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Spatial Distribution and Influencing Factors of Urban Shrinkage from the Perspective of Factor Flow - A Case Study of National Urban Agglomerations

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Abstract: This paper examines national urban agglomerations by taking factor flows as the focal point as the research subject. By dividing the stages of urban agglomeration development, a comprehensive framework of urban shrinkage is constructed, encompassing economic, population, and social shrinkage. The study explores the spatial distribution characteristics of urban shrinkage during different stages of urban agglomeration and investigates the influencing factors using a geographic detector model. The findings reveal that urban shrinkage within urban agglomerations is widely spread, predominantly in peripheral areas. During the diffusion stage, urban shrinkage is scattered, with population shrinkage concentrated in peripheral regions, economic shrinkage concentrated on old industrial cities, and social shrinkage concentrated on the northeast. The outcomes of the geographic detector model indicate that traffic flow, capital flow, information flow, node importance, network connectivity, government investment, openness, and environmental regulations all play significant roles in shaping the spatial distribution of urban shrinkage.

Keywords: Urban shrinkage; Factor flow; National urban agglomeration

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1. Introduction

As the “new normal” of urban development under the interweaving effects of globalization, suburbanization, deindustrialization, local financial crisis, and social transformation, the concept definition, characteristic mode, formation mechanism, and coping strategies of urban shrinkage have sparked heated discussions [1]. As far as the definition of urban shrinkage is concerned, it shows the expansion characteristics from the single factor measurement of population size to the multi-dimensional factor [2], and gradually focuses on the accompanying problems such as economic decline, reduced fiscal revenue, vacant facilities, and increasing unemployment rate indirectly caused by population loss [3]. With the extension of the connotation of urban shrinkage, there

are diversified urban shrinkage modes in different regions. On the urban scale, there are not only the circle mode characterized by the decline of tax revenue in the city center and the deterioration of living environment promoted by suburbanization [4], but also the anti-circle mode of core prosperity and peripheral recession caused by the promotion of deindustrialization and gentrification [5], and the perforation mode represents a pattern of growth and shrinkage characterized by the disintegration of "unit compounds" and the simultaneous rapid growth of state-supported market enterprises following the social and economic transformation in East Germany [6]. On the regional scale, there are not only the shrinkage of big cities caused by the industrial transformation dilemma of the old industrial city promoted by the trend of "deindustrialization" [7], but also the small and medium-sized cities with marginal status, which are limited by the imperfect infrastructure and urban network, and are difficult to effectively participate in the international division of labor [8]. Briefly, urban shrinkage is a natural paradox between the free flow of population, capital, and many other factors, and the fixed characteristics of urban construction physical space [9]. Although not explicitly stated, there are inherent links between urban shrinkage and the flow of factors. However, there is still no direct evidence to determine whether the ability of cities to attract and distribute factors in the regional system affects the occurrence of urban shrinkage. At the same time, considering that the urban agglomeration strategy aiming at the free flow of factors will inevitably reshape the pattern of regional growth and recession by influencing the flow of factors, this paper takes national urban agglomerations as the research object, builds a framework of urban shrinkage including economic shrinkage, population shrinkage, and social shrinkage on the basis of dividing the development stages of urban agglomerations, explores the spatial distribution characteristics of urban shrinkage in different development stages, and investigates the complex relationship and differences between urban agglomeration factor flow and urban shrinkage in different stages through the geographical detector model, with a view to providing guideline for expanding the analytical perspective of urban shrinkage and promoting urban shrinkage governance.

2. Calculation method and data source

2.1. Measurement of urban shrinkage

This paper argues that urban shrinkage occurs among urban populations under market economy conditions during the transition from regional urbanization to advanced organizational forms. The migration of population, capital, industry, and other factors to high-efficiency areas in pursuit of maximum benefits leads to the restructuring of the regional urban spatial structure. Cities with strong factor aggregation capabilities experience growth, while those with weak factor aggregation capabilities shrink, resulting in the geographic reality of development opportunities being "deprived of space" [10]. Therefore, the formation of urban shrinkage is rooted in localization and embedded in globalization. Globalization influences the strengthening of regional cooperation, competition, and collaboration, which promotes factor flow and risk transmission among cities [11]. The weak "factor aggregation ability" of cities with inferior regional competitiveness causes the displacement effect of development factors [12], thus highlighting the need to discuss the formation mechanisms of factor flow and urban shrinkage from a network perspective. To comprehensively measure urban shrinkage, this paper adopts a multi-dimensional approach and constructs an index system encompassing population, economy, and society. The index system follows the principles of scientificity, systematicness, and accessibility [13]. The urban shrinkage index is calculated using the entropy method. The results are presented in **Table 1**.

Table 1. Urban shrinkage evaluation indicator system

First-level index	Second-level index	Three-level index	Weight
Population shrinkage (0.5)	Population size	Resident population in municipal districts	0.10
	Population structure	Natural growth rate	0.04
	Population density	Population density of municipal districts	0.10
	Population vitality	College students' proportion	0.26
Economic shrinkage (0.25)	Economic growth	Gross domestic product (GDP) growth rate	0.01
	Economic structure	Value added of tertiary industry/value added of secondary industry	0.03
	Economic density	GDP/area ratio of municipal districts	0.15
	Economic level	GDP per person	0.06
Social shrinkage (0.25)	Educational facilities	Middle school teacher-student ratio	0.02
	Medical facilities	Hospital beds per thousand people	0.12
	Living environment	Green coverage rate of municipal districts	0.01
	Social consumption	Total consumption of social retail goods	0.11

2.2. Analysis of urban shrinkage mechanism

2.2.1. Variable selection

The formation of urban shrinkage reflects the multi-dimensional effect of different factors, thus this paper chooses the geographical detector model to reveal the driving mechanism of factors [14]. The core driving force of urbanization lies in the improvement of urban factor aggregation ability [15], and shrinking cities are essentially the product of the outflow of urban population, industry, capital, and other factors, and the economic downturn, which affects the ability to aggregate urban factors, forming an organic unity of processes-phenomena-problems [16]. Therefore, this paper attempts to explain the formation mechanism of urban shrinkage from the perspectives of factor flow, urban network, and economic transition, as shown in **Table 2**.

Table 2. Indicator system for analysis of urban shrinkage formation mechanisms

First-level index	Second-level index	Three-level index	Code
Factor flow	Traffic stream	Number of trains between different cities in urban agglomeration	TF
	Material flow	The relative importance of 15 logistics companies in different cities of urban agglomeration	MF
	Capital flow	The relative importance of four big banks among different cities in urban agglomeration	FF
	Information flow	Measurement of Baidu users' attention intensity between different cities in urban agglomeration	IF
City network	Node importance	City grade	IN
	Node accessibility	Number of high-speed rail stations	AN
	Network connectivity	Time distance from the nearest core city	NC
Economic transition	Industrial employment	Number of manufacturing employees	IE
	Industrial structure	Change rate of secondary industry's proportion in GDP	IS
	Openness	The actual amount of foreign capital used	LO
	Environmental rules	Utilization ratio of industrial solid waste	ER
	Government investment	The total investment in fixed assets	GI

2.2.2. Data sources

Taking 10 national urban agglomerations approved by the State Council, the Central Committee of the Communist Party of China in 2020 as the empirical analysis object, the basic geographical unit is defined as cities above prefecture level. The data comes from the Statistical Yearbook of China City (2011–2021), statistical yearbooks of relevant provinces, and statistical bulletins of relevant cities. The basic data of geographic information comes from the database of National Geographic Information Center. The data of traffic flow comes from the trains between cities in the 12306 website (https://www.12306.cn/). Material flow data comes from the statistics of logistics outlets of 15 logistics companies in cities of Express Network (http://www.kuaidi.com/). The data of capital flow comes from the statistics of bank outlets in the official websites of major banks, including tier-one branches, tier-two branches, and sub-branches. The information flow data comes from Baidu users' attention among cities in Baidu Index website (https://index.baidu.com/) [17]. The time distance from the nearest core city is measured by Baidu map.

3. Urban agglomeration development stage and spatial characteristics of urban shrinkage

3.1. Urban agglomeration development stage

In this study, the Jaffe index |q| of rank scale rule is used to judge the development stage of urban agglomeration, so as to further explore the relationship between urban agglomeration stage and urban shrinkage. Using SPSS software, the rank-scale log regression model of national urban agglomerations is constructed. The results show that the fitting degree R^2 of the model is above 0.65, and it passes the significance test of 0.01 confidence interval. According to the analysis results in **Table 3**, national urban agglomerations are divided into two categories: agglomeration and diffusion. In the stage of agglomeration, the |q| value of urban agglomerations presents a gradually increasing change feature, including eight urban agglomerations of Hubao Eyu, Zhongyuan, Hachang, the middle reaches of the Yangtze River, Beibu Gulf, Lanxi, Guanzhong Plain, and Chengdu-Chongqing. In the stage of diffusion, the |q| value of urban agglomerations presents a gradually decreasing change feature, including the Yangtze River Delta and Guangdong, Hong Kong, and Macao.

Table 3. |q| values for the rank order size of national-level urban agglomerations

Stage	City cluster	2000	2005	2010	2015	2020
Tendency to concentration	Hohhot Baotou Erdos Yulin	0.42	0.51	0.59	0.62	0.69
	Central Plains	0.45	0.55	0.62	0.69	0.72
	Hachang	0.69	0.72	0.78	0.81	0.85
	Lanxi	1.04	1.15	1.22	1.29	1.34
	North	0.82	0.88	0.94	0.98	1.02
Trend dispersion	Middle reaches of Yangtze River	0.61	0.75	0.80	0.84	0.88
	Central Shaanxi	1.21	1.31	1.26	1.34	1.42
	Chengyu	1.11	1.23	1.28	1.31	1.39
	Yangtze River Delta	1.33	1.28	1.24	1.17	1.13
	Guangdong, Hong Kong, and Macao	1.03	1.01	0.98	0.90	0.89

3.2. Spatial distribution characteristics of urban shrinkage

On the basis of calculating the weight of each index, this paper calculates the urban shrinkage of each prefecture-level city in the national urban agglomeration and the three dimensions that constitute the urban shrinkage, namely, population shrinkage, economic shrinkage, and social shrinkage, and uses the natural fracture method to classify and visualize the grades. Based on the spatial distribution of urban shrinkage, the urban shrinkage of urban agglomerations in the trend of agglomeration is relatively scattered, and most of them are located in the peripheral areas of urban agglomerations. Among them, the urban shrinkage of Hachang urban agglomeration and Lanxi urban agglomeration is widely distributed, while the urban shrinkage of urban agglomerations in the middle reaches of the Yangtze River and the Central Plains is mainly distributed in the peripheral areas of urban agglomerations. This shows that Northeast China, as an old industrial base of the country, is under the influence of many constraints such as industrial transformation, resource depletion, and institutional environment. The trend of population outflow and industrial recession in Northeast China is obvious, and the risk of urban shrinkage continues to rise, while the living environment in the western region is harsh. Except for the regional central city, which can attract the inflow of population and industrial factors through economic agglomeration effect, the surrounding cities are facing the dilemma of factor loss, and there is a trend of urban shrinkage. Although the central region is also facing the situation of population outflow, but it benefits from the industrial transfer and the subsequent "population return" movement, the high-density and large-scale rural population provides enough resilience for urban population agglomeration, so urban shrinkage is only scattered around urban agglomerations. The shrinkage of urban agglomerations in the trend diffusion stage is characterized by scattered distribution, which shows that with the formation and stability of urban agglomeration network structure, surrounding cities gradually integrate into the urban system and achieve self-growth, thus reducing the possibility of urban shrinkage.

Based on the spatial distribution of population shrinkage, the population shrinkage of urban agglomerations in the trend of agglomeration is concentrated in the peripheral areas of urban agglomerations, among which the population shrinkage of Hachang urban agglomerations and Lanxi urban agglomerations spreads in the non-core areas of urban agglomerations, while the urban shrinkage of urban agglomerations in the middle reaches of the Yangtze River and the Central Plains is mainly distributed in the peripheral areas of urban agglomerations, and the population shrinkage of urban agglomerations in the trend of diffusion is scattered in the marginal areas of urban agglomerations. This shows that population mobility is an intuitive reflection of "voting with their feet" under the comprehensive effect of employment opportunities, public services, living environment, and many other conditions in different cities. With the function of agglomeration-diffusion mechanism of urban agglomerations, the population presents a process of mobility from rural areas to cities and from small cities to big cities, and indirectly affects the population structure and population vitality of the places where the population flows out, forming a peripheral pattern of population shrinkage in urban agglomerations.

Based on the spatial distribution of economic shrinkage, economic shrinkage is concentrated in the old industrial cities. With the transformation of energy structure and the exhaustion of resources, the old industrial cities are facing the dilemma of having to be transformed, but limited by labor structure, urban environment, management structure, and path dependence, the transformation process of the old industrial cities may face the risk of economic recession. Based on the spatial distribution of social shrinkage, social shrinkage is concentrated in Northeast China, which shows that the long-term stagnation of economic development in Northeast China leads to the decrease of local fiscal revenue and the phenomenon of social shrinkage.

4. Analysis of influencing factors of urban shrinkage from the perspective of factor flow

This paper takes prefecture-level cities in national urban agglomeration as the basic spatial analysis unit, and takes whether there is urban shrinkage as the explained variable to analyze driving factors in the process of urban shrinkage formation, as shown in **Table 4**.

From the perspective of factor flow, traffic flow, capital flow, and information flow, all of them have a significant impact on the spatial distribution of urban shrinkage, which shows that factor flow plays an important role in the formation of urban shrinkage. The flow of factors helps to change the distribution of factors in cities, enhance the complementarity of factors among cities, promote the free flow and cooperation of factors such as labor and capital among cities, achieve the coordinated development among different cities, and reduce the possibility of urban shrinkage. However, the influence of material flow on the spatial distribution of urban shrinkage is not significant, which may be because on the one hand, the flow of goods is the result of many factors such as population size, urban location, and traffic conditions, and the node position and logistics position of urban system structure are more closely related to material flow. On the other hand, due to limitation by the availability of data, this paper uses the relative importance of logistics companies to reflect the intensity of material flow, which makes it easier to amplify the influence of the node position of urban architecture on material flow. From the perspective of urban network, the importance of nodes and network connectivity has a significant impact on the spatial distribution of urban shrinkage, indicating that the higher city level can attract the surrounding population, resources, and other factors to the city through agglomeration effect and siphon effect, and promote the urban population scale and rapid economic growth. From the perspective of economic transformation, government investment, openness, and environmental regulation, all of them have significant effects on the spatial distribution of urban shrinkage. This shows that with the improvement of urban fixed assets investment and the use of foreign capital, it will promote industrial development, attract the surrounding population to concentrate in cities, raise the level of local fiscal revenue, and build a virtuous circle of urban growth. Environmental regulation plays an important role in the formation of urban shrinkage, which may be because the improvement of environmental regulation level means the upgrading of urban industries, further improving the production efficiency of cities and attracting the influx of talents, funds, and other factors.

5. Conclusion

This paper took national urban agglomerations as the research object, and on the basis of dividing the development stages of urban agglomerations, it constructed a framework of urban shrinkage including economic shrinkage, population shrinkage, and social shrinkage, explored the spatial distribution characteristics of urban shrinkage in different development stages of urban agglomerations, and investigated the influencing factors of urban shrinkage in different stages of urban agglomerations through the geographic detector model, and the following conclusions were drawn:

(1) The shrinkage of urban agglomeration is widely distributed, and most of them are in the peripheral areas of urban agglomeration. The shrinkage of urban agglomeration in the stage of diffusion presents the characteristics of scattered distribution. The population shrinkage of urban agglomerations in the trend of agglomeration is concentrated in the peripheral areas of urban agglomerations, while the population shrinkage of urban agglomerations in the trend of diffusion is scattered in the marginal areas of urban agglomerations. Economic shrinkage is concentrated in the old industrial cities. Social shrinkage is concentrated in Northeast China.

Table 4. Factors influencing urban shrinkage at different stages of development

Index	City cluster				Trend agglomeration				Trend dispersion			
	Comprehensive shrinkage	Population shrinkage	Economic shrinkage	Social shrinkage	Comprehensive shrinkage	Population shrinkage	Economic shrinkage	Social shrinkage	Comprehensive shrinkage	Population shrinkage	Economic shrinkage	Social shrinkage
IN	0.16***	0.16***	0.01	0.03*	0.11***	0.15***	0.01	0.02	0.11	0.01	0.03	0.01
AN	0.03	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.03	0.36**	0.18
NC	0.05*	0.09**	0.02	0.01	0.08**	0.12***	0.03	0.01	0.03	0.05	0.10	0.05
IE	0.01	0.01	0.05	0.01	0.01	0.01	0.06*	0.01	0.09	0.16	0.04	0.06
IS	0.03	0.04*	0.08*	0.01	0.02	0.03	0.06*	0.01	0.01	0.01	0.15	0.07
ER	0.06**	0.12***	0.02**	0.02	0.04	0.10**	0.04	0.01	0.04	0.02	0.21	0.10
GI	0.17***	0.18***	0.02	0.04*	0.12***	0.13***	0.02	0.04	0.25	0.19	0.17	0.31*
LO	0.11***	0.13***	0.04	0.03	0.09**	0.09**	0.04	0.02	0.02	0.03	0.06	0.18
TF	0.12**	0.12**	0.11	0.04	0.10**	0.17**	0.02	0.01	0.11	0.11	0.03	0.01
MF	0.06	0.05	0.05	0.03	0.03	0.02	0.04	0.02	0.04	0.01	0.02	0.01
FF	0.09***	0.08**	0.08***	0.02	0.15**	0.01	0.07**	0.01	0.14	0.01	0.02	0.01
IF	0.11**	0.09**	0.06**	0.03	0.11**	0.03*	0.02	0.03	0.17	0.02	0.01	0.01

(2) From the results of the geographical detector model, from the perspective of factor flow, traffic flow, capital flow, and information flow, all of them have significant effects on the spatial distribution of urban shrinkage. From the perspective of urban network, the importance of nodes and network connectivity has a significant impact on the spatial distribution of urban shrinkage. From the perspective of economic transformation, government investment, openness, and environmental regulation, all of them have significant effects on the spatial distribution of urban shrinkage.

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