Does Land Finance Contraction Accelerate Urban Shrinkage? A Study Based on 84 Key Cities in China

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Abstract: After approximately 30 years of sustained and rapid development, some Chinese cities have seen urban shrinkage marked by a decreasing population size. Land finance, which is the *second public finance* of local governments in China, influences urban development through capital and land supply. It is the primary source of funds for urban infrastructure construction and the driving force behind promoting urban boundary expansion. In the context of the overall downturn of domestic land finance, land finance contraction for shrinking cities may accelerate the further decline of population in these cities. This paper investigated 84 key cities across China between 2008 and 2015 and found that (1) the contraction of land finance has heterogeneous impacts on shrinking cities and nonshrinking cities, which, in turn, has significant catalytic effect on population loss in shrinking cities; and (2) the insufficient replenishment of capital caused by the contraction of land finance in shrinking cities has a more significant impact than the insufficient supply of land. Infrastructure investment has a complete mediation effect in this influencing mechanism. **DOI: 10.1061/(ASCE)UP.1943-5444.0000613**. © *2020 American Society of Civil Engineers*.

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Introduction

Urban shrinkage has occurred globally over the past few decades. Since the 1970s, due to the acceleration of deindustrialization, adjustment of the economic structure, and emergence of suburbanization, some cities in Germany, Canada, Japan, and other countries have experienced economic recession and urban shrinkage marked by a decrease in population (Xu and Pang 2014; Schetke and Haase 2008). Due to its multidimensional effect, urban shrinkage affects most countries and regions in the world. According to Martinez-Fernandez et al. (2016), between 2000 and 2012, 20% of the world's cities displayed shrinkage, among which those in developed countries such as the United States, Germany, France, and the United Kingdom experienced the most contraction. Therefore, in the recent decade, the phenomenon of shrinking cities has attracted extensive attention from media, academics, and policymakers in Europe and the United States.

After sustained and rapid development lasting approximately 30 years, with the growth of Chinese cities entering a new normal, China's urban economic and development conditions have undergone structural changes. Urban shrinkage was observed by some resource-based cities, outward processing and manufacturing cities, cities located on the edge of metropolises, and some provincial capitals in central and western China. Long and Wu (2016) identified 19,882 out of 39,007 townships in China that experienced a decline in population between the two censuses (2000–2010), and these declining townships are spread across urban and rural areas. China's shrinking cities, which show relatively high spatial correlation in space, are mainly concentrated in northeastern China and the Chengdu–Chongqing city cluster. Some cities and towns in the Beijing–Tianjin–Hebei region, the Yangtze River Delta region, and the Pearl River Delta region have also shown shrinkage (Zhang et al. 2018; Deng et al. 2019).

In China, the system of *land finance* with Chinese characteristics plays a significant role in urban development (Zheng et al. 2014; Qun et al. 2015). Land finance promotes the flow of land factor into cities, meets the land demand for urban development, and effectively promotes urban space expansion. At the same time, the land transfer income, reserved land mortgage income and related taxes as a result of land finance increase the capital factor of the city, meet the capital demand for upgrading the urban infrastructure, improve the commercial environment and external attraction of the city, stimulate the urban demand growth of land factor, and further develop the land finance. As China's urban development strategy has been oriented by long-term growth expectations, government planning departments tend to adopt an expansionary development strategy when formulating plans and policies of urban development, which makes the land finance develop faster under such an expansionary development and planning strategy. However, for shrinking cities with a declining urban population, increasingly poor economic development prospects, and gradually decreasing competitiveness in the process of attracting investments, their economic entities' demand for urban land decreases, resulting in a continuous decline in land revenue.

This paper shows that when land finance of shrinking cities begins to contract, it accelerates further loss of population and an even further increase in shrinkage. Moreover, the authors test the mechanisms by which land finance affects population mobility. These

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findings will not only help shrinking cities adjust their land finance mode accordingly but also make contributions to the knowledge domain of shrinking cities. Simultaneously, this study provides implications for cities or regions that implement a land finance system and serves as a reference for policymakers, urban planners, and academics in the new era of nonincremental urban development.

Literature Review

Definition of Urban Shrinkage

The study of urban shrinkage first emerged in Germany, where the term *shrinking cities* was used to define German cities experiencing population decline and economic recession. Since the late 1990s, as an increasing number of cities began to suffer from urban decay and population loss, scholars have generally started using the concept of shrinking cities to observe relevant cities (Howe et al. 1998; Rybczynski and Linneman 1999; Wolff and Wiechmann 2018).

Presently, scholars have not reached consensus on the definition of the shrinking city. The Shrinking Cities International Research Network defines shrinking cities as those with a population density of more than 10,000 per square kilometer that has been declining for more than two years. Pallagst (2009) also defined a shrinking city as a city area facing population loss for more than two years and experiencing some symptoms of structural crisis and economic transformation. Some scholars defined urban shrinkage from a broad perspective, believing that it is reflected in the overall decline of population, economy, society, environment, and culture in the spatial dimension (Xu and Pang 2014). Although the specific definition of urban shrinkage has not yet been agreed upon in the academic world, scholars have already reached consensus on one point: population loss is the main criterion for determining shrinking cities (Long and Wu 2015; Gao 2015).

Factors Affecting Urban Shrinkage

Weak economic growth is considered one of the main factors affecting urban shrinkage. Against the background of the rapid development of globalization, some old industrial areas and cities with a single industrial structure lack competitiveness in the international division of labor and are gradually declining (Reckien and Martinez-Fernandez 2011). Moreover, with the gradual exhaustion of energy sources, all resource-based cities are facing a serious resource crisis. The decline of traditional resource-dominated industries, reduction of enterprises and production suspension, and relocation slow down urban economic development (Liu 2018). At the same time, technological innovation and the development of transportation have changed the economic structure of traditional old industrial cities. Many enterprises have moved out of old industrial bases with high land and labor costs and a lack of new business growth space, which has increased the unemployment rate of these cities and the original economy. The structure has disintegrated, new economic growth is extremely slow, and these cities are facing recession (Yang and Sun 2015).

Natural population growth and structural changes also affect urban population growth. Aging of population not only reduces the production capacity and demand of cities but also affects the natural growth of the population, resulting in weak urban economic growth and spatial shrinkage, which is common in Japan and a few European countries (Martinez-Fernandez et al. 2012; Wang and Fukuda 2019). Environmental changes also influence the migration of city residents. The accumulation of environmental pollutants in old industrial cities affects residents' health, and the city then becomes less attractive to people who pursue a high quality of life. The social environment factors such as transportation, education, medical care, housing, infrastructure, and human capital provide a material guarantee for residents' life quality and enterprise production, so the lack of these social factors also affects urban shrinkage (Weaver and Holtkamp 2015; Zhang et al. 2019).

Political factors are believed to contribute to a city's shrinkage as well. Cities with high administrative levels have absolute advantages with regard to resource allocation, public service provision, economic development conditions, and other aspects, thereby triggering the outflow of population in cities with low administrative levels through a siphon effect. This phenomenon is particularly evident in small cities located near large cities (Matanle 2008). Further, fiscal expenditure is the primary source of funds for maintaining urban operations, especially in regions with slow economic development, which need large-scale fiscal expenditure to provide infrastructure and public services, and the decline of fiscal revenue due to urban shrinkage triggers further contraction in these regions (Haase et al. 2016). Urban planning also plays an important role in urban development. A reasonable and effective planning scheme, especially for shrinking cities, can improve the utilization efficiency of urban public resources and help cities avoid the disconnection between urban construction and population growth (Hartt 2018).

Role of Land Finance in Urban Development

Compared with Western countries, the government plays an important role in China's urban development. The Chinese government is not only the provider of public services but also the guide for urban development. As the *second public finance* of Chinese local governments, land finance plays an essential role in promoting urban development. As per previous research, land finance mainly refers to the income obtained from land transfer by local governments. However, since the financial crisis of 2008, with the tightening of land for urban construction and the sharp rise in land acquisition costs, reserved land mortgage financing has gradually become another important part of land finance (Liu 2018). This land finance mode combining *land transfer* and *reserved land mortgage financing* has become a significant source of funding for most cities (Zheng et al. 2014). Therefore, this paper considers land transfer and reserved land mortgage financing as a generic land finance (hereinafter referred to as land finance).

In the context of China, land finance is a critical force for urban expansion and a major source of funds for improving the urban infrastructure. On the one hand, land transfer provides a large amount of construction land for urban development and expansion and improves the per capita land resource of urban residents, thereby pushing the production curve to the right, promoting capital formation and the economic growth of a city, and increasing the urbanization process (Lin and Yi 2011). On the other hand, land finance supplies the capital resources owned by the city, and a large amount of funds obtained from land finance are used for municipal investment and upgrading infrastructure, thereby effectively improving the level of urban hardware facilities, enhancing urban appearance, and optimizing the community environment (Guo and Shi 2018). A superior living and business environment will attract more residents and enterprises to enter the city. The inflow of these land users will further stimulate the growth of urban land demand, and land finance will be more prosperous (Huang and Chan 2018; Zheng et al. 2014).

In addition, there is also a "reserved land mortgage financing—upgrading urban infrastructure—promoting business investment—income from land transfer increase—generating land, real estate-related taxes—economic growth—newly acquired land

increases land reserve" cycle mechanism, which can effectively promote urban economic development (Wang and Tang 2013). Consequently, economic benefits generated from land finance produce a huge attraction for the population, making land finance a major driving force for China's urbanization (Ye and Wu 2014).

Therefore, for expanding cities, under the demand of higher land use, a positive circle can be formed between the growth of land finance and the development of the city, which reinforce each other and promote the rapid growth of cities. However, for shrinking cities, the decreasing land demand causes their land finance to be inactive, and the reduction of land and capital factors leads to slower economic development, which accelerate population decrease and the further shrinkage of these cities. A study by Manville and Kuhlmann (2018) on the fiscal revenue of American cities also found that the fiscal capacity of shrinking cities is relatively lower and that there is a vicious circle between the shortage of fiscal revenue and urban shrinkage.

Although existing studies have investigated the impact of land finance on urban growth, few have discussed the impact of land finance on urban shrinkage. The innovations of this paper are that land finance is initially linked to urban shrinkage and the heterogeneous influences of land finance on shrinking cities and nonshrinking cities are discussed, and the catalytic mechanism of land finance on shrinking cities is investigated.

Research Hypotheses

As mentioned previously, land finance does have an impact on the urban population, but is there any heterogeneity in the impact on shrinking and nonshrinking cities?

For nonshrinking or growing cities, the prospects for economic development are bright, and the demand and price for urban land stay high, which make land finance continue to grow, leading to the further development of urban economy and urbanization. In this way, there is a positive circle between the growth of land finance and urban development (Huang and Chan 2018; Wang and Tang 2013). Even in the context of the overall decline in land finance across the country, due to the better development prospects and relatively high demand for land, the degree of land finance contraction in nonshrinking cities may be relatively mild, which may have little impact on urban economy and population.

However, for shrinking cities, the land demand from economic entities decreases due to the reduction of urban population. Meanwhile, the asset depreciation and interest-rate risk of land mortgage financing increase, leading to a more obvious contraction of land revenue in shrinking cities. The contraction of land finance may, in turn, lead to problems such as reduced government funds, old urban hardware facilities, and deteriorating urban economic, residential, and employment environments, which may result in a further decline of population in shrinking cities, thereby forming a vicious cycle. Hence, in the context of the overall decline in land finance, shrinking cities would suffer a severer contraction of land finance, catalyzing further population loss, and then lead to a further shrinkage of land finance.

Therefore, the authors propose the first research hypothesis.

Hypothesis 1: The impacts of land finance contraction on the population of shrinking cities and nonshrinking cities is heterogeneous. Due to the negative catalytic cycle in shrinking cities, land finance contraction has a more significant catalytic effect on shrinking cities.

We further explore the catalytic path of land finance contraction in shrinking cities, as reviewed previously, there are two possible ways in which the mechanism of land finance contraction can have an impact on shrinking cities: (1) The reduction of land finance results in insufficient supplement of the land factor, which directly accelerate urban shrinkage. (2) Insufficient capital supplement caused by land finance shrinkage results in insufficient investment funds for the urban infrastructure, which then leads to outdated urban hardware facilities and the deterioration of the living environment, and this mechanism indirectly accelerates urban shrinkage, and infrastructure investment plays a mediating role in this catalytic pathway (Fig. 1). For cities that have experienced population shrinkage and economic slowdown, their land factor may have reached a stage of saturation or diminishing marginal benefits, while the capital factor is an indispensable resource for the further development. The outdated infrastructures caused by insufficient construction funds will directly lower the living standards of urban residents and further reduce the attractiveness of cities to enterprises and residents. Therefore, for shrinking cities, the lack of infrastructure investment funds caused by the land finance contraction may have a more significant impact on population decrease. There, we have Hypothesis 2.

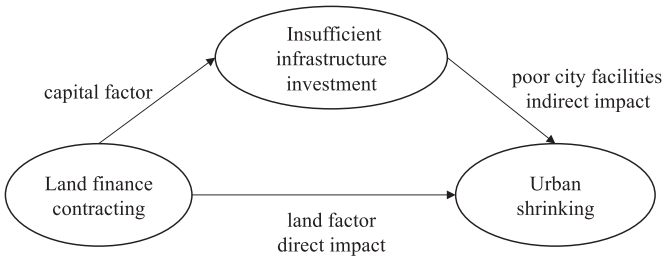

Fig. 1. Impact mechanism of land finance on shrinking cities.

Hypothesis 2: insufficient replenishment of capital factors caused by contracting land finance has a more significant impact on shrinking cities, and infrastructure investment plays a mediating role in this indirect influencing mechanism.

Status Analysis of Sample Cities

Selection of Sample Cities

The paper considers the period between 2008 and 2015, when China's urbanization grew rapidly and the growth trend of land revenue changed significantly, as the research period. Based on China's Land Management Law, 84 key cities that are required to submit construction land to the state council for approval are taken as research objects. These 84 key cities have relatively high administrative levels, and most of them are political, economic, and population centers in their regions. However, some of them still show shrinkage. Therefore, the study on the shrinkage of these cities is of great significance. Moreover, the land transfer market and the land mortgage financing market of these 84 key cities are relatively developed, and their land financial behavior is relatively typical. Finally, these 84 cities have amounts and areas data of land transfer and reserved land mortgage financing, and the data integrity is higher than other cities. Therefore, it is more representative to explore the relationship between land finance contraction and urban shrinkage with these 84 key cities as samples.

Population Change of Sample Cities

This paper classifies the shrinkage of 84 cities according to the number of years of negative population growth during the selected study period, as shown in Table 1.

Table 1. Population changes in 84 key cities

Shrinkage type	Number of years with negative population growth	Number of cities	List of cities
Nonshrinking	0–1 year	46	Anyang, Changzhou, Chengdu, Datong, Baotou, Beijing, Handan, Fuzhou, Guangzhou, Hangzhou, Hefei, Hengyang, Hohhot, Yellowstone, Jiaozuo, Kaifeng, Linyi, Nanning, Liuzhou, Nanchang, Nanjing, Ningbo, Qingdao, Xiamen, Shantou, Shanghai, Shenzhen, Suzhou, Shenyang, Shijiazhuang, Tangshan, Tianjin, Weifang, Urumqi, Xinxiang, Xuzhou, Wuxi, Xi 'An, Xiangyang, Yinchuan, Zaozhuang, Zhanjiang, Zhangjiakou, Changsha, Chongqing, Zibo
Potential shrinkage	2 intermittent years or above	12	Baoding, Dalian, Guiyang, Haikou, Jinan, Lhasa, Taiyuan, Xiangtan, Yantai, Zhengzhou, Zhuzhou, Lanzhou
Segmental shrinkage	2 consecutive years	12	Daqing, Harbin, Huaibei, Huainan, Jiamusi, Kunming, Luoyang, Pingdingshan, Tai 'An, Wuhan, Xining, Changchun
Continuous shrinkage	3 consecutive years or above	14	Anshan, Benxi, Dandong, Fushun, Fuxin, Hegang, Jixi, Jilin, Jinzhou, Jingzhou, Liaoyang, Mudanjiang, Qiqihar, Yichun

Source: Data from Former Ministry of Land and Resources (2017a).

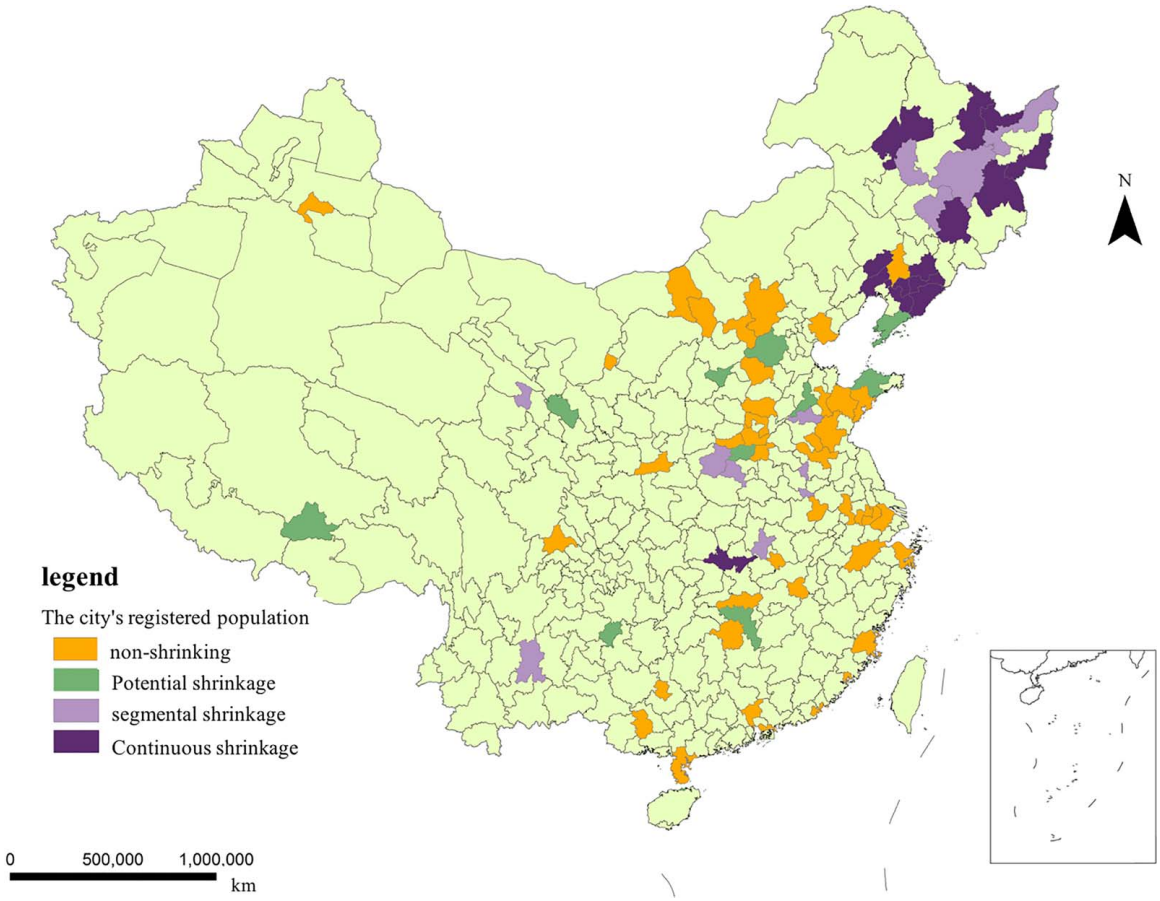

Fig. 2. Spatial distribution of population shrinkage in 84 key cities.

Among them, cities with negative population growth account for 45% of the total, and 12 cities have intermittently appeared shrinkage for two years and more. The population has experienced negative growth, with 12 cities showing a negative population growth for two consecutive years, and as many as 14 cities showing persistent population shrinkage. From the perspective of spatial distribution, the continuously shrinking cities are mainly concentrated in northeastern China, while the segmental shrinking cities are mainly distributed in the central and western regions. Moreover, some central and western provincial capitals, such as Jinan, Taiyuan, Zhengzhou, and Lanzhou, show potential shrinkage (Fig. 2).

According to the consensus on shrinking cities discussed in the literature review, this paper defines cities with continuous negative growth of the registered population for two years or more as shrinking cities, which is a total of 26 cities (namely, segment-shrinking cities and continuous-shrinking cities).

Land Finance in Sample Cities

Since 2011, with the continuous tightening of China's real estate market policies, the worsening of urban housing problems, and the prominent issue of land transfer by local governments, the growth trend of local government land revenue has experienced an obvious downturn. Since then, land revenue of the 84 key cities has shown a declining trend, and the shrinking cities have

shown a more prominent land revenue contraction. Compared with the peak period, by 2015, the per capita land revenue of nonshrinking cities decreased by 42%, while that of shrinking cities declined by 57%, and since the land finance began to decline in 2011, the average annual growth rate of land revenue in shrinking cities was −15.1%, while that in nonshrinking cities is only −3.5% (Fig. 3), demonstrating that shrinking cities show more pronounced and faster land finance contraction. Further, the proportion of land revenue in GDP in the shrinking cities is lower than that in nonshrinking cities during the research period (Fig. 4), indicating that the economic entity has a lower demand for land in shrinking cities, and that the land finance market in shrinking cities is inactive.

Therefore, during the change of the land finance growth trend, the shrinking cities did show a more prominent phenomenon of land finance contraction. Hypothesis 1 of this paper does have a realistic background, that is, land finance in 84 key cities in China has indeed contracted, and the degree of land finance contraction in shrinking cities is more obvious than in nonshrinking cities, which may cause heterogeneous impacts.

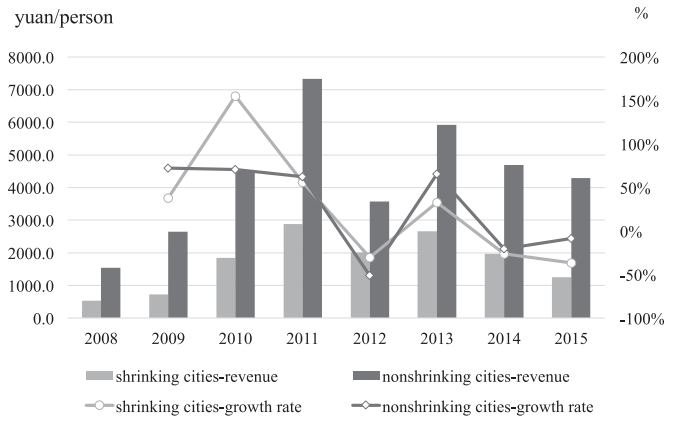

Fig. 3. Comparison of per capita land revenue and its growth rate. Data source: *China City Statistical Yearbook*, *China Land and Resources Statistical Yearbook*, and Database of Land Mortgage Registration of 84 Key Cities in China.

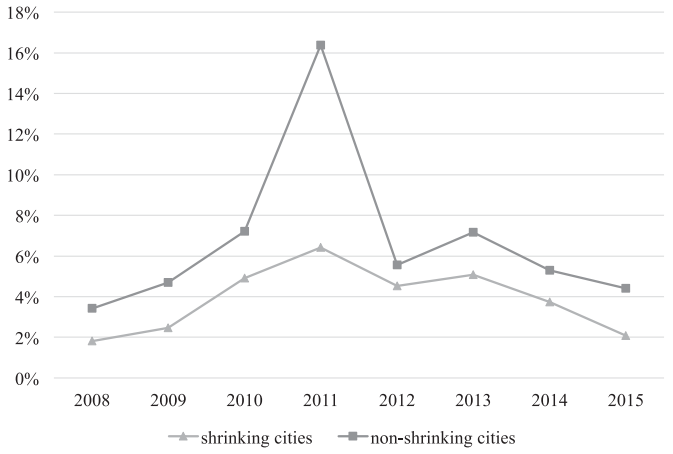

Fig. 4. Proportion of land finance to GDP in different categories of cities. Data source: *China City Statistical Yearbook*, *China Land and Resources Statistical Yearbook*, and Database of Land Mortgage Registration of 84 Key Cities in China.

Data and Methods

Data Sources

Referring to the existing quantitative research on shrinking cities and considering the availability of data, this paper selected a registered population as the dependent variable to measure urban population change and considered land revenue as the independent variable to study whether land finance can accelerate urban shrinkage. In terms of control variables, 10 alternative influencing factors are selected from four aspects: urban macroeconomic fundamentals, natural population growth, urban environment, and social resources (as shown in Table 2).

However, considering the possible multicollinearity between control variables, we first adopted principal component analysis (PCA) to analyze and extract the main influence factors to achieve data dimension reduction. The above 10 control variable data sets had a Kaiser–Meyer–Olkin value of 0.8524 and a Bartlett's spherical test P value of 0, indicating that significant multicollinearity does exist between these control variables, and that the PCA method was needed to reduce the dimension.

The correlation coefficient matrix between indexes was established, and the principal components $F1$–$F3$ whose eigenvalue is greater than 1 were selected. The cumulative interpretation strength of these three indexes is 74.82%.

As shown in Table 3, $F1$ is mainly explained by GDP, retail sales of consumer goods, urban road area, and financial education expenditure, reflecting the economic level and social resources. $F2$ is mainly explained by the proportion of the secondary industry in GDP and industrial smoke emission, reflecting secondary industry development; $F3$ is mainly explained by the natural population growth rate, reflecting the factors of natural population growth. It can be concluded that economic development level and social resources, the proportion of the secondary industry, and the natural population growth rate are the main factors affecting population growth.

To control the influence of noninterest variables on dependent variables, the extracted principal component factors $F1$–$F3$ were added into the regression model as elements of the control variable set Z.

Table 2. List of alternative control variables

Aspect of measurement	Influencing factors	Alternative control variables
Macroeconomic fundamentals	Vitality of urban residents' consumption	Retail sales of consumer goods
	Vitality of Urban production	Amount of foreign capital utilized this year
	Eeconomic growth	GDP
	Industrial structure	Secondary output as a share of GDP
Natural population growth	Natural population growth	Natural population growth rate
Urban environment	Air quality	Industrial emission
	Urban greening	Green coverage in builtup areas
Social resources	Traffic resources	Urban road area
	Education resources	Financial education expenditure
	Human capital	Average wage

Source: Data from State Statistical Bureau (2017) and Former Ministry of Land and Resources (2017a).

Table 4 shows the descriptive statistics of each variable, and we used this panel data for model regression. The data sources of *China City Statistical Yearbook* and *China Land and Resources Statistical Yearbook* can be found in State Statistical Bureau (2017) and Former Ministry of Land and Resources (2017a), respectively. The database of Land Mortgage Registration of 84 Key Cities in China (Former Ministry of Land and Resources 2017b) is not open to the public, and we access to the database through research collaboration with government departments.

Model Development

For Hypothesis 1

To test the heterogeneity of the impact of land finance on shrinking cities and nonshrinking cities, the following two steps were taken. First, to verify the significant impact of land finance on the population of shrinking cities and nonshrinking cities, the basic Model (1) was used to perform the regression of 26 shrinking cities and 58 nonshrinking cities. Second, in the sample of the 84 cities, the heterogeneity of the impact of land finance on shrinking cities and nonshrinking cities was verified by adding the form of shrinkage and land finance interaction terms, shown as Model (2). The basic models are as follows:

$$\ln\_pop_{it} = \alpha_0 + \alpha_2 \ln\_finance_{it} + \lambda Z_{it} + \varepsilon_{it} \quad (1)$$

$$\ln\_pop_{it} = \alpha_0 + \alpha_1 shrink + \alpha_2 \ln\_finance_{it} + \alpha_3 shrink * \ln\_finance_{it} + \lambda Z_{it} + \varepsilon_{it} \quad (2)$$

Table 3. Coefficient matrix of comprehensive principal factors

Index of influencing factors	$F1$ economic level and social resources	$F2$ secondary industry development	$F3$ natural population growth
Retail sales of consumer goods	0.9728	0.04284	0.05102
Amount of foreign capital utilized this year	0.8678	0.05525	0.07201
GDP	0.9767	0.06077	0.004595
Secondary output as a share of GDP	0.07398	0.7232	0.4804
Natural population growth rate	0.1366	0.3742	0.7737
Industrial emission	0.221	0.7709	0.1033
Green coverage in builtup areas	0.2879	0.04323	0.4577
Urban road area	0.9271	0.03852	0.002006
Financial education expenditure	0.9527	0.05336	0.05112
Average wage	0.7537	0.07604	0.01582

where ln_pop represents the registered population of the entire city at the end of the year, ln_finance represents the land revenue of the year, shrink is a dummy variable for whether a city shrinks, and the value is 1 for a shrinking city; otherwise, it is 0. The interaction term shrink * ln_finance measures whether the land finance has a significant difference of influence on a shrinking city and a nonshrinking city, and Z is the control variable vector.

For Hypothesis 2

In this step, the impact mechanism of land finance contraction on shrinking cities was studied. Therefore, 26 shrinking cities were taken as samples. In terms of the model, we drew on the mediation effect test method proposed by Baron and Kenny (1987) and Zhang et al. (2016) and developed the following sequential recursive model (3–5) to verify whether land finance directly affects shrinking cities and indirectly influences them through infrastructure investment

$$\ln\_pop_{it} = \beta_0 + \beta_1 \ln\_finance_{it} + \eta Z_{it} + \upsilon_{it} \quad (3)$$

$$\ln\_inv_{it} = \gamma_0 + \gamma_1 \ln\_finance_{it} + \theta Z_{it} + \nu_{it} \quad (4)$$

$$\ln\_pop_{it} = \delta_0 + \delta_1 \ln\_finance_{it} + \delta_2 \ln\_inv_{it} + \phi Z_{it} + \omega_{it} \quad (5)$$

where ln_pop represents the registered population of the city at the end of the year; ln_finance represents the land revenue of the year; ln_inv represents the investment in infrastructure; and Z is the control variable vector. In the aforementioned mediation effect model, if β_1 is significantly positive, γ_1 is significantly positive, and δ_1 and δ_2 are also significantly positive; however, δ_1 is smaller than the absolute value of β_1, and it indicates that land finance has both a direct and an indirect influence on shrinking cities. In other words, infrastructure investment plays a mediating role in the mediation effect. If β_1 is significantly positive, γ_1 is significantly positive, and δ_1 is not significant; however, δ_2 is significantly positive, and this indicates that the impact of land finance on shrinking cities is completed through the indirect path of infrastructure investment, which has a complete mediation effect.

Empirical Analysis

Results of Heterogeneity of Land Finance's Impact on Cities

Table 5 shows analysis results of a heterogeneous impact of land finance on the population of shrinking cities and nonshrinking cities. Although the differences between shrinking cities and nonshrinking cities are not obvious, they show a similar trend during the study period, indicating that the panel data do not change with individuals, but change with the time instead. Due to the

Table 4. List of descriptive statistics of main variables

Variable	Measuring aspect	Variables	Variable name	Observation	Mean	Standard deviation
Dependent variable	Population change	Registered population	ln_pop	672	6.13	0.68
Independent variables	Land finance	Land revenue (the sum of land transfer income + reserved land mortgage income)	ln_finance	672	13.62	1.53
	Shrinking cities or not	Dummy variable	shrink	672	0.31	0.46
Mediate variable	Infrastructure investment	Fixed asset investment	ln_inv	672	16.45	1.01
Control variables	Economic level and social resources	Principal component 1	$F1$	666	0.00	2.27
	Secondary industry development	Principal component 2	$F2$	666	0.00	1.13
	Natural population growth	Principal component 3	$F3$	666	0.00	1.03

Source: Data from State Statistical Bureau (2017) and Former Ministry of Land and Resources (2017a, b).

Table 5. Impact of land finance on urban population in shrinking and nonshrinking cities

Independent variable	Shrinking cities	Nonshrinking cities	84 Cities	84 Cities
	(1)	(2)	(3)	(4)
shrink	—	—	—	−0.947*** (−2.57)
ln_finance	0.053** (1.83)	0.093*** (2.51)	0.100*** (3.7)	0.055* (1.73)
shrink * ln_finance	—	—	—	0.066** (2.39)
$F1$	0.272*** (11.86)	0.141*** (6.21)	0.162*** (8.89)	0.167*** (8.94)
$F2$	−0.217*** (−8.93)	0.135*** (7.42)	0.053*** (3.44)	0.059*** (3.78)
$F3$	−0.007 (−0.34)	0.062** (2.4)	0.013 (0.77)	−0.006 (−0.35)
Intercept item	6.006*** (15.16)	5.536*** (12.46)	5.063*** (13.82)	5.699*** (13.16)
Year-fixed effect	Yes	Yes	Yes	Yes
Sample size	208	458	666	666
Adj-r^2	0.7774	0.4258	0.5336	0.5380

Note: *Significant at the 0.10 level; **significant at the 0.05 level; and ***significant at the 0.01 level.

relatively small sample size, we choose an OLS model with year-fixed effect regression to test Hypothesis 1. The results of the first column show that taking 26 shrinking cities as samples, land finance has a significant positive impact on the population of shrinking cities. The second column shows that with 58 nonshrinking cities as samples, land finance also has a significant positive impact on the population of nonshrinking cities. The third column takes 84 cities as a whole, and the direction and significance of ln_finance are consistent with the results of individual regression. This shows that considering these 84 cities as samples, land finance does have a significant and positive impact on the population of Chinese cities. When land revenue starts declining, the population of these cities also decreases. Hence, the remaining question is whether there is any heterogeneity in the impact of land finance on shrinking and nonshrinking urban populations. To answer this, the fourth column regression was performed.

In the fourth column, the dummy term shrink and the interaction term shrink * ln_finance were added. In the "Model Development" section, we explained that if the coefficient of interaction term is significantly positive, then it indicates that the contraction of land finance has a more significant impact on shrinking cities. The results show that the coefficient of shrink is −0.947 and is significant at the 99% confidence level, indicating that the shrinking city itself has 61.2% less population than the nonshrinking city. In addition, the ln_finance coefficient is in the same direction as that in the previous three models. Although the significance decreases slightly, it still shows that land finance has a significant positive impact on urban population. The coefficient of the interaction term is 0.066, which is significant at the 95% confidence level, indicating that the population of shrinking cities will drop by 0.066% more than that of nonshrinking cities when land revenue decreases by 1%. Therefore, Hypothesis 1 of this paper is verified. The results show that land finance does have a heterogeneous impact on the population of shrinking cities and nonshrinking cities, and it has a more significant impact on shrinking cities, which means that the contraction of land finance does accelerate the further decline of population in shrinking cities.

Moreover, the influence of other control variables on shrinking and nonshrinking cities is different. $F1$ represents the economic development level and social resources factors, which are significantly positive in all four models, indicating that social resources such as urban economic development level, education, and transportation owned by citizens have a significant positive effect on urban population, which is consistent with the research conclusion of Long and Wu (2015). $F2$ represents the impact of secondary industry development on urban population. It can be seen that $F2$ is significantly negative in shrinking cities, while significantly positive in nonshrinking cities. It can be explained that, because of the outdated industrial structure and production technology in shrinking cities, the higher the proportion of the secondary industry in GDP, the more serious the environment pollution, which will aggravate population loss.

$F3$ represents the impact of natural population growth on urban population. It can be seen from the results that the natural population growth rate has no significant impact on shrinking cities and the 84 cities as a whole, but has a significant impact on nonshrinking cites. This is also consistent with China's national conditions: during the study period, the average natural population growth rate of shrinking cities was −0.91‰, the total sample was 5.35‰, and the nonshrinking cities was as high as 8.17‰. Therefore, the near-zero natural population growth rate of shrinking cites contributed little to urban population growth, but the relatively high natural population growth rate of nonshrinking cities may have a significant impact.

Results of Mediation Effect of Infrastructure Investment

The previous empirical results indicate that the impact of land finance on shrinking and nonshrinking urban populations is indeed heterogeneous and that the impact of land finance on shrinking cities is more significant, meaning that the contraction of land finance accelerates the further decline of population in these cities. In this section, the mediation effect model was used to discuss the impact mechanism of land finance on shrinking cities.

Table 6 shows the direct impact of land finance on shrinking cities and the results of indirect impact through the conduction of infrastructure investment. The results of Step 1 show that the coefficient of land finance variable is significantly positive at the 95% confidence level. When land revenue decreases by 1%, the population of a shrinking city will decrease by 0.053%, indicating that without considering the indirect impact of infrastructure investment, the contraction of land finance has a significant direct impact on the population of shrinking cities. Step 2 conducted regression analysis on infrastructure investment and land finance, and the results show a significant positive correlation between infrastructure investment and land finance, which confirms the conclusions of other scholars cited in the literature review, namely, land revenue is the main source of funds for infrastructure investment, and the shrinking of land revenue dramatically affects infrastructure investment. In Step 3, we used the population of the shrinking city as the independent variable, but land finance and infrastructure investment were both added as the dependent variables in the model.

The results show that the coefficient of land revenue (ln_finance) is no longer significant; the coefficient of infrastructure investment (ln_inv) under the confidence level of 99% is 0.445, indicating that the indirect effect of land finance through the

Table 6. Mediation effect of infrastructure investment on urban population via land finance in shrinking cities

Independent variable	Model (1) Step 1	Model (2) Step 2	Model (3) Step 3
Explained variable	ln_pop	ln_inv	ln_pop
ln_finance	0.053** (1.83)	0.209*** (7.73)	−0.040 (−1.31)
ln_inv	—	—	0.445*** (6.35)
*F*1	0.272*** (11.86)	0.362*** (16.97)	0.111*** (3.37)
*F*2	−0.217*** (−8.93)	−0.023 (−1.01)	−0.206*** (−9.3)
*F*3	−0.007 (−0.34)	−0.006 (−0.32)	−0.004 (−0.23)
Intercept item	6.006*** (15.16)	13.704*** (37.21)	−0.095 (−0.09)
Year-fixed effect	Yes	Yes	Yes
Sample size	208	208	208
Adj-r^2	0.7774	0.9296	0.8146

Note: *Significant at the 0.10 level; **significant at the 0.05 level; and ***significant at the 0.01 level.

Table 7. Impact of land finance on urban population in shrinking and Nonshrinking cities (with land-BAL income indicator)

Independent variable	Shrinking cities	Nonshrinking cities	84 Cities	84 Cities
	(1)	(2)	(3)	(4)
shrink	—	—	—	−0.872*** (−2.48)
ln_finance_BAL	0.0539* (1.96)	0.0883*** (2.68)	0.0926*** (3.8)	0.053* (1.85)
shrink * ln_finance_BAL	—	—	—	0.061** (2.29)
*F*1	0.2702*** (11.94)	0.143*** (6.79)	0.164*** (9.59)	0.167*** (9.525)
*F*2	−0.2165*** (−8.94)	0.135*** (7.44)	0.0526*** (3.43)	0.0588*** (3.78)
*F*3	−0.008 (−0.41)	0.063** (2.46)	0.0124 (0.73)	−0.007 (−0.38)
Intercept item	6.006*** (16.21)	5.197*** (11.58)	5.169*** (15.7)	5.73*** (14.65)
Year-fixed effect	Yes	Yes	Yes	Yes
Sample size	208	458	666	666
Adj-r^2	0.7779	0.4269	0.5341	0.5383

Note: *Significant at the 0.10 level; **significant at the 0.05 level; and ***significant at the 0.01 level.

supplement of capital on the population of shrinking cities is more significant; and infrastructure investment plays a complete mediation effect in this conduction mechanism. Hence, Hypothesis 2 is verified.

Robustness Test

Previously, we use the sum of land transfer income and reserved land mortgage financing income as the land finance indicator for empirical analysis. However, due to the limited reserved land, the reserved land mortgage financing income is relatively small, and land transfer income is still the most important part of land revenue. In China, land transfer income is composed of land bidding, auction, and listing (hereinafter referred to as land-BAL) income and land negotiated transfer income. Among them, the land-BAL is applicable to various types of profit-oriented land such as commercial, tourism, entertainment, and residential land, which is a land transfer activity determined by market supply and demand, and this type of transfer income usually accounts for most of the total land transfer income. Meanwhile, the land negotiated transfer is applicable to non-profit-oriented land, and the government sets the land price in consultation with the land users. This is a government-led and administratively oriented land transfer activity, and its proportion in the total land transfer income is relatively small. Therefore, as the most important contributor to land revenue, the income from land-BAL can represent the land finance well.

Land-BAL, as a market-oriented way to supplying profit-oriented land, can directly reflect the real demand for profit-oriented land in the market. As mentioned in the "Research Hypotheses" section, in the shrinking cities, the decline in the demand for profit-oriented land from enterprises is the main cause for the decline in land finance and insufficient capital for urban construction, which, in turn, leads to further urban shrinkage. Therefore, the use of land-BAL income can mainly reflect the impact of land finance changes on urban population.

For these reasons, we use land-BAL income (ln_finance_BAL) as an alternative indicator of land finance, and the aforementioned models (1)–(5) are validated by a robustness test. The data come from Former Ministry of Land and Resources (2017a).

Hypothesis 1 Test

Table 7 shows the regression results of Hypothesis 1 using the land-BAL income indicator. As shown in Columns 1–3, the income from land-BAL has a positive relationship with the population of shrinking cities and nonshrinking cities. In Column 4, after adding the dummy and interaction terms, the coefficient of shrink is significantly negative, and the coefficient of interaction term shrink * ln_finance_BAL is significantly positive, which indicates that the contraction of land-BAL income has a more significant impact on shrinking cities. The test results are consistent with the findings of the aforementioned empirical analysis.

Hypothesis 2 Test

Table 8 reports the regression results of Hypothesis 2 using alternative indicators of land finance. The results in the first step show that there is a positive correlation between the land-BAL income and the population of shrinking cities. The results from the second step show that the land-BAL income has a positive correlation to the infrastructure investment in shrinking cities. In the third step, after adding both land-BAL income and infrastructure investment, the coefficient of infrastructure investment is significantly positive at a confidence level of 99%, and the coefficient of land-BAL income is no longer significant, indicating that infrastructure investment has a complete mediation effect. Therefore, the test results are consistent with the findings of the aforementioned empirical analysis.

Table 8. Mediation effect of infrastructure investment on urban population via land finance in shrinking cities (with land-BAL income indicator)

Independent variable	Model (1) Step 1	Model (2) Step 2	Model (3) Step 3
Explained variable	ln_pop	ln_inv	ln_pop
ln_finance_BAL	0.0539* (1.96)	0.191*** (7.39)	−0.029 (−1.01)
ln_inv			0.434*** (6.23)
*F*1	0.2702*** (11.94)	0.366*** (17.35)	0.110*** (3.34)
*F*2	−0.2165*** (−8.94)	−0.0227 (−0.99)	−0.207*** (−9.29)
*F*3	−0.008 (−0.41)	−0.011 (−0.59)	−0.003 (−0.18)
Intercept item	6.006*** (16.21)	13.98*** (40.13)	0.056 (0.05)
Year-fixed effect	Yes	Yes	Yes
Sample size	208	208	208
Adj-r^2	0.7779	0.9281	0.8139

Note: *Significant at the 0.10 level; **significant at the 0.05 level; and ***significant at the 0.01 level.

Discussions

For the cities or regions that implement a land finance system, the empirical results verify that the contraction of land finance has a heterogeneous impact on shrinking cities and nonshrinking cities and has a more significant impact on shrinking cities. The reason may be that, in shrinking cities, the declining population lead to the decrease in land demand and the increase in land mortgage financing risk, which cause land finance contract. Meanwhile, the contraction of land finance will lead to a reduction in available government funds, aging of urban hardware facilities, and deterioration of the urban economy, housing, and the employment environment, which, in turn, result in the further decline of population in shrinking cities, thereby forming a vicious cycle and catalyzing the shrinkage rate of these cities.

As for the impact mechanism of land finance contraction on shrinking cities, the insufficient replenishment of infrastructure investment funds caused by the contraction of land finance is the main influencing route. Citizens of shrinking cities pay more attention to the overall hardware facilities and the city image. Because these factors are closely related to people's daily life, they are a visual indicator by which people can evaluate life satisfaction and urban attractiveness, and increasingly outdated urban hardware facilities are more likely to accelerate the further decline of population. However, the land supplement brought by land finance has little impact on residents of shrinking cities. This may be due to the slow economic development of these cities, leading to a low demand for land. The current level of per capita land use has met the needs of urban development, and land oversupply even occurs in some cities. In this case, insufficient supplement of land will not affect the development of the city but can improve the efficiency of land use and optimize the input–output ratio of the land.

This study also proves that economic development level and social resources factors such as urban economic development level, education, and transportation facilities have a significant impact on urban population. Specifically, we find that the secondary industry factor has a significant positive impact on nonshrinking cities, but a significant negative impact on shrinking cities. The reason may be that the industrial structure of shrinking cities is relatively outdated, and the production technology level is low, which would result in air pollution, water pollution, aging of infrastructure, and other problems, catalyzing the decline of urban population.

Regarding the natural population growth rate, the results show that it has a significant positive influence on nonshrinking cities while has no noticeable impact on shrinking cites. The reason may be that nonshrinking cities mainly consist of first-tier cities, provincial capitals, and other economically developed cities, which generally have higher living standards and better medical resources, and their natural population growth rates are far above the mean, leading to a positive impact on urban population. However, in shrinking cities, a massive loss of young adults leads to a lower natural population growth rate than average, resulting in an insignificant impact on urban population.

Conclusion

Due to the shortage of construction land and the significant increase in land acquisition costs, the land revenue of Chinese municipal governments began to experience a downturn. As the main source of funds for urban infrastructure investment and the primary force for urban expansion, the land finance contraction has heterogeneous effects on shrinking cities and nonshrinking cities. This paper verifies that the contraction of land revenue has a more significant negative impact on shrinking cities than on nonshrinking cities. Moreover, as for the impact mechanism of land finance contraction on shrinking cities, we find that outdated urban infrastructure caused by the insufficient capital factor is the primary reason for the further loss of population in shrinking cities, the infrastructure investment has a complete mediation effect.

When shrinking cities or regions face the catalytic effect of land finance contraction, they could focus on the replenishment of capital factor and consider how to increase urban construction funds by improving the fiscal expenditure structure or introducing a new financing structure. In addition, from the perspective of urban planning, shrinking cities should abandon expansionary development strategies by adjusting their urban strategic or master plans. Unlike nonshrinking or growing cities, expansionary development strategies will not only fail to increase land revenue, but also causes financial burden, waste of land resources, and even ghost towns in shrinking cities. Instead, these cities should focus on the upgrade of urban infrastructure and the improvement of urban image, so as to improve residents' satisfaction with the city and to achieve a healthy and beautiful *smart shrinkage*.

In addition, this paper initially introduces land finance systems to the research area of shrinking cities and expands the theory of urban shrinkage. The research findings could help shrinking cities adjust their land finance mode accordingly and offer implications for urban planners, policymakers, and academics in the new era of nonincremental urban planning and development.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available from the corresponding author by request

(items including socioeconomic statistics, urban environment, and land finance data).

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