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Population Shrinkage in Resource-dependent Cities in China: Processes, Patterns and Drivers

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Abstract: Resource-dependent cities (RCs) are a vulnerable group of urban settlements that often face population shrinkage; however, population changes in RCs in China are not well understood. This study offers new insight into this matter through a robust analysis that features a longer time scale, a larger sample of RCs, and a finer unit of analysis. It finds new evidence that problems of population shrinkage in RCs are more serious than previous literature has suggested. Approximately 30% of the studied units have experienced either long-term or short-term population shrinkage, and many more are experiencing a slowing down of population growth. Problems are especially common among three types of RCs: the resource-depleted RCs, the forestry-based RCs, and RCs in Northeast China. These results underscore transition policy inadequacies in addressing population loss, and call for a more comprehensive and diversified population policy that tackles the multifaceted factors that contribute to population shrinkage, including lack of industrial support, maladjustment to market oriented reformation, poor urban environment and natural population decline.

Keywords: resource-dependent cities; urban shrinkage; population change; urbanization, China

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1 Introduction

Resource-dependent cities (RCs) are a vulnerable category of urban settlements developed in relation to extracting and processing natural resources. Because of their long-term reliance on extractive industries, these cities are disadvantaged by a mono-industrial structure, peripheral location, boom-and-bust economic instability, isolation from global knowledge networks, and environmental degradation (Lockie et al., 2009; Prior et al., 2012; Li et al., 2015b). Furthermore, when the relevant resource has been exhausted or is no longer considered economic to exploit, RCs often experience sustained population loss, employment restructuring and decline, disinvestment, and protracted economic downturns (Bradbury and St-Martin, 1983; Martinez- Fernandez et al., 2012). To survive, RCs must adopt transition strategies before it is too late, although evidence shows that economic restructuring strategies are speculative and difficult to plan, with few successful cases reported (Marais and Nel, 2016; He et al., 2017; Hayter and Nieweler, 2018).

China has a high number of resource-dependent cities, with most of them established by the government during the 1950s under an economic strategy that strongly favored heavy industrialization (Wang et al.,

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2014b). Geographically, most Chinese RCs are located inland, where abundant natural resources are located. According to official documents (State Council, 2013), China has 262 RCs, including 126 prefecture-level administrative units and 136 county-level administrative units. While these RCs played an important historical role in supporting nation-building projects in the planned economy era, many of them have begun to face multiple economic, social and environmental challenges after nearly four decades of large-scale resource exploitation. Up to 2011, 69 RCs (26%) had been identified as 'resource exhausted' by the central government (National Development and Reform Commission, 2011). In addition to resource depletion, the demanding situation of the RCs has been exacerbated through the opening up of China which has allowed the importing of resources, as well as through more rigorous environmental regulation and a national goal to restructure the economy away from resource exploitation. In this increasingly challenging context, the survival of RCs and their transition towards a post-resource economy have become key problems for the sustainable development of these cities (Dong et al., 2007).

The central government was relatively late in recognizing the significance of the problems facing RCs in China. Only in 2001 was Fuxin chosen as the first pilot city to undergo economic transition in relation to resource-exhausted cities (Li et al., 2009; Hu and Yang, 2018). Since then, a series of measures has been undertaken to restructure the economies of RCs. Reviewing the relevant literature shows that many studies have attempted to critically examine the economic restructuring strategies and practices in RCs (Long et al., 2013; Li et al., 2013; 2015a; 2015b; Woodworth, 2015; Yu et al., 2016; He et al., 2017), and evaluate their transition performance through using various kinds of index systems (Yu et al., 2008; Li et al., 2010; Su et al., 2010; Zhang et al., 2014a; Lu et al., 2016; Chang and Dong, 2016; Tan et al., 2017; Chen et al., 2018). According to these studies, the transition performance of China's RCs has been uneven, with the transition of western RCs occurring more rapidly than eastern and central RCs, and oil-resource cities having the best performance while forestry-resource cities have had the worst. Moreover, developing improved performance of economic, social, and environmental subsystems has not been synchronized, because transition policies have largely focused on economic revitalization, resulting in a stagnation or even deterioration in social and environmental subsystems.

Population change in RCs is closely linked to their economic fortunes, and consequently has been used in the literature as the main indicator of changing urban conditions (Turok and Mykhnenko, 2007). However, few studies have looked at population change in China's RCs. This is likely because, until recently, China's population growth has been rapid and the potential for urban shrinkage has not been sufficiently recognized. However, it is becoming increasingly apparent that urban population loss may become a new challenge facing some of China's RCs. By comparing household registration data from 2000 and 2010 among China's prefecture-level RCs, He (2014) found that approximately 17% of resource-depleted prefecture cities in China were experiencing population loss between 2000 and 2010. Woodworth (2016) examined changes in household registration data within RCs in northwest China from 2000 to 2013 and found that most cities had experienced slower population growth than the national average and that two cities (Lingwu and Yumen) had undergone population decline. Up to date, existing studies mainly focus on the population shrinkage of resource-exhausted cities, thus resource depletion has been commonly regarded as the leading driver for this phenomenon.

In addition, there are methodological issues in existing studies that affect the validity of their findings. First, the use of household registration as an indicator of population introduces a potential for major inaccuracy because a person's household registration (hukou) is designated at birth and difficult to change (Chan, 2009), and therefore this data can not account for migrants, whose movements are massive in number and increasing rapidly (Wu and Logan, 2016). Second, the use of prefecture-level city data as a unit of analysis is problematic for two reasons: 1) prefecture-level cities are large administrative regions that typically consist of a core city, a number of surrounding smaller cities, and countryside; and 2) this unit of analysis is too coarse as it can not detect intra-city population changes. This feature exposes a critical spatial gap in analysis as parts of an RC may experience population decline even if the whole city is growing. This spatial unevenness maybe common because of the dispersed nature of urban development which characterized RCs (Li et al., 2015b). Third, as RCs move through different economic phases, the urban population of these cities may evolve in a non-linear manner. Existing studies, when taking a single time period as a unit of analysis, have failed to take into account this non-linear temporal dynamic. Fourth, given the considerable number RCs in China, there is extensive diversity both in terms of location and in the type of resources involved. Existing studies typically focus on a particular type of resource or a particular region, and are not, therefore, sufficiently comprehensive to detect relevant nuances. Against this background, this study tries to provide a finer method to investigate urban population shrinkage within China's RCs and analyze the multiple drivers for this phenomenon.

2 Data and Methods

Measuring population size of a Chinese city precisely can be complicated, mainly for two reasons (Zhou and Ma, 2005; Chan, 2007). Firstly, 'cities' in China are not exclusively urban entities, but rather administrative units comprising, typically, both an urban core (roughly comparable to the continuously built-up area) and surrounding peri-urban and rural areas. In other words, the municipal boundaries of Chinese cities extend far beyond their functional limits. Second, the criteria used to calculate the population size of Chinese cities are also confusing. Estimating the population size of a city using Hukou population data would include many people who are registered there (typically at birth) but who no longer live in the locale, and exclude those who live in the locale without the local Hukou permit (Chan, 2003). A more accurate data source is the census, which counts all long-term residents of a locality at the time of the exercise. Currently, there are two approaches using census data to count the long-stay population. The first approach uses the overall administrative boundary of a local authority (e.g., the city council area), which may potentially over-estimate the permanent urban population through covering the inhabitants living at the outskirts in peri-urban and rural areas of the municipality. An alternative, and ostensibly more accurate, approach involves counting the long-stay population within a primary urban area, as defined by the National Bureau of Statistics. This is the ideal way to estimate the actual population of Chinese cities. However, the main challenge to this approach is that the criteria for defining primary urban areas have not been consistent over time (Kamal-Chaoui et al., 2009). Furthermore, detailed population breakdown figures below the town/township level, which would be necessary for defining its functional boundary, are not readily or officially available.

Based on the available published population census data, this article has taken the following approach to estimate the population size of RCs:

(1) For large RCs with inner-city boroughs (an administrative unit below municipalities, also known as urban districts), this study has treated the population change in each inner-city borough individually to discover the spatial unevenness of urban population change. Long-stay population figures, covering the administrative boundaries of 297 inner-city boroughs were used accordingly.

(2) For small RCs without inner-city boroughs (including 71 county-level cities (CLCs) and 132 counties), this study did not have access to all the necessary population and lower-tier boundary adjustments data to measure the long-stay population of each urban area individually. Hence, this study used the total long-stay population residing in urban area of specific cities and towns.

The observed period was split into two decade-long intervals (1990–2000 and 2000–2010), with the population data (Table 1) derived from the National Population Census of China (by county) in 1990, 2000 and 2010 (National Bureau of Statistics, 1992; 2002a; 2002b). In terms of statistical adjustments, this study had to deal with several significant administrative type changes occurring between 1990 and 2010, especially between counties, CLCs, and inner-city boroughs, which generated dramatic population decline or growth accordingly. In addition, the study confronted a number of more fundamental boundary changes, which fragmented the time series data and prevented comparisons across the time period under investigation. To maintain continuity, we had to re-draw the administrative boundaries of most county-level units of analysis, based on official central government information concerning administrative boundary adjustments (Central People's Government, 2006; Administrative Division Website, 2016) and population data of the lower tier units (National Bureau of Statistics, 2002a). Some units had to be removed from the sample due to missing data.

Table 1 Data and resources

Data	Resources
Long-stay population of inner-city boroughs of prefectural-level RCs in 1990, 2000 and 2010	《China Population Statistics Yearbook 1991》(National Bureau of Statistics, 1992) 《Tabulation on the 2000 Population Census of the People's Republic of China by County》(National Bureau of Statistics, 2002b), 《Tabulation on the 2010 Population Census of the People's Republic of China by County》(National Bureau of Statistics, 2012)
Long-stay population residing in urban area of county-level RCs in 1990, 2000 and 2010	《China Population Statistics Yearbook 1991》(National Bureau of Statistics, 1992), 《Tabulation on the 2000 Population Census of the People's Republic of China by County》, (National Bureau of Statistics, 2002b), 《Tabulation on the 2010 Population Census of the People's Republic of China by County》(National Bureau of Statistics, 2012)
Long-stay population of township in 2000	《China Population by Township》(National Bureau of Statistics, 2002a)
Information about administrative boundary adjustments	www.gov.cn http://www.xzqh.org (Administrative Division Website)

3 Results

3.1 An overview of urban population changes in RCs

China has undergone a process of rapid urbanization, almost doubling the overall share of urban population from 26.41% in 1990 to 49.95% in 2010. However, the speed of urban population growth has slowed recently, and the pace of urban population growth in China's RC has also slowed, down from an increase of 26.6% between 1990 and 2000 to 18.5% between 2000 and 2010 (Fig.1). This change has been accompanied by a slowing down in absolute growth numbers overall, with the RC populations as a whole increasing by 21.4 million between 1990 and 2000, but only by 19.1 million between 2000 and 2010. RC population growth accounted for 13.4% in the first period and 9.1% in the second period within national urban population growth overall, which means that the contribution of RCs to China's urbanization is declining. The proportion of the RC population in relation to the national urban population declined from

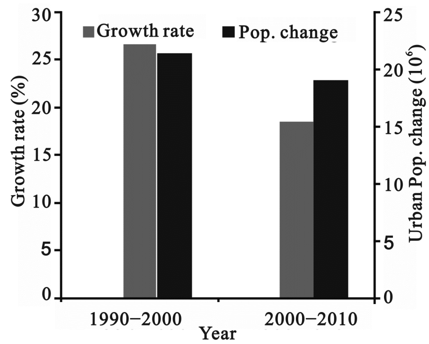


Fig. 1 Urban population change of RCs in China

27.4% in 1990 to 18.4% in 2010. The overall picture is that RC population growth has been outpaced by other parts of China.

There are diverse trajectories of urban population changes over the studied period, involving the following (Units without continuous population data during 1990–2010 are unclassified): a) continuous growth: 323 units experienced continuous urban population growth during the period from 1990 to 2010; b) recent resurgence: 29 units suffered negative urban population growth during the 1990s but exhibited positive growth in the 2000s; c) recent shrinkage: 60 units experienced positive urban population growth during the 1990s, followed by negative growth in the 2000s; d) long-term shrinkage: 45 units experienced continuous urban population loss during the period from 1990 to 2010. Overall, while most units in the RCs maintained population growth, shrinkage was identified as a growing problem in some RCs. A total of 74 units (16% of total units) had experienced urban population shrinkage in the 1990s, whilst in the 2000s that figures grew by over 47% to include 109 units (22% of the total units) (Figs. 2a–2b). Focusing on the units with shrinking population, the total population loss raised from 0.99 million in 1990s to 1.94 million in 2000s, the average population loss per unit in the 1990s was 13 400, while in the 2000s it was 17 800 (Figs.2c–2d). Population shrinkage is also a highly persistent phenomenon, as 61% of the units with shrinking populations in the 1990s experienced urban population loss in the 2000s. These findings suggest that population shrinkage is more severe than revealed in previous research (He, 2014; Woodworth, 2016).

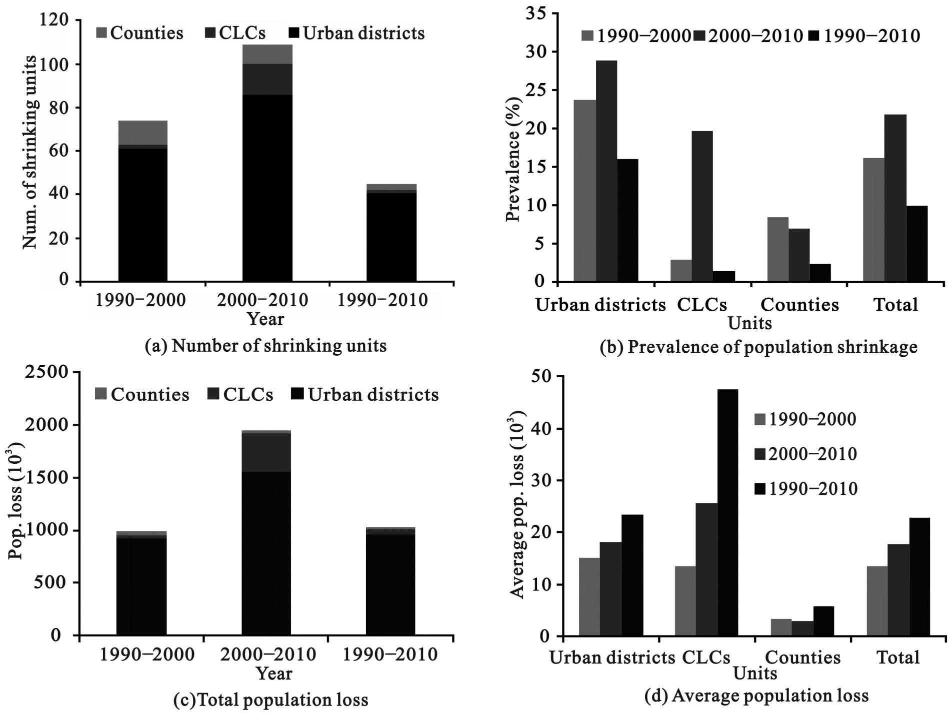


Fig. 2 Disparities of urban population shrinkage in counties, county-level cities (CLCs) and urban districts. Shrinking units in 1990–2010 are the units experienced population loss both during 1990–2000 and 2000–2010

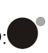
Population shrinkage varied across county-level RCs in China. Large RCs with inner-city boroughs are more attractive than smaller counties and CLCs for floating migrants in China (Liu et al., 2015). Consequently, the inner-city boroughs are the main growth poles of RCs. Nevertheless, being dependent on volatile resource-based industries, the inner-city boroughs of RCs have also been more susceptible to a sudden reversal of migration flows. Fig. 2 indicates that the disparity in urban population growth within inner-city boroughs was more significant than in counties & CLCs during the study period. Comparatively, the number of shrinking units, the prevalence of population shrinkage and the total population loss in inner-city boroughs of RCs are much higher (Figs. 2a–2c). For example, in the 1990s, around 23.7% of inner-city boroughs experienced urban population loss. In the 2000s, the figure increased to almost 29%. Moreover, 16% of inner-city boroughs suffered from long-term population shrinkage between 1990 and 2010. Meanwhile, it should be noted that population shrinkage in CLCs increased significantly in terms of the number of shrinking units, the prevalence of population shrinkage, the total population loss and the average population loss (Fig. 2).

3.2 Morphologies of urban population shrinkage

We identified six different morphologies of urban population shrinkage in China's prefecture-level RCs (Table 2). Type A refers to 'total shrinkage'. This type is quite rare, but is becoming more common. Cities with total shrinkage typically have a shorter urban history, are smaller in size, and are economically relatively underdeveloped. It should be noted that none of the RCs experienced this type of population shrinkage long-term, either experiencing it in the 1990s or in the 2000s. Furthermore, apart from Guangan, population loss was modest at less than 10%. Type B refers to 'near-total shrinkage'. This type represents cities with serious population shrinkage problems, and some Type B cities such as Yichun, Shuangyashan, and Jixi in Heilongjiang were already very close to Type A. Type B usually occurs at RCs established in the 1950s, and typically involves cities that are resource-exhausted because of a prolonged period of resource extraction. The scale of population loss is more serious than Type A, most districts of Yichuan, Shuangyashan, and Jixi experienced over 10% population loss between 2000 and 2010. Type C refers to 'peripheral shrinkage'.This type is uncommon and typically occurs among cities that have not exhausted their resources. Type D refers to 'satellite shrinkage', and involves the most common form of shrinkage. These shrinking districts are typically places of resource extraction suffering resource decline. The severity and persistence of shrinkage are also the most pronounced in Type D. Between 1990 and 2000, there were 12 cities experiencing this type of shrinkage, and these cities continued to suffer shrinkage in the period between 2000 and 2010, with more than half of them losing more than 10% of their populations per decade. Type E refers to 'disjointed shrinkage'. This type of RC was typically formed in the period between the 1950s and the 1970s, when urban areas were built near resource sites, contributing to a highly fragmented urban footprint. Compared to other types, the population shrinkage in these RCs is typically not as severe, usually less than 10% population loss over 10 years, and typically not persistent. Type F refers to 'partial shrinkage', and is the second most common type of shrinkage. Cities of this type represent many differing varieties of resource use and were built at varying times, but we observed that most of these cities are located in the northeast. We further noted that some cities, such as Fushun, changed from this type to Type B (near-total shrinkage) in the studied period as more districts began to experience urban shrinkage in those cities.

Different from the total shrinkage widespread in western RCs (Martinez-Fernandez et al., 2012), the above result shows that total shrinkage (Type A) is not the leading morphology of population shrinkage in China's prefecture-level RCs. Most RCs experienced population shrinkage and growth in different parts of city simultaneously. Considering the differentiation of urban population shrinkage in terms of morphology, severity and persistence, coping responses for these RCs should not be the same, either. Among these RCs, Type B and Type D should receive more attentions. Comparatively, they had higher severity and persistence of urban population shrinkage. It's more likely that they would keep losing population without effective interventions. For these two types of RCs, corresponding measures should be adopted according to their potential for further urbanization. For example, if some RCs, such as some urban districts spatially disconnected from the main urban core, could not attract and support a larger population, then measures should be taken to make them adapt to a smaller population. For large RCs with potential and need for regaining population, how to reverse the long-term population shrinkage should be the focus of the coping policies. In contrast to type B&D, urban population shrinkage of most RCs in other types was just a periodical phenomenon with a relatively lower shrinking degree. The experiences of coping urban population shrinkage in these RCs could provide useful lessons for RCs suffered long-term population shrinkage. However, it is hard to say whether these RCs will suffer long-term population shrinkage. For RCs in Type C, E&F, long-term population shrinkage only emerges in few urban districts and most parts of these cities still have attractiveness for migrants. Thus, a more balanced development strategy should be implemented in these RCs. For RCs in type A, countermeasures should be taken if some of them experienced long-term population shrinkage. Likewise, corresponding measures should be based on their potential for further urbanization.

Table 2 Urban morphology of population shrinkage in China's prefecture-level RCs

Types	Number			Typical cities	Characteristics
	1990–2000	2000–2010	1990–2010		
A: 	1	5	–	Chizhou, Anshun	All urban districts suffer population loss
B: 	4	8	4	Yichun (13/15 boroughs shrinking), Jixi (4/6 boroughs shrinking)	More than half of the urban districts suffer population loss
C: 	3	3	1	Datong (Nanjiaoqu), Changzhi (suburb)	Urban districts located at the urban fringe suffer population loss but the urban core continues to grow
D: 	12	22	12	Tangshan (Guye), Fuxin (Qinghemen)	Shrinkage occurs at one or two urban districts that are spatially disconnected from the main urban core
E: 	7	8	2	Baishan (Jiangyuan), Ezhou (Huarong)	One district in RCs with loosely connected urban districts suffer population shrinkage
F: 	12	11	2	Liaoyuan (County), Jiaozuo (Zhongzhan)	Less than half of the urban districts suffer population shrinkage

Note: Grey areas stand for shrinking areas and black areas are growing areas

3.3 Spatial differentiation of urban population shrinkage in RCs

Population change varied significantly across the four economic macro-regions of China (Fig. 3 and Fig. 4). RCs in Northeast China, the industrial heartland during the era of planned economy, experienced significantly slower urban population growth and higher prevalence of urban population loss during the period from 1990 to 2010. Moreover, the northeast had the highest number of population shrinking units in both time periods, with 40 shrinking units in the 1990s and 52 shrinking units in the 2000s. It is worth highlighting that there were more shrinking units in the 2000s than growing units, perhaps for the first time in the development process concerning RCs in Northeast China. Between 1990 and 2010, there were 30 continuously shrinking units in Northeast China, accounting for 66.7% of the national total. Some studies have contended that, since 2000, the economic situation in respect of RCs in Northeast China has improved (Tan et al., 2016; Lu et al., 2016), but any such improvement, assuming it is occurring, does not seem to be accompanied with population growth. On the contrary, the

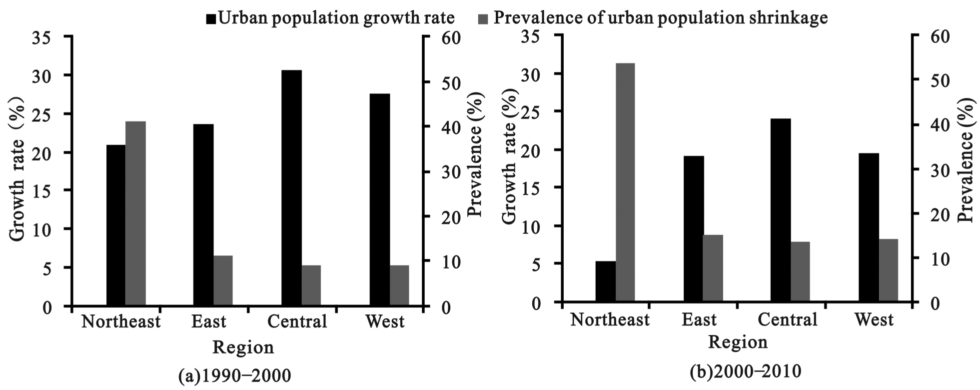


Fig. 3 Urban population change of RCs in four economic macro-regions

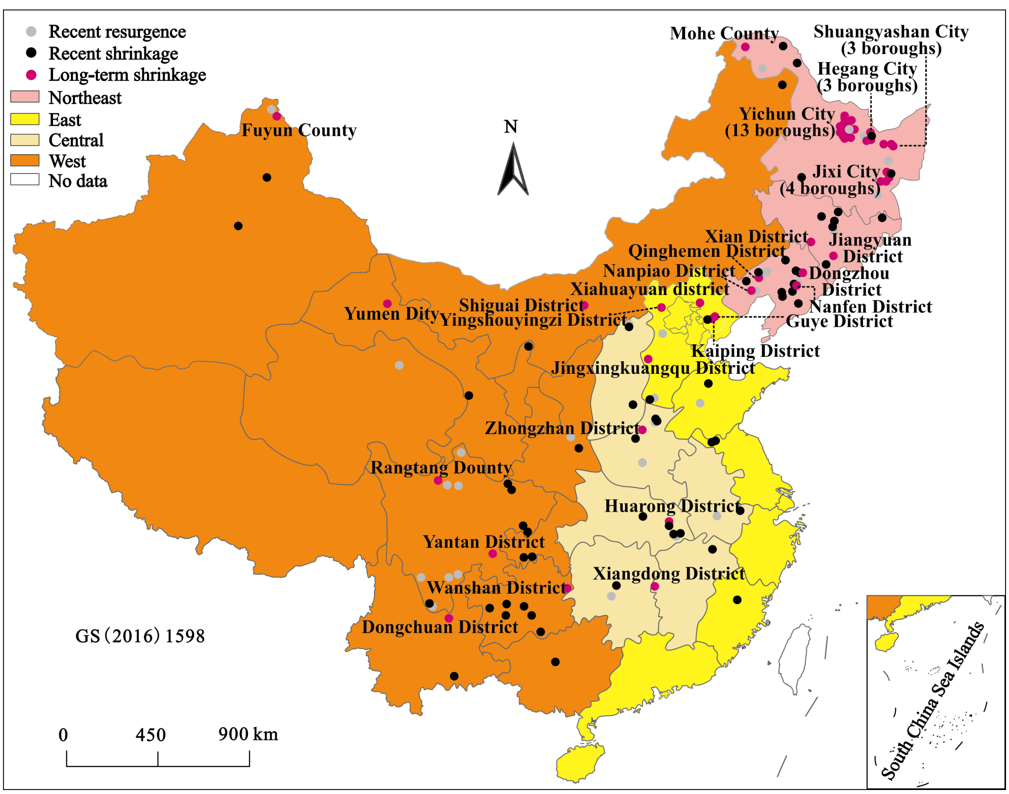


Fig. 4 Spatial differentiation of urban population shrinkage in China's RCs. Only the long-term shrinking units are labeled

problem of population loss of RCs in Northeast China has significantly worsened. This fact indicates that without a more comprehensive approach to urban transition, it will be difficult for RCs to replenish their populations and avoid shrinkage. On the other hand, given the large number of long-term shrinking RCs in the northeast, reversing population shrinkage would not be the only choice for all shrinking RCs, some of them might have to adapt to a smaller population.

Eastern (coastal) China comprises the country's most developed and urbanized region. With a vibrant economy, it was not expected that population decline would be significant. Overall, our data show that the RCs in this region grew throughout the studied period, but the speed of growth is declining (Fig. 3). Shrinking units are uncommon in this region, with the exception of Hebei Province (Fig. 4). During the period from 1990 to 2010, 7 out 26 resource-dependent units in Hebei experienced urban population loss. These shrinking units in Hebei involved districts isolated from the urban core (Type D), such as Zhangjiakou (Xiahuayuan District), Chengde (Yingshouyingzi District), Tangshan (Guye District), Handan (Fengfengkuangqu District), and Shijiazhuang (Jingxingkuangqu District). Among them, Xiahuayuan District, Yingshouyingzi District, and Jingxingkuangqu District have been listed as resource-depleted cities. Due to being next to Beijing and Tianjin, these shrinking RCs have potentials to receive industrial transfer of the metropolises, which could provide new opportunity for urban growth. Thus, stopping and reversing population shrinkage would be the practical choice for these RCs. Currently, these RCs are implementing urban renewal program under central government's supports with the aim of improving local living conditions.

For less developed central and western China, the urban population growth rate of RCs remained at a relatively high level in spite of some slowing down. In the period from 1990 to 2000, population growth in RCs in central and western China accounted for 63.8% of the total RC growth, and the figure rose to 71.2% in the period from 2000 to 2010. Compared with the northeast, urban population loss within RCs in these regions is less severe. Generally, the exploitation and utilization of natural resources continued to be key drivers of urbanization within these regions during the period from 1990 to 2010. Only a limited number of RCs that emerged in the heavy industry-oriented phase of the early planning era, particularly in Sichuan, Guizhou, and Hubei provinces, experienced urban population loss (Fig. 4). Comparing with other regions, shrinking RCs in central and western China differ greatly in terms of urbanization conditions, which should be considered in designing countermeasures for population loss of these RCs. For some shrinking RCs located in remote areas with unfavorable conditions for further urbanization, relocation program, which has been practiced in Yumen, should also be taken into consideration.

3.4 Disparity among RCs based on different resources type

The resources that drive RCs can be either renewable (e.g., timber) or non-renewable (e.g., coal, metals). Since non-renewable resources will eventually be depleted, it has been standardly argued that the development trajectory of RCs based on non-renewable resources would be more problematic to maintain. However, from our data on China (Fig. 5), population growth within forestry-dependent RCs was the slowest among all RCs. This occurred primarily for two reasons. First, the forestry RCs are typically located in very remote and sparsely populated areas of China's northeast and southwest, which makes it difficult to attract more people. Second, the protection of natural forests has become increasingly stricter since the introduction of natural forest protection policy in 1998. Many RCs are facing challenges due to policy-driven reductions in forest harvesting, even the complete halting of harvesting. Between 2000 and 2010, the population in this type of RC only increased by 0.48 million, which involved a 60.1% reduction compared to the previous decade. Population growth reduced from 24.9% in the 1990s to 7.6% in the 2000s. Moreover, population shrinkage has become a commonly shared problem among forestry RCs. In the 2000s, 45.7% of units experienced shrinkage, which was significantly higher than in other types of RCs.

As the world's largest coal producing and consuming country, China has a large number of coal RCs. Coal RCs accounted for most population growth over the studied period (approximately 40% of all urban population growth of RCs). However, population growth in coal RCs has slowed down significantly in recent years, with the population growth rate ranked the second lowest after forestry RCs. Moreover, population shrinkage

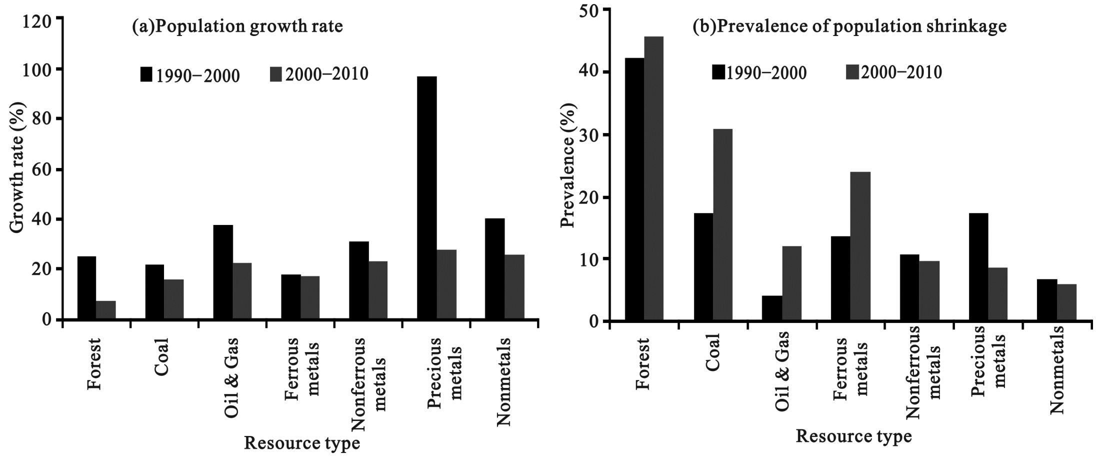


Fig. 5 Urban population growth and shrinkage of RCs based on different kinds of resources

has also become a commonly shared problem among coal RCs. In the 2000s, coal RCs had 56 shrinking units, or 44% of the total number of shrinking units. RCs based on oil & gas, nonferrous metals, precious metals and non-metals all experienced population growth slow-down, but overall maintained a relatively fast growth rate, and had a small number of shrinking units. RCs based on ferrous metals experienced few changes in terms of growth rate, but the number of shrinking units was on the rise in the 2000s, which shows that population shrinkage is also a problem for this type of RC.

Overall, population shrinkage is a common phenomenon of RCs based on different types of resources. Comparatively, RCs based on forest, coal and ferrous metals need more attentions, as they suffered a relatively higher prevalence of population shrinkage. RCs based on different types of resources differ in many aspects, such as location, industrial development, environmental problem and transition mode, so countermeasures for population shrinkage should also be differentiated. For example, restoration of mining-related environmental and geological problems is a necessary measure for RCs based on non-renewable resources to cope with population shrinkage, but for forestry-dependent RCs, more attentions should be paid on increasing employment and improving living conditions by fully utilizing their ecological advantages.

3.5 Comparison of RCs in different stages

From a global perspective, economic decline usually occurs in the later stages of RC development and contributes further to urban shrinkage (He et al., 2017). Chinese RCs face a similar trajectory. It can be seen in Fig. 6 that RCs in China within a stage of recessionary are the ones with slowest population growth and face the greatest challenges in terms of population shrinkage. Between 2000 and 2010, population only increased by 10.3% in these recessionary RCs, much lower than in other RCs, and 45% of the units in these cities had experienced shrinkage. Resource depletion triggers a chain of events, including the shutdown of mining enterprises, job losses, and urban poverty, which has a significant negative effect on the population change of these cities. Although the central government has invested in resource-depleted RCs to facilitate post-resource transitions, most of them are still in the stage of recessionary according to official documents (State Council, 2013). Comparing with RCs in other stages, recessionary RCs face multiple problems in the aspects of economic development, employment and environment restoration. Thus, population recovery of recessionary RCs is a more difficult and much longer process, which needs a more comprehensive approach. Many cases in western countries show that not every recessionary RC could achieve population recovery. Considering the high prevalence of population shrinkage in China's recessionary RCs, right-sizing would be a coping strategy for some recessionary RCs that can not regain population in a short term.

In contrast, population growth rate is higher for RCs in other stages of development. Growing RCs have the fastest population growth, followed by mature RCs and regeneration RCs (RCs transiting from resource

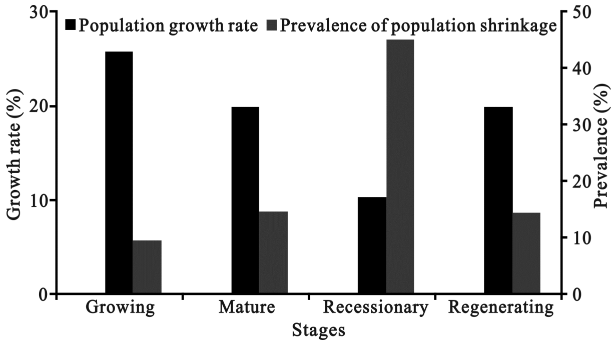


Fig. 6 Urban population change of RCs in different development stages (2000–2010). The classification of RC development stages was first proposed in (State Council, 2013)

dependency to alternative sources of growth). However, these cities also experienced population shrinkage to varying extents, despite not facing problems with resource depletion or already transiting to a new development path. For example, some growing and mature RCs in the remote Sichuan and Guizhou provinces, such as Nanchong, Guangan, Liupanshui, and Anshun, experienced population shrinkage in some of their urban districts (Fig. 4). Some regenerating RCs such as Tangshan and Anshan also experienced partial population shrinkage (Fig. 4). Comparing with shrinking recessionary RCs, most shrinking RCs in the stages of growing, mature and regenerating were recent shrinkage. Only a few of these RCs, such as Guye district in Tangshan (Type D in Table 2), suffered long-term population shrinkage. Coping strategy for this type of population shrinkage, as mentioned in section 3.2, should be taken accordingly. Generally, the population change of RCs in the stages of growing, mature and regenerating needs continued attention.

4 Typical drivers for urban population shrinkage of China's RCs

Up to date, little has been written on the drivers of population shrinkage of China's RCs. Existing studies usually attribute the phenomenon to economic factors, such as slowdown of economic growth in China, single industrial structure and the 'boom and bust' industrial cycle (He et al., 2017). It is certain that economic factor is an important driver for population shrinkage of China's RCs, but it might not be the only driver. A recent study about urban population shrinkage of China identifies four drivers with Chinese characteristics, which are not limited to economic factor, but also include institutional, environmental and demographic factors (Li and Mykhnenko, 2018). Although this work can not provide direct explanation for urban population shrinkage of RCs, it provides us with directions for driver analysis. Based on this work, the study tries to analyze the drivers for urban population shrinkage of China's RCs in the following four aspects.

4.1 Lack of industrial support

Since the 1990s, as China's urbanization has sped up, the drivers of urbanization have changed fundamentally, moving away from the industrialization-driven model to a more balanced approach that involves both industrialization and service-oriented growth (Gaubatz, 1999; Cao and Liu, 2010; Gu et al., 2015). However, for most shrinking RCs, the traditional drivers of urbanization have been weakening and the rise of new drivers is not strong enough.

Firstly, the role played by resource-based industries on urban population growth is weakening, especially for resource-depleted RCs. For RCs at other stages of development, jobs created by the resource sector are also declining. For example, while the production of coal increased from 1.08 billion t in 1990 to 32.35 billion t in 2010, jobs in the sector decreased from 5.39 million in 1990 to 5.27 million in 2010 (National Bureau of Statistics, 2011). Fewer workers are needed because of increased productivity per worker. Another factor causing population shrinkage is a reduction in production due to unfavorable market conditions and/or the government's environmental protection policy. Taking oil as an example, the profit margins of Daqing Oil Field have been significantly eroded by falling oil prices on the international market and an increase in production costs (Li et al., 2015b). Consequently, Daqing's oil production in 2016 was only 36.56 million t, which was a significant drop from the 1997 peak of 56 million t. In the forestry sector, Heilongjiang's timber harvest has declined from 10.2 million m^3 in 1998, the year in which the natural forest protection policy was introduced, to only 1.46 million m^3 in 2011.

Secondly, the development of post-resource industries has been slow, with only limited capacity to stimulate population growth. RC economic development is characterized by strong path-dependency, and many RCs lack sufficient motivation to transition before entering a resource-depletion phase. Even though the central government has pushed for the economic transition of RCs since 2001, experience has shown that most RCs find it difficult to develop new internet-based or service-oriented industries (Li et al., 2013). Most RCs have been seeking a pathway of reindustrialization (Wang et al., 2014a). The newly-developed sectors have involved mostly capital-intensive heavy industries comprising petrochemicals, metallurgy, and equipment manufacturing, which do not provide large numbers of jobs. As of 2010, there were over 600 000 jobless miners (State Council, 2013), which suggests that new industries had failed to absorb the surplus labor from the resource sectors.

4.2 Maladjustment to market-oriented reformation

With the acceleration of market-oriented reformation since 1990s, China's urbanization is shifting from a government-led model to a more balanced approach where the private-sector economy, in terms of both domestic and foreign involvement, also plays a significant role (Liu, 1992; Shen and Ma, 2005). As developed by the central government, State-owned enterprises (SOEs) used to be a leading role in urban development of China's RCs. They have not only controlled the extraction and processing of resources, but have also contributed to local jobs and fiscal budgets, and have provided an array of public services such as water supply, electricity, heating, and road construction (Li et al., 2015b). Local governments, on the other hand, have played a minor role in urban development. Following China's market-oriented reformation, SOEs in RCs have begun to experience difficulties, and have downsized their staff and handed over public service responsibilities to local governments to increase efficiency and streamline operations (Wang et al., 2014a). Meanwhile, the long-entrenched dominance of the SOEs and their monopoly of resources have made it very difficult for private companies to thrive in these cities. For example, in Daqing, the private-sector economy only contributed approximately 20% to the city's GDP in 2010 (Li et al., 2015b). The weakening of SOEs and the weak private sections created problems, such as unemployment and dilapidated urban infrastructure, which contributed to the slowing down of population growth and shrinkage in RCs.

Another aspect of market-oriented reformation of RCs is the resources pricing mechanism. During the era of planned economy, RCs contributed resources products under the command of central government and sold resources products at the price solely determined by central government, which ensured the stable development of China's RCs. However, the market-based pricing mechanism of resources products has been gradually introduced during the process of market-oriented reformation. Under this situation, RCs have to face the fluctuation of resources market. As a result, the economic instability of China's RCs has been greatly enhanced, which could also lead to the periodical or long-term population shrinkage of China's RCs.

4.3 Poor urban environment

During the period from 1990 to 2010, urban population growth in China was mainly fueled by extensive rural-to-urban migration (Chan, 2014). According to the 2010 National Population Census, the overall size of China's floating population living and working outside their registered localities had reached 261.4 million or 20% of China's total population. Research shows that coastal regions with more developed economies and better living environments have been more attractive to migrants. The coastal regions attracted 61.2% of total migrants in 2005 (Duan and Yang, 2009). RCs, in comparison, have been unattractive to migrants for their poor urban environment.

First, economic development is more limited and salaries lower in RCs. While the central government has increased its support especially to resource-depleted RCs, the overall economic development of RCs remains unimpressive (Li et al., 2013; He et al., 2017). In 2010, the per-capita salary of prefecture-level resource-depleted RCs was 28 202 RMB/year, which was 79% of the national average for cities (Zhang et al., 2014b). Second, because RCs are mainly located where resources are readily found, they are typically located in remote locations, far away from large metropolitan areas (Sun and Li, 2013). Third, influenced by the ideal of 'production first, living second' of the planning era, RCs typically focus on their production function, with urban services such as education, health, housing, and transportation tending to be neglected. Fourth, pollution and environmental degradation problems are more serious in the RCs (Wan et al., 2015). A long history of resource exploitation and processing typically results in a poor environment with many pollution problems. For instance, resource-depleted RCs' average industrial waste water, SO_2 emissions, and smoke emissions were all 10 times higher than the average city level in China. Land subsidence is another problem, with an estimated 140 000 ha of subsidence needing to be treated before the land can be used again. Because of these problems, RCs are typically not the first choice of the floating population.

4.4 Natural population decline

Internationally, an aging population and a low birth rate are key reasons for a slowing down and shrinkage of population growth, especially in developed countries such as the UK, Japan, and Scandinavian countries (Mykhnenko and Turok, 2008; Matanle and Rausch, 2011). While China is a developing country, these demographic factors also play a role because of the country's implementation of a strict birth control policy since the 1980s. Because of this policy, China's natural population growth declined from 14.39% in 1990 to only 4.79% in 2010. As the population control policy is stricter in the cities than in rural areas, the impact of population control on urban populations has been of even greater significance.

The natural population growth of RCs in 2000 was 6.37%, dropping to 4.24% in 2010, which was below the national average. A total of 79.8% of the studied units had a natural population growth decline. Moreover, in 2000, there were 17 units with a negative natural population growth, which had increased to 68 units in 2010. This phenomenon is especially strong in the northeast. Between 2000 and 2010, of 97 units in the northeast, 85 had experienced a decrease in natural population growth. In 2000, there were 13 negative growth units in the northeast, whereas in 2010 there were 54.

5 Conclusions and Recommendations

Population shrinkage is a long-neglected topic in the study of resource-dependent cities in China. This study has advanced research in this area through conducting an analysis featuring a longer time scale, a larger sample of RCs, and a finer unit of analysis. Results from our more fine-tuned analysis suggest that approximately 30% of the studied units have experienced either long-term or short-term population shrinkage, and it is becoming increasing common within RCs in China, especially among three types of RCs, namely, the resource-depleted RCs, the forestry-based RCs, and RCs in northeast China. Based on the spatial characteristics of population shrinkage, the paper indentified six morphologic types of population shrinkage in China's RCs. Furthermore, the paper presented typical drivers for this phenomenon in China's RCs, including: 1) Lack of industrial support; 2) Maladjustment to market-oriented reformation; 3) Poor urban environment; 4) Natural population decline.

Comparing with RCs in western countries, population shrinkage in China's RCs manifested some distinctiveness. First, total shrinkage is not the leading morphology of population shrinkage in China's RCs, and abandoned RCs have not been found in China during research period. That means most RCs don't completely lose attractiveness for migrants. These cities, at least some parts of these cities, might still have potential for further urbanization. Second, although population shrinkage is more severe in recessionary RCs, it is not a phenomenon limited to recessionary RCs. This suggests that population change of RCs is not solely governed by 'boom and bust' industrial cycle, multiple drivers other than economic factor have impacts on population shrinkage in China's RCs. Third, under the special economic system of China, the role of central government can be felt in every driver identified in the paper, which is rarely mentioned in RCs of Western capitalist economies.

As an important part of China's urban system, population shrinkage of RCs is not a negligible phenomenon in China's urbanization. However, up to date, this phenomenon has not been widely considered by local government's plan for urban development. Within China's institutional arrangements regarding land-related finance, local officials tend to aspire after larger population size so as to get more constructible land. In reality, many RCs have failed to achieve their population growth targets, and the commitment to urban expansion is neither sustainable in the long-run, nor helping RCs address their many barriers to growth. Our study shows that population shrinkage of China's RCs has significant differences in terms of morphology, severity and persistence. Thus, the tackling strategies for these RCs should also be diversified. For some shrinking RCs, population shrinkage is just a short-term phenomenon which is reversible even without specific interventions. For RCs suffered long-term population shrinkage, depending on their potential for further urbanization, different interventions should be adopted to reverse population shrinkage or make them adapt to a smaller population.

Addressing the population shrinkage is a critical matter for RCs, and particularly so for China as a country in a phase of rapid development. This study provides a comprehensive analysis on this phenomenon, but greater efforts are needed in the future to gain a more robust understanding of the challenges and opportunities faced by RCs regarding their populations. First, the population change of China's RCs after 2010 is not mentioned in the paper, due to the unavailability of the new population census data in 2020. With the enhancement of China's population mobility, population shrinkage of China's RCs might keep intensifying. Further research about this phenomenon should reflect the latest population change of China's RCs. Second, this study shows that, by using a longer time scale, population change in RCs may exhibit divergent trends in different time periods. Questions remain concerning under what conditions population shrinkage may become a long-term trend, and under what conditions the phenomenon may be reversed. Addressing these questions is paramount to the formulation of effective responses to population shrinkage. Third, little has been known about the effects of population shrinkage on China's RCs. For policy makers, it is essential to know the multiple effects of this phenomenon. Thus, more research is vital to discover the full range of good and bad consequences of population shrinkage at different scales.

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