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A Study on the Long-term Spatio-Temporal Changes of Shrinking Cities in China

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Abstract Urban shrinkage has become a global phenomenon, appearing not only in developed countries but also in China, which is undergoing rapid urbanization. Although numerous studies have investigated the distribution of shrinking cities, most of them analyzed from the population dimension. It is necessary to consider the economic dimension and long-term studies. This study takes all prefecture-level cities in mainland China as the research subject. It addresses three questions: 1) How did the spatio-temporal distribution of shrinking cities change between 2000 and 2020, from the perspectives of demography and economy? 2) What are the types of shrinking cities and their distribution, according to the shrinking dimensions and shrinking period? 3) How does the distribution of shrinking cities vary across different urban contexts, such as city size and urban resources? The results show that more than half of Chinese cities are experiencing permanent resident loss. And population shrinkage is observed before the economic decline. Among shrinking cities, the largest proportion shows shrinkage in the single dimension of the population. Additionally, the number of cities with both shrinkage in population and economy increased significantly after 2015, accounting for 19.7% of all shrinking cities. Moreover, 44.7% of shrinking cities are suffering continuous shrinkage. Furthermore, the proportion of shrinking cities is higher in small and medium-sized cities and resource-based cities. This study describes the evolution of shrinking cities in China and enriches the discussion on urban shrinkage worldwide. The findings can remind urban policymakers and planners of more attention on shrinking cities and planning strategies to cope with urban shrinkage.

Keywords. *Shrinking Cities, China, Identification, Spatio-Temporal Changes*

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1 Introduction

In recent decades, many cities are experiencing population loss, accompanied by the declining economy. Urban shrinkage is becoming a global phenomenon (Richardson & Nam, 2014). Although population loss is affected by natural disasters, epidemics, wars, and climate change, the current phenomenon of shrinking cities is more the result of various transformation processes, including deindustrialization, suburbanization, post-socialist change, and demographic aging (Oswalt, 2005). The phenomenon emerged in the United States and a few European countries in the 1960s and 1970s. In the 1990s, as a result of German reunification, East Germany saw a large number of cities with demographic and economic downturns. In Japan, shrinkage has become a prominent reality, as the low birth rate and aging have been challenges for many decades (Hattori, Kaido, & Matsuyuki, 2017).

Urban shrinkage has attracted increasing attention from scholars and urban planners. Many terms are used in the discourse on shrinking cities, such as “decline,” “decay,” “blight”, “legacy city,” and “postindustrial city”. The term “shrinking cities” was proposed by German scholars in early 2000s, and is internationalized and widely used by scholars in the world nowadays. Compared to other terms describing population loss, “shrinkage” is more neutral (Haase, Nelle, & Mallach, 2017). Since 2002, Oswalt (2005) and the “Shrinking Cities” group [(1)] investigated the worldwide phenomenon of urban shrinkage focusing on typical shrinking cities in Germany, Britain, Russia, the United States, and Japan. The Shrinking Cities International Research Network (SCIRN) [(2)], founded in 2004, explored the causes, manifestations, spatial variations, and planning interventions of urban shrinkage. After 2010, shrinking cities have gained wider attention. Numerous studies have investigated the distribution of shrinking cities, the influence factors, as well as the planning strategies and policies in different countries (Hollander, 2011; Wiechmann and Pallagst, 2012; Haase et al, 2014; Martinez-Fernandez et al, 2016; Haase et al, 2016; Hattori, Kaido, & Matsuyuki, 2017; Hartt, 2018).

Although there have been many discussions about shrinking cities, there is no consensus on the definition of a shrinking city. Many scholars consider population loss as a necessary characteristic for urban shrinkage (Döringer, 2020), and use the single indicator of the population to identify shrinking cities; while some researchers analyzed shrinking cities from both demographic and economic perspectives (Wiechmann & Pallagst, 2012). However, the relationship between population loss and economic decline in shrinking cities is complex and the chain of causality remains unclear. Many researchers argue that population shrinkage is strongly associated with economic shrinkage, and the linkage between population and economy is a downward spiral and negative cumulative causation (Hospers, 2014; Weaver et al, 2016). Nevertheless, some studies pointed out that not all cities with population loss are experiencing economic decline. Hartt (2018) found that 12 out of 20 largest shrinking American cities are experiencing population loss but economic growth. Therefore, a more differentiated understanding of urban shrinkage requires focusing not only on the demographic dimension but also on the economic dimension.

Additionally, urban shrinkage is both spatially and temporally uneven (Haase, 2016). The process of shrinkage is temporal, with some cities will disappear, while others will remain stable at a smaller population size after an extreme shrinkage, and may also grow again (Oswalt, 2005). Therefore, understanding the development of shrinking cities needs long-term observation. Moreover, various urban contexts (demographic, sociocultural, and economic conditions) shape the pathways of shrinking cities (Haase, Nelle, & Mallach, 2017). It is necessary to explore in what urban contexts shrinkage is more likely

to occur.

In China, some researchers are becoming aware that many cities are witnessing a continuous population decline, while most of cities are under rapid urbanization and urban growth. Research on Chinese shrinking cities emerged in 2014 and the Shrinking City Research Network of China (SCRNC) was established to explore this phenomenon in various regions in China (Long and Wu, 2016; Gao and Long, 2019; Jiang et al, 2020). However, urban shrinkage in China is still academically undervalued and unacceptable by most policy makers. Growth-oriented planning is still deeply embedded in policy makers. There is a mismatch between the urban population and the scale of land, buildings and infrastructures, which will cause a huge waste of land, financial and other recourses. Therefore, it is necessary to accurately identify shrinking cities in China and comprehensively grasp their distribution and development trajectory to provide reference for policy makers and urban planners.

This study takes all 297 prefecture-level cities (including four municipalities directly administered by the Central Government) in mainland China as the research subject, analyzing spatio-temporal changes in shrinking cities over 20 years (2000–2020) from demographic and economic perspectives. This study addresses the following three questions:

1. How did the spatial and temporal distribution of shrinking cities change between 2000 and 2020? The analysis of long-term changes in demographic and economics provides an overall picture of the trajectory of shrinking cities.

2. What are the types of shrinking cities according to the shrinking dimensions and shrinking period? What is the spatial distribution of each type of shrinking city? Classifying shrinking cities can help to take appropriate countermeasures for different types. For example, for cities with double shrinkage in demography and economy or continuously shrinking cities, there is an urgent need to adjust their planning paradigm.

3. How does the distribution of shrinking cities vary across different urban contexts, such as city size and urban resources? In many countries (e.g., the United States and Japan), urban development presents a concentration of population in large cities, i.e., larger cities experiencing faster population growth. This study hopes to explore whether the situation is similar in China, i.e., whether smaller cities are more likely to lose population. In addition, resources such as minerals affect the industrial development of cities, so it is also one of the important urban contexts that affect urban shrinkage. This further study of the differences in the distribution of shrinking cities across various urban contexts can help us predict cities that are prone to shrinkage.

2 Literature Review

When discussing shrinking cities, although scholars use the same term “shrinkage”, it may mean different things. Demography is the most fundamental dimension considered in shrinking cities. Many studies have used population decline as an indicator to identify shrinking cities in Europe and the United States (Oswalt & Rieniets, 2006; Hill et al, 2012; Ryan, 2012; Morrill, 2014; Wolff et al, 2018). It is an easily accessible and simple indicator for analysis (Wolff and Wiechmann, 2018), and it can well satisfy the demand for comparison in space and time (Beauregard 2009). Furthermore, studies differ in the thresholds of the degree and duration of population decline. Oswalt & Rieniets (2006) considered short-term or ongoing population losses of more than 10% as shrinking cities. While Schilling & Logan (2008) argued city with a 25 percent

or greater loss in total population over four decades as shrinking cities.

In addition to the demographic dimension, many scholars have also taken the economy into consideration. It is generally accepted that population and economy are closely linked, although the precise causality between population loss and economic decline is still under discussion. According to the Shrinking Cities International Research Network (SCIRN), shrinking cities refer to cities meeting the following criteria: a densely populated urban area with a minimum population of 10,000 residents that has faced considerable population losses for more than two years and is undergoing economic transformations with some symptoms of a structural crisis (Wiechmann, 2007). Reckien et al. (2011) use population loss, employment decline, and protracted economic downturn until very recently as indicators in their study on Germany and England. Wiechmann & Pallagst (2012) consider the change in one economic sector and population loss as indicators of shrinking cities. The often-used indicators include the GDP and the per capita income.

In Chinese studies, there is also no uniform definition of shrinking cities. Table 1 summarizes the geographical scope, time span, indicators, spatial analysis unit, and results of the studies on Chinese shrinking cities. It shows that population is the most used indicator, which is in line with international studies. The thresholds include negative population growth rates (Hu et al, 2021; Deng et al, 2019; Zhang et al, 2019; Li and Mykhnenko, 2018; Yang and Dunford, 2018; Long and Wu, 2016), population growth rates below the national average (Guo et al, 2021) or below a specific value (Guan et al, 2021).

Additionally, some studies also considered economic dimension. The GDP (Jin and Sui, 2021; Liu et al, 2020), per capita GDP (Wang et al, 2021), per capita fiscal revenue (Wang et al, 2021), employment (Liu et al, 2020), and investment (Liu et al, 2020) data are used in identifying shrinking cities.

Their results show that there are differences in the spatial distribution of population-shrinking cities and economy-shrinking cities. And the number of cities with population loss is more than twice the number of cities with the economic decline (Jin & Sui, 2021). However, studies analyzing from both demographic and economic perspectives only investigated the changes over 5 or 10 years, and focus on specific regions, do not cover the whole of mainland China. Therefore, there is still a lack of studies on long-term and larger geographical scales.

Table 1. Indicators Used in the Literature on Shrinking Cities in China

Literature	**Geographical Scope and Time Period**	**Indicators**		**Spatial Analysis Unit**	**Results**
Guo et al. (2021)	Chinese mainland; 2003-2018	single indicator (population)	the population change rate in municipal districts is lower than the national average	prefecture-level cities	35 out of 279 (2003-2008); 59 out of 279 (2008-2013); 67 out of 279 (2013-2018)
Hu et al. (2021)	Chinese mainland; 2006-2016	single indicator (population)	negative annual average growth rate of the urban population or the density of population	prefecture-level cities	37 population-shrinking cities and 144 density-shrinking cities
Guan et al. (2021)	Chinese mainland; 2000-2015	single indicator (population)	population change rate below 1%	urban area in 2,434 county administrative units	267 out of 2,434 (2000- 2005); 216 out of 2,434 (2005-2010); 502 out of 2,434

					(2010-2015); 315 out of 2,434 (2000-2015)
Zhou et al. (2021)	Chinese mainland; 2012-2019	single indicator (NTL)	average slope of NTL changes≤ 0	built-up areas in county-level cities	422 out of 2,079 cities
Yang et al. (2021)	Chinese mainland; 1992-2019	single indicator (NLT)	cities that have lost a substantial amount of light brightness	prefecture-level cities and county-level cities	153 out of 654 cities
Deng et al. (2019)	Chinese mainland; 2006–2015	single indicator (population)	urban population decline	municipal districts of prefecture-level and above cities	43 out of 286
Zhang et al. (2019)	Chinese mainland; 1990-2010	single indicator (population)	population decline	prefecture-level and above cities	28 out of 342, (1990-2000); 86 out of 342, (2000-2010)
Li, H., & Mykhnenko, V. (2018)	Chinese mainland; 1990-2010	single indicator (population)	long-stay population decline	urban areas, county-level cities and counties	164 out of 2,426 (1990-2000); 281 out of 2,760 (2000-2010)
Yang, Z., & Dunford, M. (2018)	Chinese mainland; 2000-2010	single indicator (population)	urban and household registered (hukou) population loss	municipalities	88 out of 336 municipalities
Long, Y., & Wu, K. (2016)	Chinese mainland; 2000-2010	single indicator (population)	permanent resident population decline	townships, prefecture-level cities and county-level cities	19,882 among all the 39,007 townships; 180 shrinking cities
Jin, S. T., & Sui, D. Z. (2021)	Chinese mainland; 2011-2015	multi-dimension indicators (demographic; economic)	household registered population decline (more than 1%); lower than the national GDP growth rate	283 prefecture-level cities and four municipalities	76 cities with a declined population; 36 cities with decline in both population and economy
Liu et al. (2020)	Chinese mainland; 2000-2010	multi-dimension indicators (demographic; economic; social)	shrinkage in at least two dimensions 1) Demographic: total population decline or a negative net migration; 2) Economic: GDP, employment, investment; 3) Social: the expenditure on public service, the annual per capita consumption expenditure of urban households, unemployment rate	269 prefecture-level cities	shrinking cities account for 12.3% of the total sample
Wang et al. (2021)	Resource-based cities in	multi-dimension	the comprehensive development index < 0	116 prefecture-	7 out of 165 (2010-2014); 53

	China; 2010-2018	indicators (demographic; economic; spatial)	1) Demographic: permanent resident population and urban population density; 2) Economic: Per capita GDP and Per capita fiscal revenue; 3)Spatial: average NTL index in urban built-up area	level and 59 county-level cities	out of 165 (2014-2018)
Dong et al. (2021)	Northeastern China (Heilongjiang, Jilin and Liaoning provinces); 1996-2020	multi-dimension indicators (nighttime light; population)	either NTL decline or household registered population decline	county, county-level city, and merged districts	102 out of 185 (1996-2009); 162 out of 185 (2010-2020)
Tong et al. (2020)	Jilin Province; 2003 -2017	multi-dimension indicators (demographic; economic; land use; employment)	urban shrinkage index (Si), Si 2017<Si2003	township	130 out of 414 towns

*Note** NTL: nighttime light

Furthermore, several studies suggest that the distribution of shrinking cities is related to the urban context. Wolff & Wiechmann (2018) analyze shrinking cities in Europe and show a strong and positive relationship between city size and urban shrinkage, with the highest proportion of shrinkage in cities with population between 200,000 and 500,000. Zhou et al. (2021) argue that small cities are more likely to experience urban shrinkage because they usually have a single industrial structure and difficult to achieve economies of scale; moreover, large cities have a siphon effect on small cities. Additionally, incidence of shrinkage in resource-based cities is increasing (Wang et al, 2021). The depletion of minerals and forest resources restricts the development of the secondary industry. The change in the output value of the secondary industry (Wang et al, 2021), a low-level industrial structure, and a single industry are important factors of urban shrinkage (Zhou et al, 2021).

3 Methods and Data

This study uses 2000 as the launch year, considering that China has undergone tremendous changes since the turn of the century, especially since its accession to the World Trade Organization (WTO) in 2001. As statistics for the population and economy of Chinese cities in 2021 are not yet available, we choose 2000–2020 as the study period. Given that cities develop dynamically, we split the study period into four five-year periods to analyze the changes over shorter periods.

The choice of geographical unit is an issue because scholars define cities differently. In China, there are prefecture-level cities, county-level cities, and townships in the administrative dimension, as well as de facto cities and densely inhabited districts in the urban function dimension. Considering the availability of demographic and economic data for all cities in five years (2000, 2005, 2010, 2015, 2020), we finally chose

prefecture-level cities as the research object. We analyzed all 297 prefecture-level cities (including four municipalities directly administered by the Central Government) in mainland China.

Based on the analysis of existing studies, this study examines urban shrinkage from two perspectives: demography and economy.

1) In terms of demography, two indicators are considered: the total population of permanent residents and the population density of permanent residents. We choose the permanent resident population ("de facto" population) instead of the household registered population ("Hu Kou" population) because the former includes the migrant population. The population density of permanent residents is added, taking into account the influence of changing urban boundaries on urban area size. The average annual growth rate of total permanent residents and the average annual growth rate of population density of permanent residents are calculated for each period.

$$R=[(P_t-P_{t-5})/P_{t-5}]/5 \quad (1)$$

If the growth rate is negative, this city is considered a population-shrinking city. In addition, the degree of population shrinkage is classified into three levels according to the average annual growth rate (R): slight shrinkage ($-1.0 < R < 0$), moderate shrinkage ($-3.0 < R \leq -1.0$), and severe shrinkage ($R \leq -3.0$).

2) In terms of economy, considering the impact of total population size on the economy, two indicators are considered: the gross regional domestic product (GRDP) and per capita GRDP. The average annual growth rate of the GRDP and the average annual growth rate of the per capita GRDP are calculated for each period.

$$R=[(E_t-E_{t-5})/E_{t-5}]/5 \quad (2)$$

If the growth rate is negative, this city is considered an economic-shrinking city. And the degree of economic shrinkage is classified into two levels according to the average annual growth rate (R): slight shrinkage ($-5.0 < R < 0$) and severe shrinkage ($R \leq -5.0$). Additionally, we also identify cities with low economic growth rates ($0 < R \leq 3$).

Data sources are the fifth, sixth, and seventh National Population Census of Mainland China, China City Statistical Yearbooks (in 2001, 2006, 2011, 2016, 2021), and Provincial Statistical Yearbooks (in 2000, 2005, 2010, 2015, 2020).

The analysis framework is shown in Figure 1. Based on the identification of shrinking cities, we visualize the spatial distribution of different dimensions in each stage and classify the shrinking cities and explore the distribution of various types. Finally, the differences in the distribution of shrinking cities in different city sizes, resource-based cities, and non-resource-based cities are analyzed.

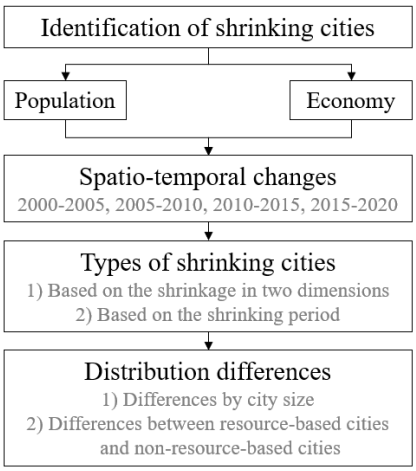

Fig. 1 Analysis Framework

4 Results

4.1 Spatio-temporal Distribution of Shrinking Cities

Demographic Changes

Within 20 years, as Figures 2 and 3 show, the number of cities with population decline has increased significantly. The spatial distribution of population-shrinking cities shows rapid expansion— from appearing only in the central provinces in China from 2000 to 2005 to covering almost all provinces from 2015 to 2020, and especially pronounced in northeast China, Inner Mongolia Zizhiqu, Shaanxi, and Sichuan Provinces.

In terms of the total population of permanent residents, the number of shrinking cities in the four periods: 2000–2005; 2005–2010; 2010–2015; and 2015–2020 are 57 (19.2%), 99 (33.3%), 91 (30.6%), and 159 (53.5%), respectively. In terms of the population density of permanent residents, the number of shrinking cities in the periods: 2000–2005; 2005–2010; 2010–2015; and 2015–2020 are 65 (21.9%), 105 (35.4%), 102 (34.3%), and 152 (51.2%), respectively.

During 2000–2005, most shrinking cities experienced a slight population decline (below 1% per year), with only 14 cities losing more than 1% of their population per year. The shrinking cities were mainly distributed in the central region, including Chongqing City and the Sichuan, Hubei, and Hunan Provinces.

From 2005 to 2010, the distribution of shrinking cities became wider, and the shrinkage became more severe. The number of cities losing population by more than 1% increased to 32, and there are cities with a population decrease rate of more than 3%, such as Guangyuan City in the Sichuan Province. Shrinking cities also emerged in the Guizhou Province in the southwest; the Gansu and Shaanxi Provinces in the northwest; the Henan and Anhui Provinces in the central region; and the Fujian and Zhejiang Provinces in the southeast.

During 2010–2015, there was a slight decrease in the number of shrinking cities, and the shrinkage in southern China was mitigated in general. However, the shrinkage accelerated in the Heilongjiang and Jilin Provinces in northeast China; and the Shanxi and Hebei Provinces in central China.

Since 2015, there have been numerous instances of shrinking cities, of which 49.7% (79 out of 159) are moderate (population decline between 1% and 3% per year) or severe shrinkages (population decline of over 3% per year). There was continued shrinkage in the Heilongjiang, Jilin, and Liaoning Provinces and Inner Mongolia Zizhiqu in northeast China; the Hebei and Shanxi Provinces in central China; and the Gansu and Shaanxi Provinces in northwest China. Furthermore, cities in the Hubei, Hunan, and Sichuan Provinces in central China and the Yunnan Province in southwest China showed shrinkage following a brief period of urban growth.

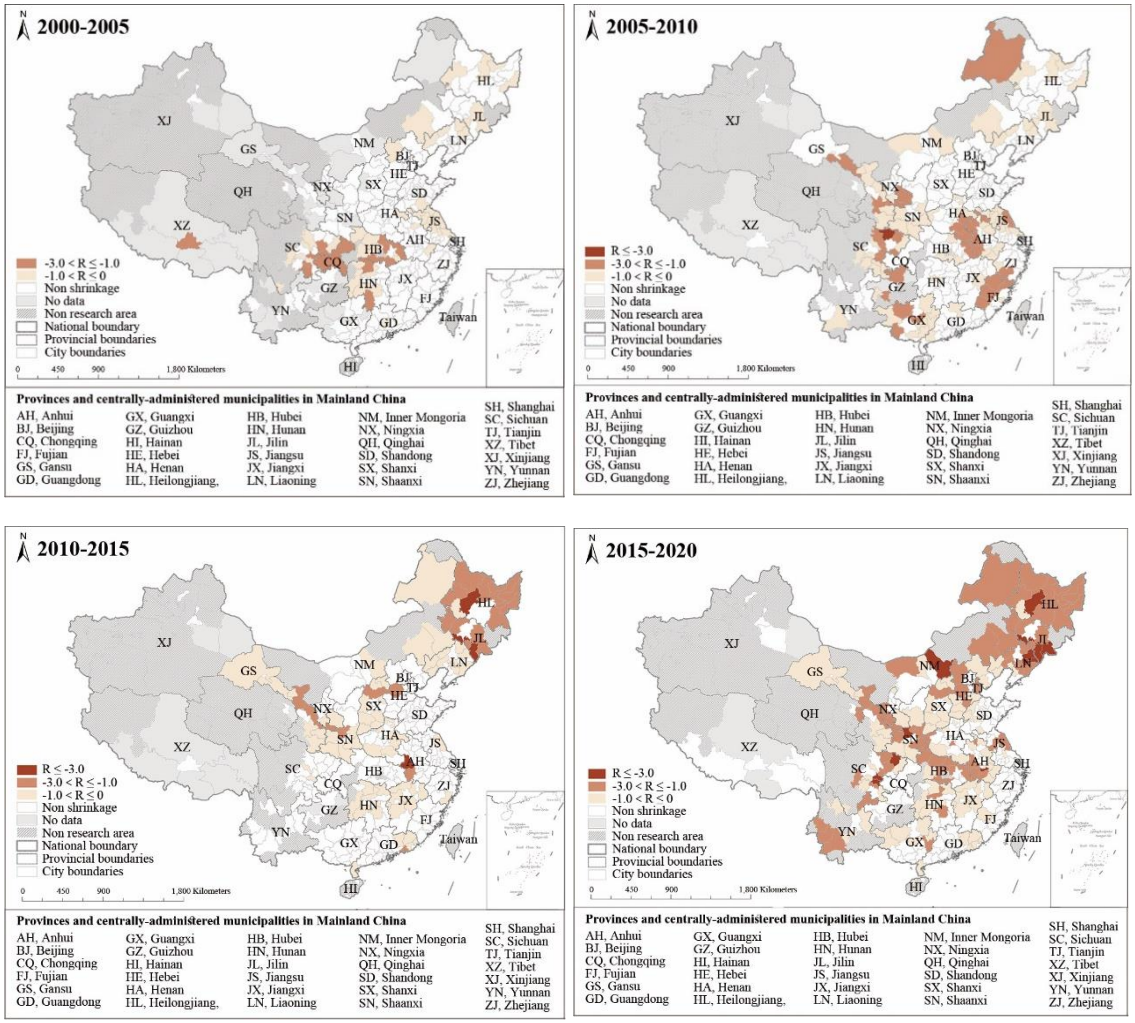

Fig.2 Distribution of Shrinking Cities (In terms of the change in the total population of permanent residents)

(R: Average Annual Growth Rate of Permanent Residents)

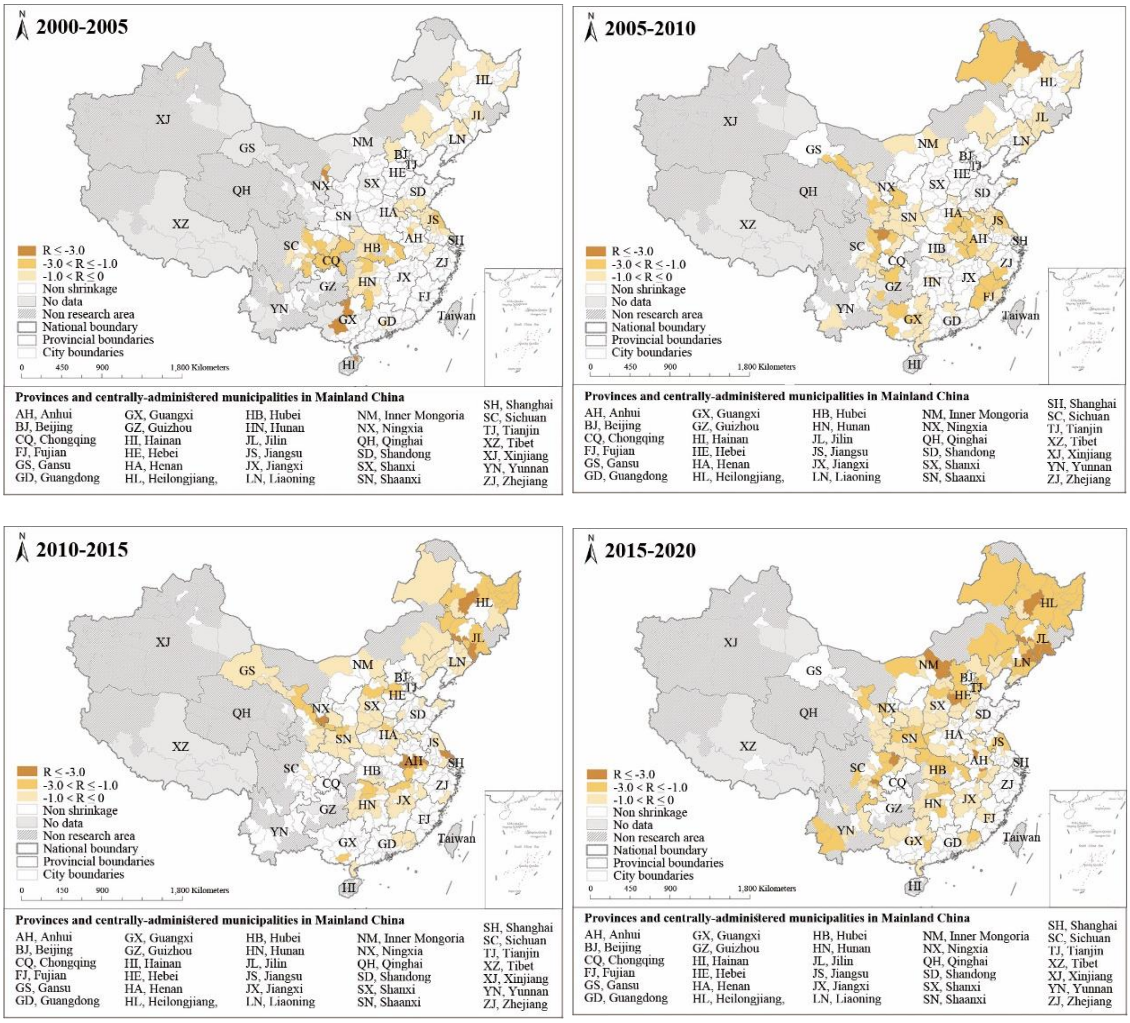

Fig.3 Distribution of Shrinking Cities (In terms of the change in the population density of permanent residents)

(R: Average Annual Growth Rate of Permanent Population Density)

Economic Changes

As Figures 4 and 5 show, compared to population-shrinking cities, the number of economic-shrinking cities in China is substantially lower, with only a few cities experiencing negative economic growth and several cities with low economic growth (annual growth rate of GRDP of below 3%) during 2005–2015. However, since 2015, the number of cities with negative and low economic growth rates has increased significantly, especially in northeast China.

In terms of the GRDP, the number of shrinking cities in the periods: 2000–2005; 2005–2010; 2010–2015; and 2015–2020 are 0 (0%), 1 (0.3%), 2 (0.7%), and 39 (13.1%), respectively. In terms of the per capita GRDP, the proportion of shrinking cities during the periods: 2000–2005; 2005–2010; 2010–2015; and 2015–2020 are 1 (0.3%), 0 (0%), 4 (1.3%), and 37 (12.5%), respectively.

From 2000 to 2005, only Wuzhong City in Ningxia Huizu Zizhiqu had negative per capita GRDP growth; while the city has shown economic growth since 2005. From 2005 to 2010, only Pingliang City in the Gansu Province had negative GRDP growth, and the city stopped negative growth after 2010. From 2010 to 2015, there were five cities with negative GRDP or per capita GRDP growth, located in the Gansu,

Anhui, and Heilongjiang Provinces and Xinjiang Uygur Zizhiqu. During 2015–2020, many economic-shrinking cities emerged in the Heilongjiang, Jilin, and Liaoning Provinces and Inner Mongolia Zizhiqu in northeast China and the Shandong Province in the east. Among the cities with economic shrinkage, severe-shrinkage cities (annual GRDP growth rate below -5%) account for 35.9% (14 out of 39).

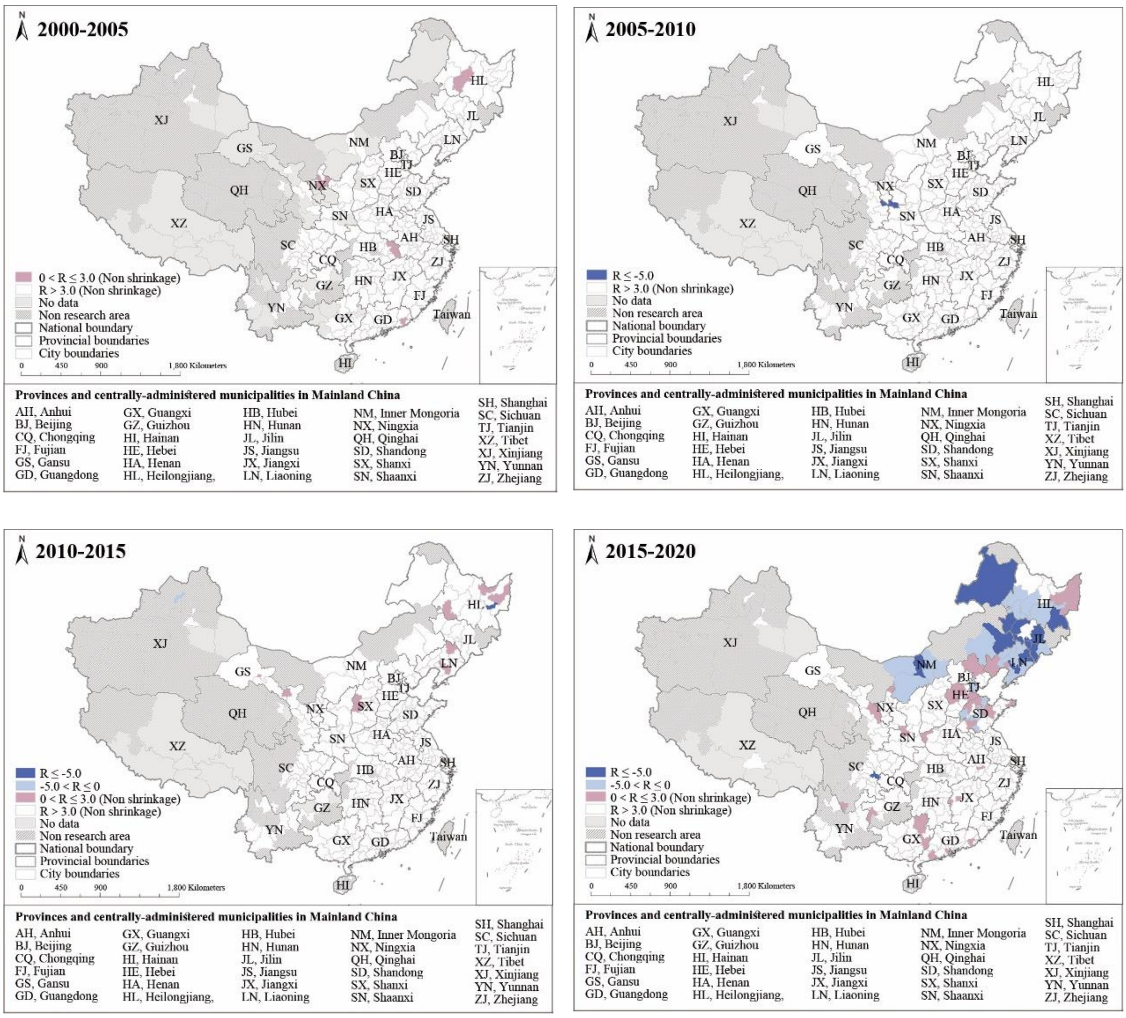

Fig.4 Distribution of Shrinking Cities (In terms of the GRDP)

(R: Average Annual Growth Rate of GRDP)

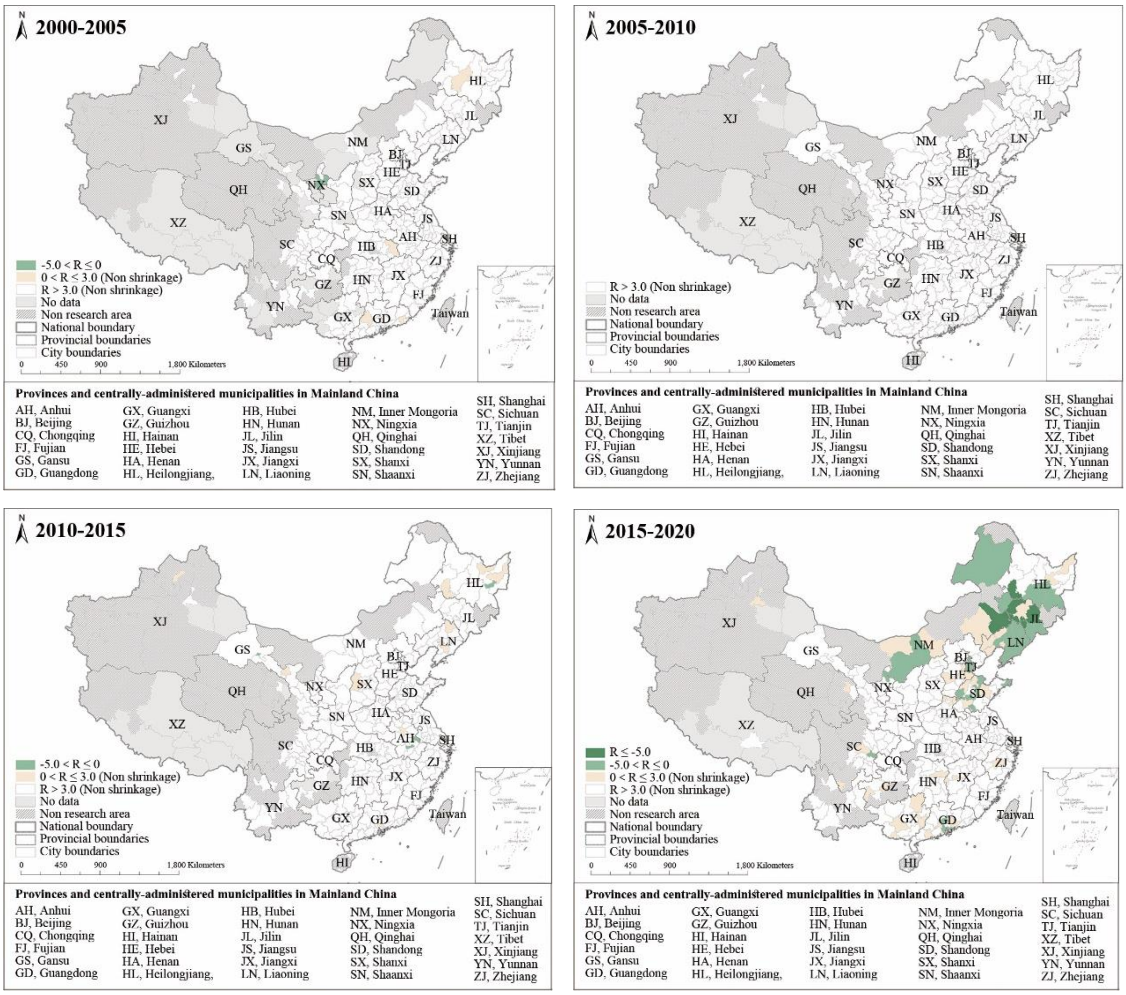

Fig.5 Distribution of Shrinking Cities (In terms of per capita GRDP)

(R: Average Annual Growth Rate of Per capita GRDP)

4.2 Types of Shrinking Cities

Based on the Dimensions of Population and Economy

Based on the shrinkage in dimensions of population and economy, shrinking cities can be classified into three categories (Table 2). The results reveal (Figure 6) that shrinking cities have gradually developed from a single population shrinkage in the early stage to a double-dimensional shrinkage, especially since 2015. Most of the shrinking cities during 2000–2015 were those with rapid economic growth but declining populations—except several cities that experienced economic decline or low economic growth. From 2015 to 2020, the type Ⅱ (P_1E_0) remains the largest proportion, accounting for 74.6% (129 out of 173) of all shrinking cities, and is distributed in most provinces. The second-largest category is type Ⅰ (P_1E_1), accounting for 19.7% (34 out of 173), mainly distributed in the Heilongjiang, Jilin, and Liaoning Provinces and Inner Mongolia Zizhiqu in northeast China. And cities of type Ⅲ (P_0E_1) account for the smallest proportion of 5.7% (10 out of 173).

Table 2. Classification of Shrinking Cities (Based on the shrinkage in two dimensions)

Categories	Population	Economy
I (P_1E_1)	shrinkage	shrinkage
II (P_1E_0)	shrinkage	non-shrinkage
III (P_0E_1)9	non-shrinkage	shrinkage

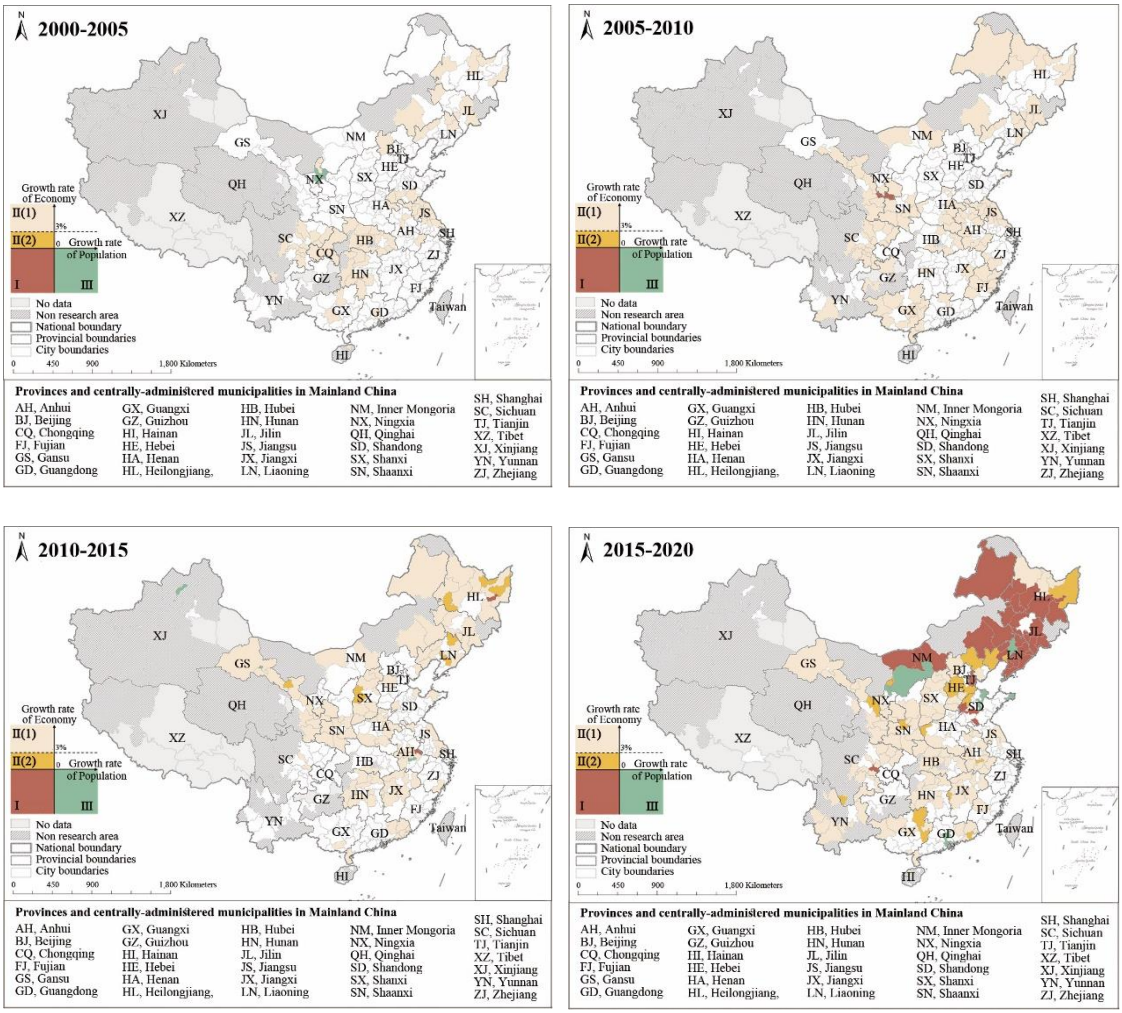

Fig.6 Types of Shrinking Cities (Based on two dimensions)

Based on Shrinking Periods

This study considers shrinkage in any of the demographic or economic dimensions as urban shrinkage and classifies shrinking cities into four categories based on when the shrinkage began and how long it lasted (Table 3).

As shown in Figure 7, the number of cities in the four categories: continuous shrinkage, recent shrinkage, periodic shrinkage, and discontinued shrinkage are 102 (44.7%), 37 (16.2%), 34 (14.9%), 55 (24.2%), respectively. The cities of continuous shrinkage account for the largest proportion, and they are

mainly distributed in the Heilongjiang, Jilin, and Liaoning Provinces and Inner Mongolia Zizhiqu in the northeast; the Shanxi and Shaanxi Provinces in the central region; the Gansu Province in the northwestern region; and the Hunan, Jiangxi, Anhui, Fujian, and Guangdong Provinces in the south. Cities of recent shrinkage are mainly distributed in northern China and the Yunnan Province in the south. Cities of periodic shrinkage are mainly in southern China.

As shown in Figure 8, the proportion of shrinking cities in each category shows significant differences across provinces. In the Heilongjiang, Jilin, Shanxi, and Gansu Provinces, more than 75% of the shrinking cities are continuous shrinking cities. In Inner Mongolia Zizhiqu and the Liaoning, Shaanxi, Hunan, and Jiangxi Provinces, cities with continuous shrinkage exceed 50%. However, in the Hebei, Qinghai, and Yunnan Provinces, the proportion of cities with recent shrinkage is higher. The provinces with a high proportion of periodic shrinkage cities include Ningxia Huizu Zizhiqu, Guangxi Zhuangzu Zizhiqu, and the Sichuan, Hubei, and Anhui Provinces. Additionally, in the eastern coastal provinces of Guangdong, Fujian, Zhejiang, Jiangsu, and Shandong, the largest proportion is of discontinued shrinkage or non-shrinkage cities.

Table 3. Classification of Shrinking Cities (Based on shrinkage periods)

Categories	**Explanation**
I Continuous shrinkage	shrinkage in at least both periods of 2010-2015 and 2015-2020
II Recent shrinkage	shrinkage occurred in 2015-2020 but no shrinkage in the previous three periods
III Periodic shrinkage	shrinkage occurred in 2015-2020 as well as in either 2000-2005 or 2005-2010
IV Discontinued shrinkage	shrinkage occurred during 2000-2015 but no shrinkage in 2015-2020

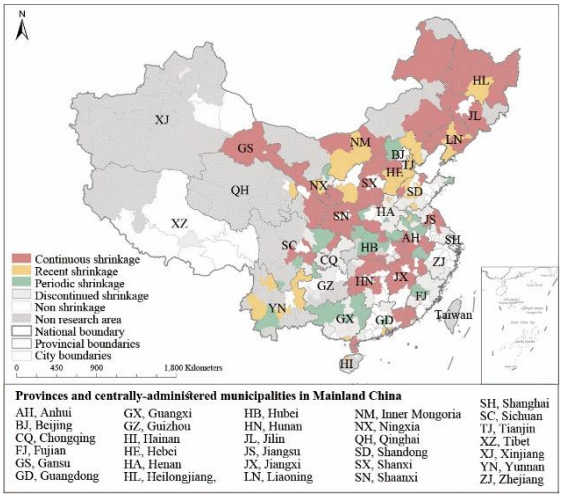

Fig.7 Types of Shrinking Cities (Shrinking periods)

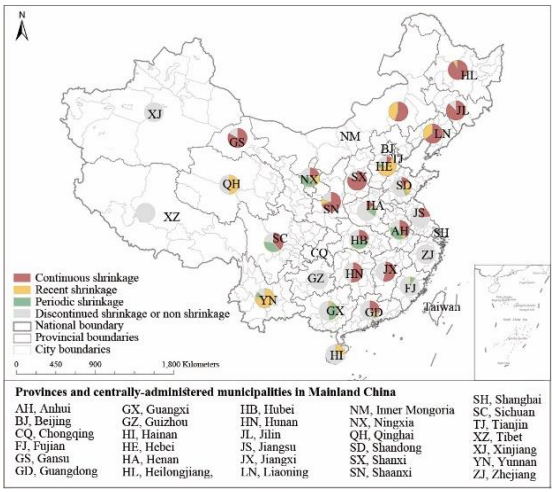

Fig.8 Proportion of Each Type in Different Provinces

4.3 Distribution Differences in Different City Contexts

Differences by City Size

According to the “Notice on Adjusting the Criteria for the Classification of City Size” promulgated by the

State Council of China in 2014, City Size is divided into five categories, taking the resident population in urban areas as the statistical caliber: (I) cities with a resident population of less than 500,000 in urban areas are small cities (total number is 36); (II) cities with a resident population of more than 500,000 and less than one million in urban areas are medium cities (total number is 88); (III) cities with a resident population of more than one million and less than five million in urban areas are large cities (total number is 142); (IV) cities with a resident population of more than five million and less than 10 million are megacities I (total number is 21); (V) cities with a resident population of more than 10 million are megacities II (total number is 10).

Considering shrinkage in either demography or economy as urban shrinkage, we analyzed the proportion of shrinking cities in each city size for four periods (Figure 9). The results show that there is a high proportion of shrinking cities in small and medium-sized cities. The proportion of shrinking cities in small and medium-sized cities increased rapidly, from 18.82% and 22.52%, respectively during 2000–2005 to 71.76% and 62.16%, respectively during 2015–2020. Additionally, megacities have also been shrinking recently.

Figure 10 shows the proportion of different city sizes in various types of shrinking cities. In continuous shrinkage cities, the proportion of small cities is 39.22% and the proportion of medium cities is 43.13%. Recent shrinkage cities are distributed not only in small, medium, and large cities but also in megacities. In periodic shrinkage cities, small cities and medium cities account for 38.24% and 32.35%, respectively. Moreover, small cities have lower proportion in discontinued shrinkage cities compared to the medium and large cities.

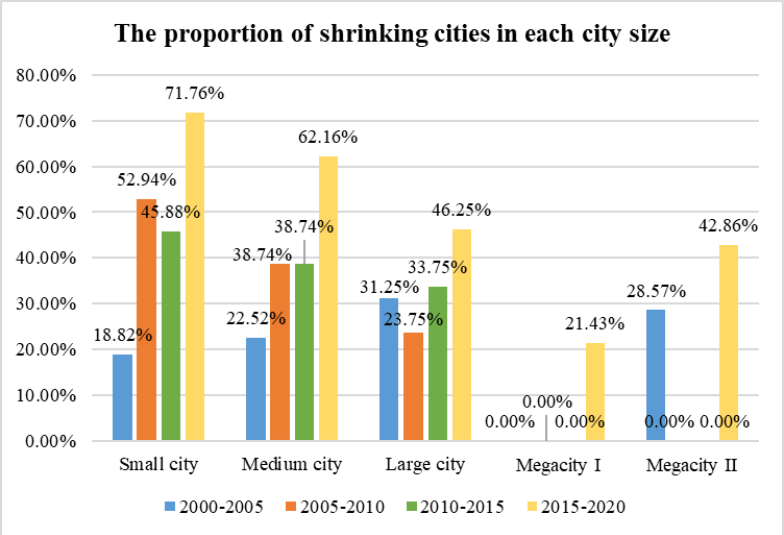

Fig.9 Shrinking Cities in Different City Sizes

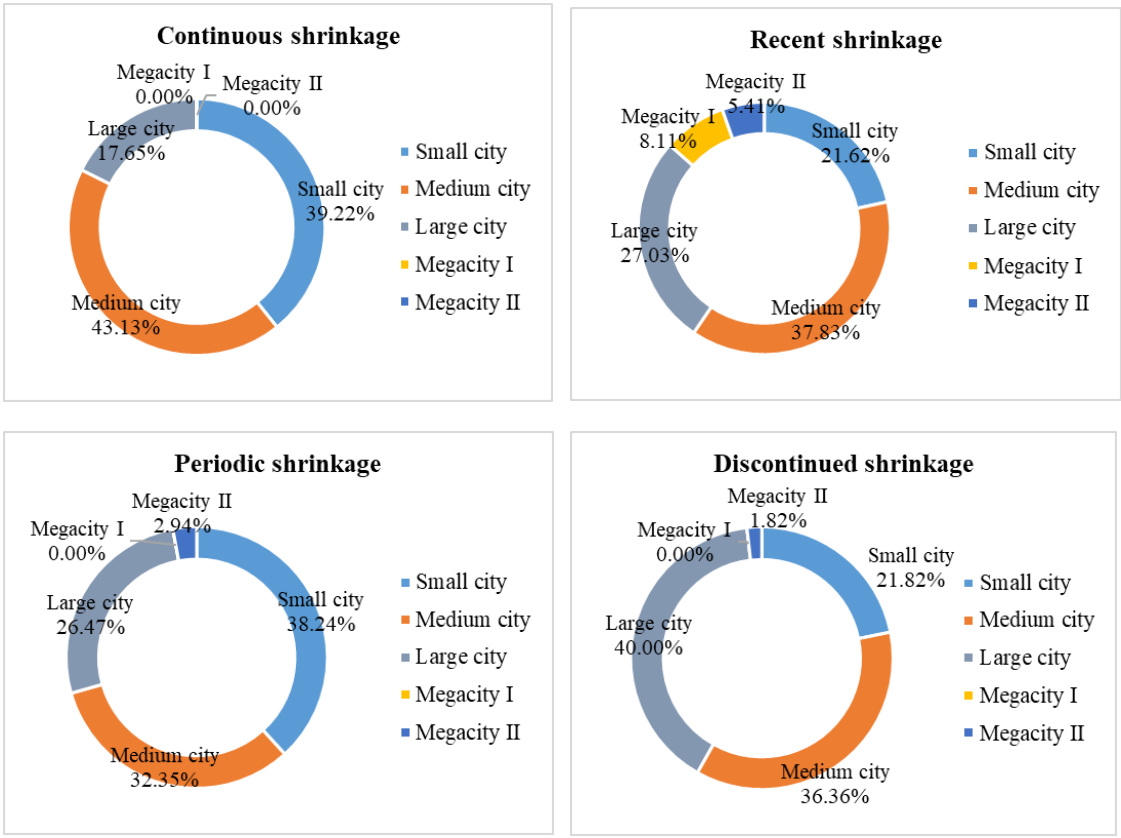

Fig.10 Proportion of Cities of Different City Sizes in Various Types

Differences between Resource-based Cities and Non-resource-based Cities

The State Council of China issued the National Sustainable Development Plan for Resource-Based Cities (2013–2020) in 2013, which designates resource-based cities, referring to cities with mining and processing of natural resources such as minerals and forests as their leading industries, including 115 prefecture-level cities (Figure 11).

As shown in Figure 12, the proportion of resource-based cities in shrinking cities has increased—from 39.71% during 2000–2005 to more than half during 2015–2020. Moreover, through the analysis of the proportion of shrinking cities in resource-based cities (Figure 13), it can be seen that the proportion increased significantly, and nearly four-fifth of resource-based cities were shrinking cities during 2015–2020.

Among the four types of shrinking cities (Figure 14), the proportion of resource-based cities is larger than that of non-resource-based cities in both continuous and recent shrinkage categories. The proportion of resource-based cities and non-resource-based cities is equal in periodic shrinking cities. In comparison, among the cities in the discontinued shrinkage category, approximately three-fourth are non-resource-based cities.

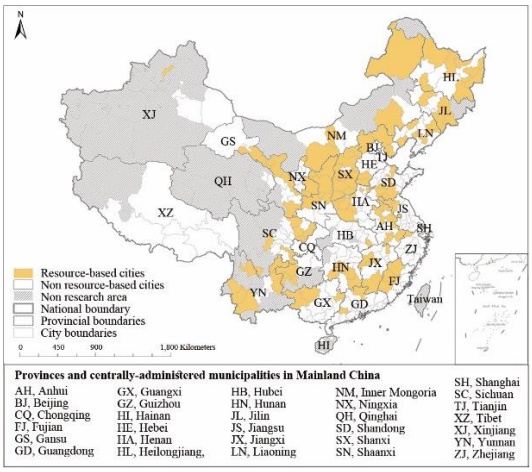

Fig.11 Distribution of Resource-based Cities in China (Prefecture-level cities)

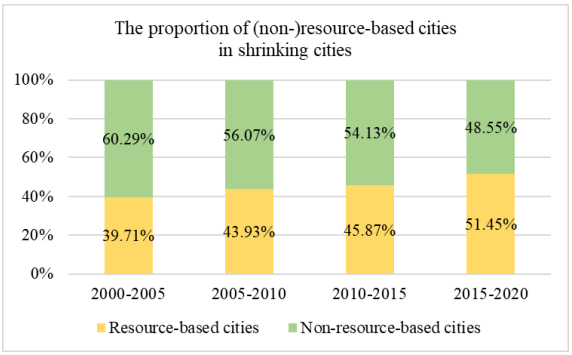

Fig.12 Proportion of (Non-)resource-based Cities among Shrinking Cities

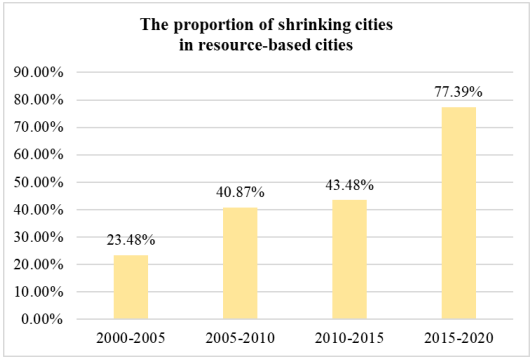

Fig.13 Proportion of Shrinking Cities among Resource-based Cities

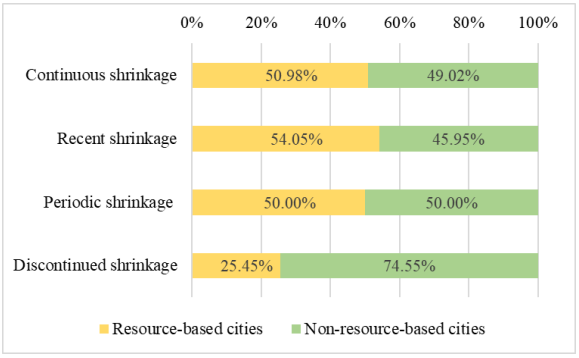

Fig.14 Proportion of (Non-)resource-based Cities among Various Types of Shrinking Cities

5 Discussion and Conclusions

This study describes the temporal and spatial changes in the distribution of Chinese shrinking cities from 2000 to 2020 in dimensions of demography and economy. Currently, shrinking cities in China have the largest proportion of population shrinkage. After 2015, the number of cities with both shrinkage in population and economy increased. The phenomenon of cities with a declining population emerged in 2000, and the proportion has grown from less than one-fifth to more than half in 20 years. The distribution has expanded from the central and southwestern provinces to most provinces, and severe population shrinking cities have appeared in northeast China, Inner Mongolia Zizhiqu, and the Shaanxi and Sichuan Provinces. Cities of economic decline have increased since 2015, accounting for approximately 13%, mainly in the northeast region.

Population shrinkage is observed before the economic decline. One possible reason for this is that in some cities the population loss is not caused by de-industrialization, so the economic decline may appear after the population loss. Haase et al (2016) argued that an economic downturn is a sufficient but not necessary cause of population shrinkage, and other causes should include demographic change and so on. In some small cities in southwestern China, high aging rates and the siphoning effect of the surrounding

large cities have led to significant population declines. And the loss of the labor force may lead to low economic growth afterward. Weaver et al (2016) also argued population shrinkage is more predictive of economic shrinkage than the converse. Another possible reason is that it takes a long time for the economic growth rate to change from high value to negative. In some traditional industrial cities in northeast China, industrial restructuring has led to a decline in manufacturing, and fewer job opportunities resulting in a large population loss, causing a further economic decline. However, the reflection of economic decline in GDP is from the lower growth rate to the negative growth, which takes time. In addition, the national government has adopted many economic restructuring policies, such as The Revitalization Plan of Northeastern China (in 2007) and The National Plan (2013−2022) for the Adjustment and Transformation of Old Industrial Bases (in 2013), which have played a role in stemming the economic decline.

The development of shrinking cities is dynamic. The number of shrinking cities increased from 2000 to 2010; however, from 2010 to 2015, this number decreased. The reason might be that after the global financial crisis during 2007–2009, the Central Government of China launched a four trillion-yuan investment plan and built a lot of infrastructures, such as high-speed railways, water conservancy projects, and highways, which significantly promoted the development of industries such as mining, energy, construction, and public facilities. From 2009 to 2013, China's economic development was in an overheating period, which mitigated the urban shrinkage from 2010 to 2015. At the end of this era of overheated investment, China's economy entered a period of cut overcapacity, reflected in the decline of employment in the secondary industry and the adjustment of the industrial structure. Consequently, more shrinking cities emerged from 2015 to 2020.

In terms of the classification of shrinking cities in two dimensions, the largest proportion (74.6%) shows shrinkage in the dimension of population. A total of 19.7% of cities are experiencing both population and economic decline. In terms of shrinkage periods, nearly half are in the continuous shrinkage category, and 16.2% are in the recent shrinkage category.

Furthermore, city sizes and urban resources are related to the distribution of shrinking cities. The proportion of shrinking cities is higher in small and medium-sized cities and resource-based cities, which mirrors the results of previous research (Zhou et al, 2021; Wang et al, 2021). In particular, the proportion of shrinking cities among resource-based cities has reached 77.39% in recent years. Urban resources (e.g., fossil minerals) are the basis for the production of goods and energy, thus economy will be threatened when resources are exhausted (Oswalt & Rieniets, 2006). Additionally, in China, there are many state-owned enterprises in resource-based cities. Since the 1990s, state-owned enterprises have undergone a series of reforms, and many of them were dissolved and downsized (Jin & Sui, 2021). The reform of state-owned enterprises has brought about massive unemployment, leading to population loss and economic decline, which results in a higher proportion of shrinking cities among resource-based cities.

This study contributes to the understanding of the current status of shrinking cities in China and enriches the discussion on urban shrinkage worldwide. The findings can remind policymakers and urban planners that urban shrinkage has already become a significant phenomenon in China nowadays, and there is an urgent need to think about responses to this issue. It can be predicted that urban shrinkage will become more severe in the future because of China's low birth rate, rapid aging of the population, and industrial transformation. There should be a paradigm shift from "growth-oriented planning" to "right-sizing planning" to adapt to the shrinkage and achieve a smaller but better city. However, this transformation will take time and will require a rethinking of planning objectives, planning methods, land use patterns, and so on. Especially in shrinking cities, planning transformation is difficult because of the concerns about the

negative impact of the "shrinking city" label and the financial pressure. Thus, policymakers and planners should act now to cope with this issue and prepare for the even greater shrinkage that will occur in the future. The accurate identification and classification of shrinking cities in this paper can provide a reference for urban policymaking. The government can think about different responding strategies for different types of shrinking cities and pay more attention to cities that are experiencing both population loss and economic decline and continuous shrinking cities.

However, this study has a few limitations. The analysis unit is the administrative prefecture-level city, not the de facto city, so the rural area is also included. Additionally, shrinking cities are also manifested in the spatial dimension, such as a large amount of vacant land and vacant buildings, which are not covered in this paper and can be further studied in the future.

Notes

(1) "Shrinking Cities" is a project of the German Federal Cultural Foundation in cooperation with the Project Office Philipp Oswalt, the Museum of Contemporary Art Leipzig, the Bauhaus Dessau Foundation, and the magazine archplus since 2002, investigating the international process of urban shrinkage.

(2) The Shrinking Cities International Research Network (SCIRN) is a worldwide research consortium of scholars from various institutions working to increase international understanding of shrinking cities in a global context. It was founded in 2004 under the aegis of the Institute of Urban and Regional Development at the University of California, Berkeley.

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