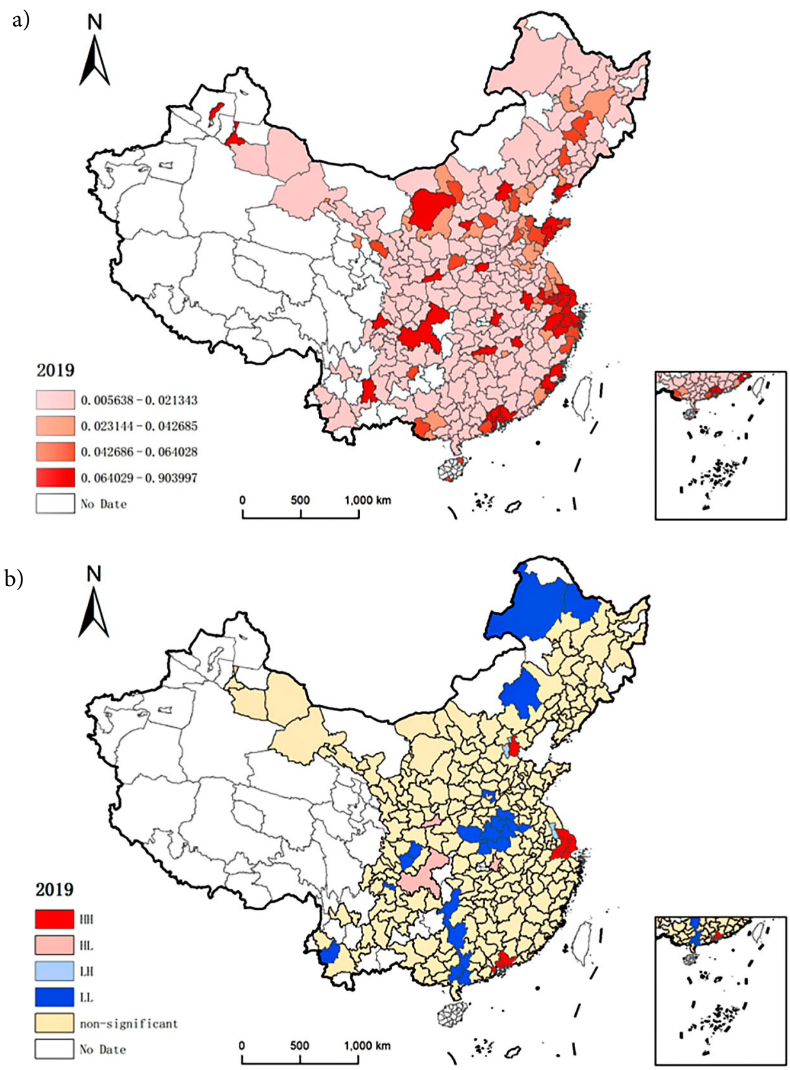

Figure 1. Distribution of economic resilience index in prefecture-level units in China:
a – Spatial pattern of economic resilience; b – Spatial agglomeration type of economic resilience

in provincial capitals and central cities of urban clusters in maculosus and spots, which have a certain spatial shading effect. The number of regions with low levels of economic resilience is the largest, and most of them are located in central, western and northeastern China with a continuous distribution. The economic resilience of the eastern region ranks first among the four regions, which may be related to the industrial distribution in the eastern region. In 2019, the eastern region's primary, secondary and tertiary industries accounted for 4.6%, 38.9% and 56.5%, respectively. The central region accounted for 8.2%, 41.8% and 50.0%; the western region accounted for 11.0%, 37.9% and 51.1%. Northeast China accounted for 13.2%, 34.4% and 52.4%. In terms of tertiary industry, which has the highest proportion in the eastern region and the lowest proportion in the central region, the proportions of the four regions are all over 50% in tertiary industry. Industries in the eastern region have more advantages in appealing to a mass of excellent social resources, especially human resources, to ensure that the eastern city economy in the face of pressure and risk impact has more strength to cope with changes and adjust the economic trend.

3.1.2. Spatial autocorrelation analysis

To reveal the spatial clustering characteristics of the correlation between local and surrounding cities, the spatial weight matrix of QUEEN adjacency was used to calculate LISA local spatial autocorrelation of economic resilience of 287 cities in China (Figure 1b). Among them, H-H clustering regions represent the city itself and surrounding cities, all of which have strong economic resilience. Most of these cities are all distributed in the Pearl River Delta, Yangtze River Delta and Beijing-Tianjin-Hebei region in eastern China. Cities in this region not only have a strong ability to cope with economic risks themselves, but also have the ability to help surrounding cities resist economic crises. Urban economic resilience shows a high level of local spatial interaction characteristics. L-L clusters represent the city itself and surrounding cities, all of which have weak economic resilience. Most of the cities with this feature are distributed in central and western China, and most of them are concentrated in urban agglomerations along the Yellow River basin of China, and a few are distributed in northern Inner Mongolia. Cities in this region not only have weak ability to cope with economic risks themselves, but also provide limited assistance to surrounding cities to resist economic crisis. The level of economic resilience is characterized by low-level spatial interaction. The H-L clusters represent strong economic resilience of the city itself but weak economic resilience of the surrounding cities. Such cities are mainly distributed in Wuhan, Xi'an, Chongqing and other central and western provincial capital cities, L-H cluster area indicates that economic resilience of the city is low, while that of surrounding cities is high. There are only two such cities, Langfang and Taizhou (Jiangsu Province).

3.2. Spatial analysis of population migration

3.2.1. General characteristics of population inflow in China

Figure 2a shows that the trend of population inflow to provincial capitals and eastern coastal cities is obvious. Among the 287 cities, 72 cities had positive population inflows, among which the Yangtze River Delta, Pearl River Delta, Beijing-Tianjin-Hebei and Shandong Peninsula accounted for 68.47% of the total. If provincial capital cities were added, the net inflow of population accounted for 98.41% of all cities. Of the 35 key cities in China, except Chongqing, the rest are net inflow areas. The LISA value of the net population inflow was calculated, and the test results show (Figure 2b) that H-H clusters of net population inflow are distributed in three major urban agglomerations in eastern China, including four in the Pearl River Delta, three in the Yangtze River Delta and two in the Beijing-Tianjin-Hebei region. These cities and their surrounding cities have relatively high net population inflows, showing strong population attraction. The consequences show that in the protracted population urbanization process, the population aggregation trend in North China and northeast China is relatively weak, and the population is concentrated in central cities and eastern coastal cities. The population accumulation characteristics of the Beijing-Tianjin-Hebei urban agglomeration are relatively slow, and the development of internal non-core cities is relatively backward among the three major urban agglomerations in the east.

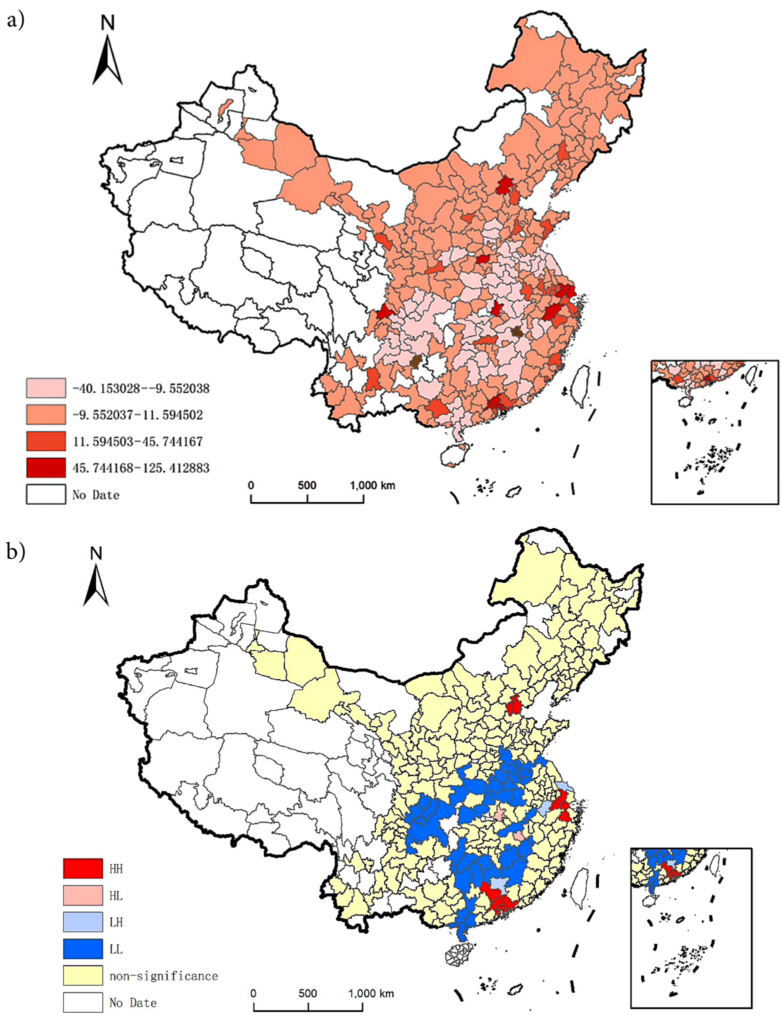

Figure 2. *To be continued*

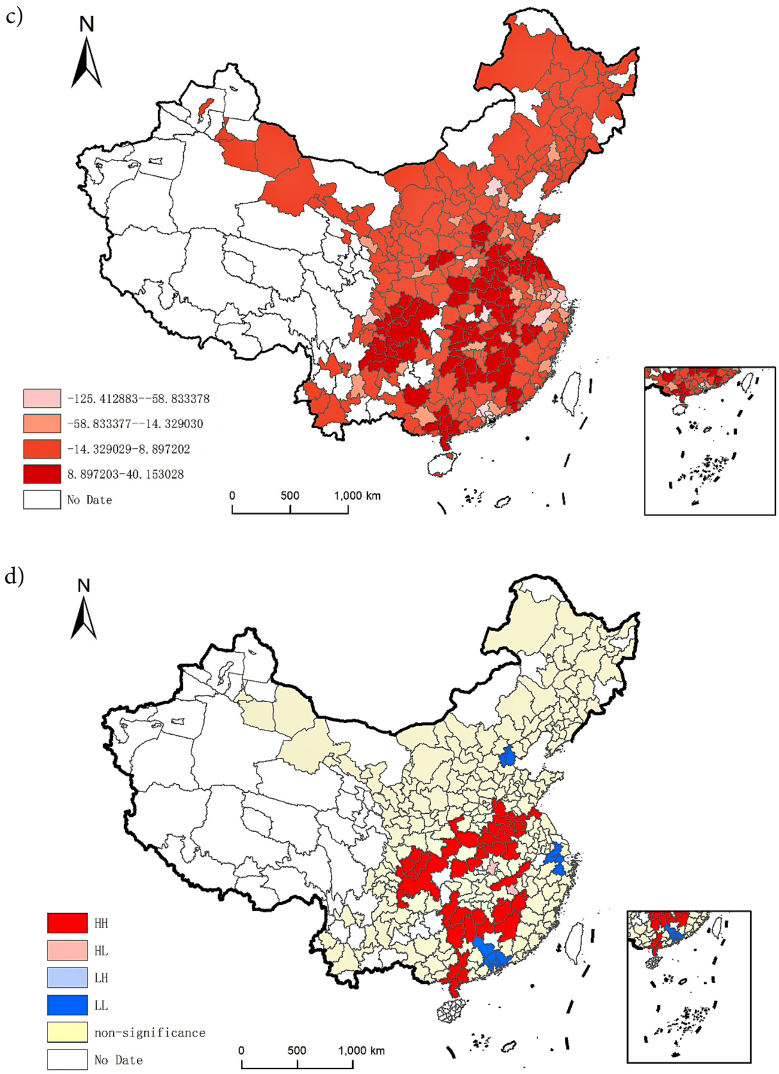

Figure 2. Distribution of population flow index after the Spring Festival in prefecture-level units in China: a – Spatial distribution of net inflow of population after the spring festival; b – Spatial agglomeration type of net inflow of population; c – Spatial distribution of net outflow of population after the spring festiva; d – Spatial agglomeration type of net outflow of population

3.2.2. General characteristics of population outflow in China

Figure 2c shows that the overall net outflow of population is spatially heterogeneous in the eastern, central and western regions. The net outflow of population in eastern China is negative and belongs to the net inflow zone, while the net outflow of population in the midwestern region is positive and belongs to the net outflow zone. The difference in the net outflow of the population in the midwestern region is divided by Hu's Line. The number and range of the net outflow of population in the east of Hu Line are much higher than those in the west.

The outflow of population in central China is most serious in Henan, Jiangxi and Hunan, followed by Sichuan and Guangxi in the west. In general, the central region has become the high-value region of population outflow in China, and population outflow areas present a large range of concentrated distributions. The LISA value of the net population outflow of 287 prefecture-level cities was calculated. The results show (Figure 2d) that H-H clustering areas of net outflow of population are distributed in central and western China, including Henan, Hubei, Hunan and Jiangxi in central China and Sichuan and Guangxi in western China. These cities have a large outflow of their own population, and the surrounding cities are also in a state of population loss; however, Northeast China and North China are not significant regions. The above results show that the midwestern areas are still the main area of population outflow, and the central region has become the main area of population outflow, replacing the longstanding northeastern region.

3.3. Summary

The Yangtze River Delta, Pearl River Delta, Beijing-Tianjin-Hebei and other urban agglomerations are the main areas of Chinese population inflow. Regions with high levels of economic resilience are also concentrated here, led by the Yangtze River Delta, Pearl River Delta, Beijing-Tianjin-Hebei and Shandong Peninsula. In addition to the three major urban agglomerations along the eastern coast, the population concentration trend towards central cities is also obvious. Zhengzhou, Chengdu, Wuhan, Changsha, Taiyuan, Guiyang and Kunming in the midwestern areas have more prominent population concentration characteristics, and these cities also have relatively high economic resilience. Most cities in the central and western areas are the main outflow places; moreover, the values of urban economic resilience index in the central and western areas are also relatively low. The central region has the most severe population outflow, and areas with low levels of economic resilience are also concentrated here, among which the Yellow River Basin in the middle has the largest number. In general, the eastern, central and western regions have significant differences not only in population migration but also in the level of economic resilience. The eastern region has a large net inflow of population and better economic resilience, while the central and western areas have a large net outflow of population and relatively poor economic resilience. These results suggest that the spatial distribution of urban economic resilience is similar to that of population mobility.

4. Correlation analysis between economic resilience and population mobility

4.1. Daily flow scale and economic resilience

Comparing the daily flow scale index and economic resilience index of 26 provinces and 35 key cities across the country (Figure 3), it is found that daily population flow scale and economic resilience are obviously positively correlated: in most areas, the economic resilience index of areas with large daily population flow scale is higher, and the economic resilience index of areas with small daily population flow scale is relatively low. According to the K-means clustering based on the daily mobility scale index and economic resilience level of 35 cities, the 35 key cities are roughly divided into four categories (Figure 4). The first category is Guangzhou, Beijing, Shanghai and Shenzhen, where the scale of personnel turnover and economic resilience are at the highest level in daily life. The second category is central cities such as Chengdu, Zhengzhou and Xi'an, where the scale of people flow and economic resilience are relatively large in daily life. The third category is Tianjin, Chongqing, and Changsha, where the scale of daily people flow and economic scale are small, and the fourth category is Xiamen, Nanchang, Dalian, Kunming and other central cities located in northwest, southwest, north and northeast China, where people flow in daily life and the level of economic resilience are both are low.

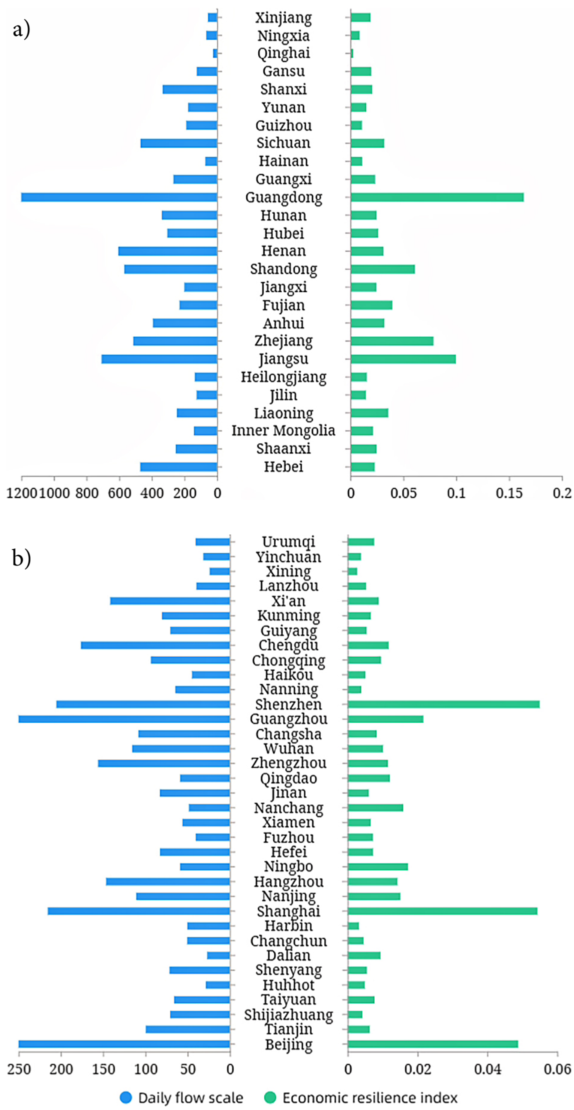

Figure 3. Comparison of daily flow scale and economic resilience in China:
a – Each province; b – Key cities

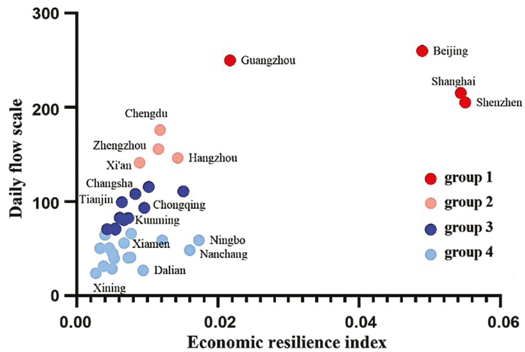

Figure 4. Daily flow scale and clustering of economic resilience in key cities of China

4.2. Correlation analysis between economic resilience and population mobility

Furthermore, Pearson correlation analysis of the post-holiday net inflow index and economic resilience index of 287 cities shows that the correlation coefficient between net inflow of population after spring festival and urban economic resilience is 0.838, that the correlation coefficient between the daily flow scale index and urban economic resilience is 0.826 and that both are significantly correlated at the level of 0.01. That is, the net inflow of population after the spring festival and the scale of daily mobility present a prominent positive relationship with urban economic resilience. The correlation between net inflow of population after spring festival and economic resilience after the holiday is slightly higher than the correlation between the scale of daily mobility and its correlation. The correlation results show that both the net inflow of the population after spring festival and the number of daily population movements has a strong linear relationship with urban economic resilience, and the closeness between net inflow of population after spring festival and economic resilience is slightly stronger than that between the scale of daily population movement and economic resilience. Because net inflow of population can provide a large amount of labour for the influx and human experience, wisdom, technology and the ability to transform crises can help the urban economy adjust its own state in time and better deal with external risks. The flow of people in daily life reflects the scientific and technological exchanges and business exchanges between cities. Such exchanges are conducive to the mutual complementation and cooperation of capital flow, information flow, logistics, etc. between cities, thereby improving the allocation of urban resources in majorization, promoting the development of the urban economy and enhancing the anti-interference ability of the urban economy (Gu & Jian, 1996).

5. Spatial scale and differentiation of influencing factors of economic resilience

In order to build a strongly resilient economic system, it is necessary to clarify the spatial scale and spatial differentiation of influencing factors of urban economic resilience. Based on the existing studies and the above analysis, this paper determined the influencing factors of urban economic resilience, and calculated the spatial scale by using the MGWR method through model comparison, and further discussed the spatial differences of influencing factors on this basis.

5.1. Variable selection

The net inflow of population injects human capital into urban economic development and increases the urban market share. Net population inflow can inject human capital and enterprise capital into urban economic development (Berliant & Fujita, 2009), and the rich knowledge reserve and experience contained in human capital can help cities learn from disturbances and quickly adapt to the new state (Glaeser, 2011; Glaeser & Lu, 2018). Corporate capital investment is conducive to the reorganization of capital factors in regional markets, and to a certain extent, it will also drive the reallocation of other factors, thus enhancing factor liquidity and improving the efficiency of resource allocation (Beckmann & Czudaj, 2017), which plays a very important role in cities' response to external crises and risks.

A moderate increase in city scale is conducive to expanding the consumer market, giving full play to the promoting function of industrial agglomeration in the economy to achieve the aim of improving the ability of the urban economy to cope with risks (Feng et al., 2020). But it's important to note that bigger isn't always better. It also needs precise analysis and scientific control, which is crucial to the improvement of urban economic resilience.

The actual utilization of foreign capital in a city can reflect the degree of economic openness of the city (Chen et al., 2021b). The introduction of foreign capital can not only create employment opportunities and increase income but also facilitate technological exchange and knowledge spillover between enterprises, enhance the adaptability of the urban economy facing external shocks and thus, improve the speed of urban economic recovery (Di Caro, 2017).

Finance is also a kind of resource, and financial efficiency refers to the allocation efficiency of financial resources, which reflects the stability of the regional financial environment (Chen et al., 2021b).

Government policy guidance is very important for urban economic development. Government policy can attract high-quality talent, promote technological innovation and point out the development direction for industry in difficult times. Public financial expenditure is an important aspect of government policy guidance, mainly reflecting the degree of regulation and control of the city to deal with risks (Giannakis & Bruggeman, 2017; Masik, 2016).

The technological level is the source of urban economic growth and industrial structure optimization. It is found that innovation ability is also an important factor for the urban economy to resist external interference and enterprises can absorb new technologies through independent innovation (Boschma, 2015; Giannakis & Bruggeman, 2017).

It can be seen from the previous analysis that population mobility is correlated with economic resilience, and previous studies have shown that demographic factor, degree of opening, financial environment, government governance and technological level will have an impact on economic resilience. Therefor the following six indicators are selected based on the above dimensions including net inflow of population, urban size, foreign capital utilization, financial efficiency, public financial expenditure and innovation ability (Table 3).

Table 3. Indicators of Driving Forces of Urban Economic Resilience

Factors	Indicators	Measurement
Demographic factors	Net inflow of population	Net inflow of population index
	Urban size	The average annual population of a city
Degree of opening	Foreign capital utilization	FDI/GDP
Financial environment	Financial efficiency	Financial loan-to-deposit ratio
Government management	Public finance expenditure	Per capita general public budget expenditure
Technology level	Innovation ability	Total number of patents authorized in prefecture-level cities

5.2. Model contrast

As seen from Table 4, the goodness of fit R2 of MGWR is higher than that of classical GWR, and the AICc value is far less than that of classical GWR. Moreover, compared with classical GWR, the sum of square residuals of MGWR is smaller. Therefore, it can be determined that MGWR is superior to classical GWR in measuring urban economic resilience. In addition, the classical GWR ignores the diversification of the action scale of each variable, resulting in considerable noise and bias in the regression coefficient. MGWR improves this point by allowing the existence of multiple action scales, so the regression coefficient is more robust.

Table 4. Test results of GWR and MGWR model

Model indicators	GWR	MGWR
Goodness of fit R^2	0.899	0.972
AICc	172.685	–50.205
Residual sum of squares	28.955	7.956

5.3. Multi-scale analysis

GWR defaults to the same variable scale, and the final fixed bandwidth is determined by calculating the average of each variable scale. In contrast, MGWR allows different variable bandwidths, and the corresponding action scale can be automatically calculated according to variable attributes so that the influencing factors have similar action size within the scale range. Once the scale range is exceeded, the difference in action is obvious. As seen from Table 5, the action scale of classical GWR is 66, accounting for approximately 23% of the total number of samples. The specific realization of MGWR is as follows: The effect scales of population net inflow, urban size, financial efficiency and public financial expenditure were 44, 46, 43 and 43, accounting for 15.3%, 16.5%, 15% and 15% of the total sample, respectively. This scale is close to the provincial scale of the Xinjiang Autonomous Region of China, indicating that the indicators are spatially heterogeneous to a large extent. The effect scale of FDI utilization and innovation capacity is 286, which approximates the global scale, indicating that there is almost no spatial heterogeneity in these two indicators. In the regression results of

MGWR, the regression coefficient of foreign capital utilization is not significant. The regression coefficient of urban size, financial efficiency and public finance expenditure is partially significant. The regression coefficients of population net inflow and innovation ability are all significant. The descriptive statistics of MGWR regression coefficient are shown in Table 6.

Table 5. Model bandwidth of GWR and MGWR

Variable	GWR	MGWR
Net inflow of population	66	44
Urban size	66	46
Foreign capital utilization	66	286
Financial efficiency	66	43
Public finance expenditure	66	43
Innovation ability	66	286

Table 6. Statistical description of MGWR regression coefficients

Variable	Mean	STD	Min	Median	MAX
NI	0.321	0.233	0.034	0.218	0.896
AAP	0.046	0.066	–0.135	0.054	0.257
FID/GDP	–0.012	0.001	–0.014	–0.012	–0.008
LTDR	–0.077	0.155	–0.616	–0.032	0.223
FE	0.233	0.169	–0.001	0.163	0.608
NOPG	0.316	0.003	0.313	0.316	0.325

5.4. Analysis of spatial pattern of coefficient

Net population inflow remarkably actively affects urban economic resilience, and the impact intensity is the highest among all variables, with a regression coefficient between 0.0924 and 0.8957. This shows that the continuous inflow of population contributes to the improvement of urban economic resilience. Figure 5 shows that the spatial influence of net population inflow on China's urban economic resilience gradually increases from southwest to northeast and declines slightly in Heilongjiang Province. The impact was greatest in the northeast and least in the central and southern regions. In recent years, there has been a serious population loss in Northeast China, the masses of people moving from northeast China to central and southern China. The loss of high-quality talent and the prime labour force makes northeast China's human capital strength weak at present. However, as China's old industrial base, Northeast China has a good social development foundation, rich resources and great potential. The biggest problem is the contradiction between economic development and lack of human resources, so the net inflow of population can greatly improve the urban economic resilience of the three northeastern provinces (You et al., 2020). In much of the central and southern provinces, the population is perennially ranked at the upper levels. Population net inflows will still be helpful to the promotion of urban economic resilience, but the effect may be weak in this areas, especially in Beijing, Shanghai, Guangzhou, Shenzhen, all first-line cities where the population tends to saturate and where human resources are relatively abundant.

Urban resilience was diversely affected by city size in different regions, with regression coefficients ranging from 0.1347 to 0.2569. The results show that moderate urban expansion actively affects urban economic resilience in the Yangtze River Delta region and Xinjiang Region but has a negative effect in the northeast region and the middle and lower reaches of the Yangtze River region (Figure 6). The Yangtze River Delta region takes advantage of the accumulation effect of urban scale development to improve the scale economy. At the same time, city planning is reasonable, adopts a dispersed design between cities to moderately expand urban development, which better promotes the integration of industry and cities and improves urban economic resilience. The construction of the "Silk Road Economic Belt" has brought rare development opportunities to Xinjiang and other places. As the Belt and Road Initiative enters the substantive promotion stage, domestic and foreign investment is pouring in, and Xinjiang has become a key area of development. The orderly expansion of the urban scale is conducive to the gathering of resources and talent in Xinjiang, which contributes to the economic construction of Xinjiang. In contrast, urban expansion has held back urban resilience in Liaoning, Jilin, Sichuan, Chongqing, Hubei and Guizhou. The reason is mainly related to the method of urban expansion. The spatial expansion and population growth in these areas are clearly out of whack. Especially in Liaoning and Jilin, under the wave of northeast revitalization, the enthusiasm for new urban construction is unprecedented. The "large-scale" spatial layout of the new town corresponds to the "low-density" population and industrial structure. It is imperative for Northeast China to change the traditional urban expansion mode and optimize the industrial structure.

Financial efficiency is significant only in the eastern coastal, northern and northeastern regions of China, with a regression coefficient between –0.6160 and 0.2229. Except for Fuzhou, financial efficiency negatively affects urban economic resilience, and the degree of influence is heavy. This indicates that improving financial efficiency will reduce the resilience of the urban economy to some extent. The reason for this phenomenon may lie in the inefficient allocation of financial resources, which is embodied in the following two points. First, there was a lack of consideration of the actual economic development situation of the city and a blind pursuit of financial efficiency. The change in financial efficiency should take the actual demand of urban development as the starting point and should not blindly pursue high financial efficiency and violate the law of urban economic development. Otherwise, it will not only cause improper allocation of credit resources and damage the development of the banking industry but also affect support for the real economy and reduce the resilience of the urban economy. Second, financial institutions cannot strongly support urban economic construction due to the consideration of their own investment risks. The government and some large enterprises often have a strong influence on bank credit behavior; therefore, financial resources may be more inclined to be state-owned enterprises or large enterprises. However, the surplus rural labor force absorbed by these enterprises is relatively limited. It is only small- and medium-sized enterprises that are the largest and most dynamic component of the Chinese market, as well as the main force to maintain social and economic stability and relieve employment pressure. In this case, the improvement of financial development

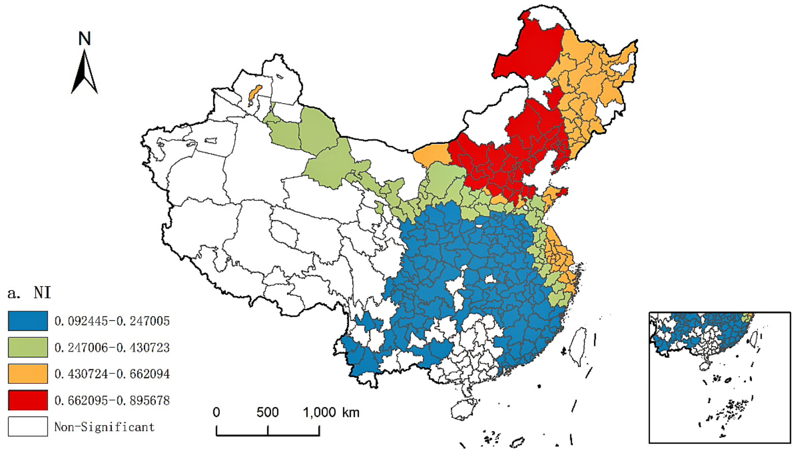

Figure 5. Spatial coefficient distribution of net inflow of population based on MGWR model

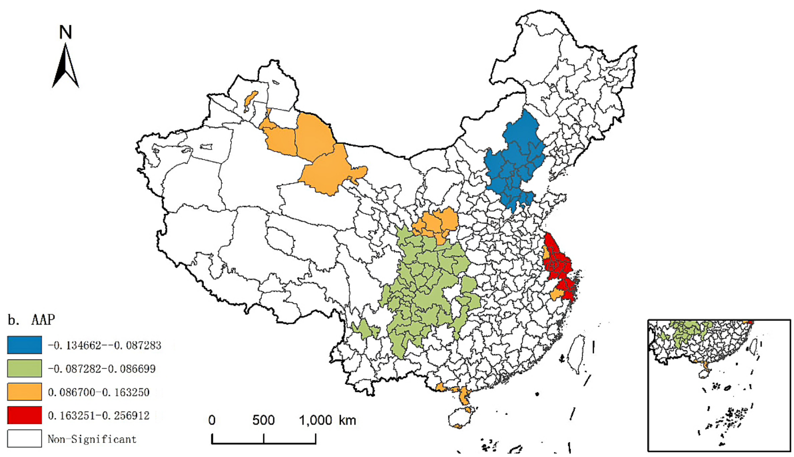

Figure 6. Spatial coefficient distribution of urban size based on MGWR model

efficiency will inhibit the improvement of the urban employment rate, leading to the outflow of urban talent and the decline of economic resilience. Figure 7 shows that the Yangtze River Delta is most negatively affected by financial efficiency, followed by the Beijing-Tianjin-Hebei, most likely because the monetary fund distribution is not reasonable, because of financial integration lag and because a lot of money excessively concentrates in big cities, hindering the rapid flow of financial capital and weakening the financial funds "blood transfusion" function for economic development, which has become a new source of economic instability (Ayadi et al., 2016). For example, in recent years, while Tianjin is "thirsty for capital", deposits and loans in Beijing are up to hundreds of billions.

Public finance expenditure is significant in Inner Mongolia, Gansu and Xinjiang in northwest China, as well as the coastal areas of east China and its peripheral areas, with a regression coefficient between 0.1185–0.6076. Public finance actively affects urban economic resilience to a remarkable degree, and the impact on different regions varies greatly.

The impact of public finance expenditure on northwest China presents a progressive structure, and the impact becomes stronger the further northwest. Inner Mongolia has the least impact, followed by Gansu, and Xinjiang has a greater impact. However, the influence of eastern coastal areas of China and its peripheral areas shows a circle structure, with the greatest influence on eastern coastal areas, which then decreases gradually with the circle layer, with the least influence on central areas (Figure 8). The impact of fiscal expenditure on economic resilience is mainly realized by fiscal expenditure scale and fiscal expenditure structure. In terms of both total and various fiscal expenditures, fiscal expenditures in the eastern region far outperformed those in the central and western regions. The investment intensity is high, and the corresponding investment return is also significant. In addition, developed eastern regions have gradually adjusted the structure of fiscal expenditure in recent years, shifting the focus of fiscal expenditure from economic construction to providing public services, which

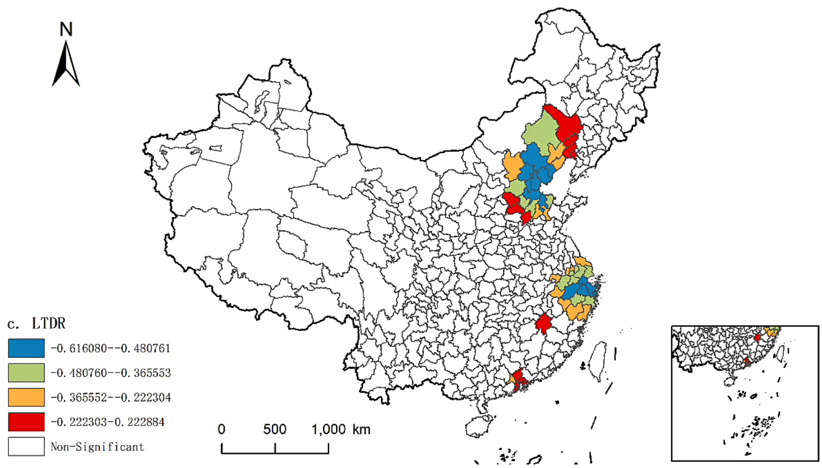

Figure 7. Spatial coefficient distribution of financial efficiency based on MGWR model

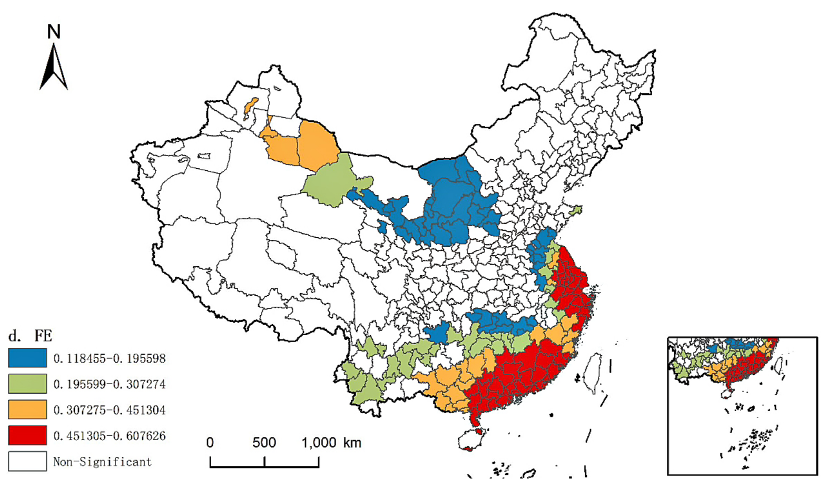

Figure 8. Spatial coefficient distribution of public finance expenditure based on MGWR model

is a major measure to better attract and retain the migrant population from agriculture, promote the process of population urbanization and enhancing economic resilience. On the other hand, in central region and Inner Mongolia, the supply scope is not standardized, the structure of fiscal expenditure is unbalanced, and the positioning of local finance in the field of resource allocation is not clear. As a result, the scope of government functions and expenditure responsibilities do not match the needs of market economic development, so it does not significantly promote economic stability.

Innovation capacity actively affects urban economic resilience, with an intermediate impact intensity, a regression coefficient between 0.3128 and 0.3250 and an average value of 0.316 (Table 5), indicating that urban economic resilience will increase by 0.316 for every 1 increase in population density. In space, it shows a stepped distribution. From northeast to southwest, the impact of innovation capacity on urban economic resilience gradually decreases. With the deepening of reform and opening-up, China's economic development has gradually stepped into a "new normal". In particular, the gradual disappearance of the "foreign trade dividend" and "demographic dividend" makes scientific and technological innovation become the main method of economic development in various regions, which objectively contributes to the improvement of urban economic resilience. Figure 9 shows that the innovative high-value areas are mainly concentrated in northeast China, indicating that the improvement of innovation capacity can greatly improve urban economic resilience in northeast China. As China's old industrial base, northeast China is now under the general trend of China's economic transformation and upgrading and high-quality development. Some traditional industries, such as steel and energy, have been severely impacted; the economic growth rate has slowed down significantly, and institutional, institutional and structural problems have become increasingly prominent. Figure 5e shows that innovative high-value areas are mainly concentrated in northeast China, indicating that the improvement of innovation capacity can greatly improve urban economic resilience in northeast China. As China's old industrial base, Northeast China is now under the general trend of China's

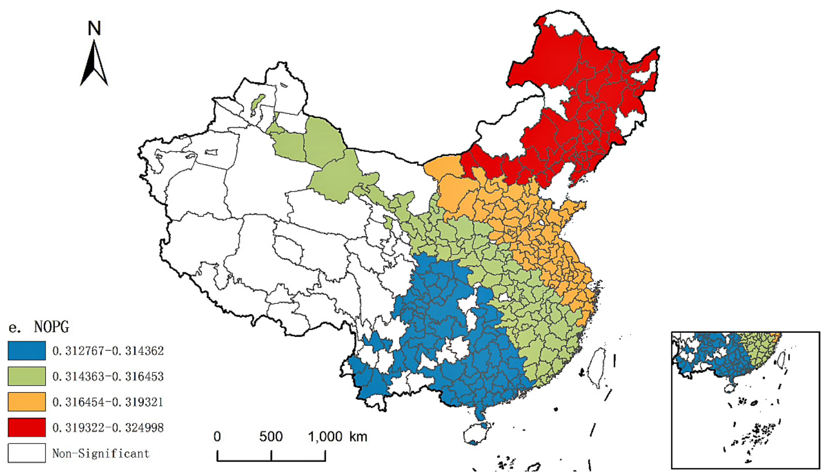

Figure 9. Spatial coefficient distribution of innovation ability based on MGWR model

economic transformation and upgrading and high-quality development. Some traditional industries, such as steel and energy, have been severely impacted; the economic growth rate has slowed down significantly, and institutional, institutional and structural problems have become increasingly prominent. Scientific and technological innovation is the key to break through the bottleneck of economic development, change the mode of economic development and realize industrial upgrading. However, the innovation ability of northeast China is obviously insufficient, which is mainly reflected in the low innovation level, insufficient investment in innovation and local industrialization of innovation achievements.

The vulnerability of the urban economy during a crisis and the ability of crisis resistance, urban recovery and risk transformation are influenced by multiple factors, and the correlation strength of each factor and the economic resilience index is different to varying degrees. The impact scale of net population inflow, city size, financial efficiency and public fiscal expenditure is small, and the spatial impact intensity changes greatly, while the impact scale of innovation capacity is close to the national, and the spatial impact is relatively stable. Assume H1 and H2 are confirmed. In addition, the net inflow of population, public financial expenditure and innovation capacity have a positive impact on urban economic resilience, financial efficiency has a negative impact on urban economic resilience, and city size has a positive and negative two-way impact on urban economic resilience. Assume H3 are confirmed.

Conclusions

Taking Baidu migration big data and population flow as the research perspective, ESDA model was performed to analyze characteristics of economic resilience and population mobility in 287 Chinese cities in 2019, and analyse the correlation between them. Finally, MGWR model was used to explore the driving factors of urban economic resilience. The results show the following: The quantity of cities with low-level urban economic resilience is the largest, most of which were located in the central, western and northeastern regions in China with a continuous distribution. The number of high-level economically resilient cities is the lowest, which mostly grouped in clusters and blocks in the Beijing-Tianjin-Hebei, Shandong Peninsula, Yangtze River Delta and Pearl River Delta regions; The LISA test results show that the H-H clusters of net inflows of population are distributed in the three major urban agglomerations in eastern China. Compared with the Pearl River Delta and Yangtze River Delta, the population accumulation characteristic is relatively slow and the development of non-core cities is relatively lagging in the Beijing-Tianjin-Hebei urban agglomeration. The H-H clustering areas of net outflow of population are distributed in central and western China. Among them, the number and range of the net outflow of population in the east of Hu Line are much higher than those in the west, and the central region has become the region with the largest outflow of population in China; Both net inflow of population after spring festival and daily flow scale are significantly correlated with urban economic resilience, and the former will affect urban economic resilience. The spatial heterogeneity of each driving factor is significant, and the impact intensity is different in different regions, and even the direction of the influence will be different in different regions. The impact scale of net population inflow, urban size, financial efficiency and public financial expenditure is small, and the spatial impact changes greatly. While the impact scale of innovation ability is close to the overall situation, the spatial impact is relatively stable. In addition, net population inflows, public financial expenditures and innovation capabilities all actively affect urban economic resilience; financial efficiency negatively affects urban economic resilience, and city scale has a positive and negative two-way impact on urban economic resilience. The intensity of influence is sorted as: net population inflow > innovation capacity > public financial expenditure > financial efficiency > urban size. In view of the impact factors have the characteristics of spatial heterogeneity, local governments at all levels should rationally promote population migration, scientifically adjust the scale of cities, improve the efficiency of financial resource allocation, optimize the structure of public financial expenditure, and stimulate the innovation vitality of cities.

Discussion

The difference between this paper and previous studies is that, on the basis of the existing research on the driving path of economic resilience, this paper creatively adds the influencing factor of population mobility. Considering the spatial scale neglected by previous studies, the MGWR model was used to explore the differences of the effects of various influencing factors on economic resilience in different regions in China. In addition, for the selection of population flow data, scholars usually use census data, which has accurate registration of permanent migrant population and can fully reflect the characteristics of population migration. However, the shortcoming is that the time span is long and once every ten years. Therefore, the independent variable of this paper avoids census data and selects Baidu migration big data. This data is an approximate estimate of population migration in long-term urbanization, which can make up for the limitation of the long time span of census data to a certain extent, and more vividly depict the population flow situation and daily large-scale flow in a continuous period.

The research in this paper also has limitations. Taking the city as the basic spatial unit of the study, the characteristics of population flow within the city cannot be reflected. However, it is also a phenomenon that cannot be ignored in population migration, which is of great significance for promoting the urbanization process with county towns as the main carrier, promoting the economic development of county towns and improving the resilience of urban economy. However, the data of population flow between different regions within the city is not available at present, and it is necessary to rely on the census of each city to conduct a more detailed investigation on this part of the characteristics and trends. In addition, big data is anonymous and cannot distinguish individual characteristics, but the characteristics of crowd flow with different social attributes need to be paid attention to. What is the relationship between population mobility with different characteristics and the spatial distribution of urban economic resilience? And how will migration trends such as "migrant workers returning" and "high-end people flying south" affect the resilience of cities? These questions are still worthy of further study.

All in all, due to the limitations of data, there is a lack of further discussion of population flow. Next, the direction of inter-regional mobility of population will be taken into consideration, and the spatial distribution characteristics and trends of population mobility in the context of the epidemic will be explored. What impact will this have on the spatial characteristics of urban economic resilience? And what is the internal mechanism of population mobility on urban economic resilience? This will be of great practical significance to the formulation of strategies to promote high-quality urban development.

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