# Identification and Mechanisms of Regional Urban Shrinkage: A Case Study of Wuhan City in the Heart of Rapidly Growing China

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**Abstract:** Urban shrinkage has been witnessed often throughout the history of Western cities and occurs concurrently with population loss, economic decline, neighborhood decay, and other profound changes to urban spaces and the built environment. Unlike in the Western context, urban shrinkage in China has occurred concurrently with rapid urbanization and urban growth, marking a relatively new urban phenomenon, known as *regional urban shrinkage*, that has recently emerged in large Chinese cities and metropolitan areas. This study aims to better understand regional urban shrinkage by identifying such shrinkage and exploring its mechanisms in Wuhan, a megacity in Central China. Drawing on population data, land-supply data, and night-time light data, this study first identifies areas of regional urban shrinkage through the dimensions of demography, land use, and economy and then conducts a qualitative investigation of Wuhan's Qingshan District as a pilot study to explore the mechanisms and causality of regional urban shrinkage from the perspectives of antiglobalization, industrial transformation, and capital circuits. This study expands the research paradigm of urban shrinkage in the Western context to Eastern society by contributing an empirical study conducted in China and broadens current scholarship by focusing on the complexity, contextualization, and localization of urban shrinkage. **DOI: 10.1061/(ASCE)UP.1943-5444.0000643**. *© 2020 American Society of Civil Engineers*.

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## Introduction

China has remained in a state of rapid urbanization since the early twenty-first century and has integrated into the accelerating progress of globalization (Liu and Yang 2017). As a consequence, Chinese cities, particularly regionally central cities, have witnessed exponential growth in their population, economy, and land supply for urban construction (Yang et al. 2015). However, the global financial crisis (GFC) that began in 2008 changed this rapid economic growth, resulting in a decrease in the growth rate of China's gross domestic production (GDP) from more than 10% to 7% or even lower in major Chinese cities in the years from 2008 to 2014 (Gao 2017). In 2014, the Chinese government officially recognized this decrease in GDP growth rate as the *new normal* status of Chinese cities (Zhang and Li 2017, p. 103). This decrease in the GDP growth rate was also accompanied by a scalar decrease of annual average land supply for urban construction, the deceleration of urban expansion and population growth, and even population loss in some regions (Yang and Dunford 2018). The slowdown in population growth, economic boom, and urban expansion has been observed in different magnitudes at various spatial scales (Li et al. 2015). The coexistence of regional population loss, shrinkage of land supply, and economic fluctuation at the microlevel with the stable growth of economy and urbanization at the macrolevel is a unique urban phenomenon with Chinese characteristics and has attracted the increasing attention of city planners, economists, urban governors, policymakers, and academicians worldwide (Gao et al. 2019). However, such "shrinkage within growth" (Gao et al. 2019, p. 29), referred to as "regional urban shrinkage" (Li et al. 2017, p. 1997), has been underaddressed in the Chinese context and warrants comprehensive research to identify and explore its mechanisms (Gao 2017). Although empirical studies on regional urban shrinkage have been conducted on some cities in Northeast China (Gao and Long 2016; He and Yang 2019; Gao 2019; Fan 2019), the Pearl River Delta in South China (Li et al. 2015; Du and Li 2017b), and the Yangze River Delta in East China (Wu et al. 2015), scant attention has been paid to the central areas in the hinterland of China, the context of our current study.

To address this research gap, our study aims to identify regional urban shrinkage and explore its mechanisms by using Wuhan, the largest capital city in Central China, as the case study. Drawing on census population data, population-sampling data, land-supply data, and night-time light data of 2000, 2010, and 2015, we have the following two research goals: (1) to identify regional urban shrinkage in the dimensions of demography, economy, and land use; and (2) to explore the mechanisms and possible causality of this regional urban shrinkage. This study contributes a practical observation and an empirical case study of regional urban shrinkage in the Chinese context to broaden the understanding of urban shrinkage from the Western to the Eastern context.

The remainder of this study is organized as follows. The ensuing section provides the study background by introducing the concept of urban shrinkage in the Western and Chinese contexts and

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explaining the approaches and data used to identify urban shrinkage in the literature. The following section details the study context and the data and methodology employed in our study. This study then presents the results identifying the areas of urban shrinkage and discussing three mechanisms of this shrinkage: antiglobalization, industrial transformation, and capital circuits. A brief discussion, presentation of conclusions, and recommendations for future research are then presented to conclude the study.

## Background

### Urban Shrinkage in the Western Context

The phenomenon of urban shrinkage has existed in the Western context during economic crises, wars, revolutions, systemic transformations, epidemics, and other catastrophes, resulting in subsequent population loss (Rieniets 2009). Researchers (Wiechmann 2008; Martinez-Fernandez et al. 2012; Hollander et al. 2009) have defined urban shrinkage as occurring in densely populated urban areas with more than 10,000 residents that have faced population loss and economic problems for more than two continuous years. This definition refers to the occurrence of population loss and economic decline that mark urban decline (Beauregard 2009; Bernt 2016; Hollander and Nemeth 2011) and is usually sensitive to spatial scales and geographic contexts (Elzerman and Bontje 2015; Martinez-Fernandez et al. 2012). For example, a shrinking city in the United States was defined as an old industrial area that had lost more than 25% of its population over a period of 40 years (Schilling and Logan 2008); however, the definition of a shrinking city may work differently for Eastern countries. Urban shrinkage is a plural and differentiated process with multidimensional causalities (Haase et al. 2014a, 2016). The economic causes of urban shrinkage include resource depletion, product obsolescence, rising costs of labors, disinvestment, industrial decentralization, deindustrialization, failure in technical upgrading, international division of labor force, and a lack of success in attracting investment in inner cities (Haase et al. 2014b; Martinez-Fernandez et al. 2012). The demographic causes of urban shrinkage can be population aging, declining fertility, and international or internal migration (Haase et al. 2014b). The political reasons may be the adjustment of city boundaries and changes in the urban structure driven by a series of urban phenomena (e.g., urbanization, suburbanization, counterurbanization, and regeneration) (Lang 2012; Martinez-Fernandez et al. 2012). Ecological and environmental triggers of urban shrinkage are also possible; for example, natural disasters, climate change, and insecurity of infrastructure can also cause urban shrinkage (Haase et al. 2014b). All of these multidimensional changes can not only be factors driving urban shrinkage but can also be a part of the effects of urban shrinkage on society; thus, the causes of urban shrinkage can also be the effects. These cause-and-effect relationships among the factors associated with urban shrinkage and socioeconomic, demographic, and environmental changes can differ substantially across geographic contexts (Bernt 2016). Therefore, it may be arbitrary to apply the theory and empirical experience of urban shrinkage originating from the Western context to other geographical contexts (Zhang and Li 2017).

### Urban Shrinkage in the Chinese Context

As the largest developing country and the second largest economy in the world, China has witnessed urban shrinkage different from that in the Western context (Zhou and Qian 2015). Since the implementation of China's Reforms and Opening-Up policy in 1978, Chinese cities have sought to attract foreign investment and international companies to create jobs, increase GDP, and raise tax revenue for governments at various levels (Yang and Dunford 2018). Most foreign and domestic investment in China has been concentrated in the coastal areas, which has widened regional disparities and created sharp regional differences in the demand and supply of migrants for China's labor force (Dunford and Liu 2015). China's rapid growth in urbanization, population, and economy continued for three decades until the onset of the GFC in 2008, which created a significant decline in demand for Chinese manufacturing exports and undermined China's export-oriented economic growth (Fu and Wu 2013). Under these circumstances, from 2008, Chinese cities began to experience a decrease in annual average land supply for urban construction, a deceleration of urban expansion and population growth, and even population loss in some regions or in some areas inside major cities (Yang and Dunford 2018). The concurrent existence of regional population loss, shrinkage of land for construction, and economic fluctuation at the microlevel with the stable growth of the economy and urbanization at the macrolevel is a unique urban phenomenon that is characteristic of the Chinese context (Gao et al. 2019) and is known as "shrinkage within growth" (Gao et al. 2019, p. 29) or "regional urban shrinkage" (Li et al. 2017, p. 1997).

Regional urban shrinkage originally occurred in cities in Northeast China and more broadly refers to urban shrinkage in resource-driven cities, cities specializing in outward processing and manufacturing, or to marginal counties on the fringes of municipalities (Li et al. 2017), which is distinct from the urban shrinkage broadly observed in central areas in Western cities. Long et al. (2019) used big data retrieved from Baidu Huiyan, a platform supported by big data retrieved from the Baidu Map, to define shrinking cities as cities with an area of more than 10 $km^2$ and a population loss of more than 5% within 2 years. This definition identified 217 shrinking cities in China, accounting for 7.2% of all the country's cities. However, it is noteworthy that a certain number of the 217 shrinking cities identified were actually municipal districts or municipal counties within large municipalities. For example, Shunyi District in Beijing, Xiangchen District in Suzhou, Zhangqiu District in Jinan, and Jingzhou District in Dalian all observed severe population loss by 15% or more after 2010, while the overall population in these municipalities did not decrease (Long et al. 2019). When referring to the definition of urban shrinkage in the Western context, these aforementioned districts would not be identified as shrinking cities given the increase or maintenance of overall population in these municipalities, even though some parts of them internally encountered severe population loss. Urban shrinkage in China cannot be indicated by only GDP or population data because its causes and effects are multifactorial and in China it often exists within a larger geographic area of growth. Thus, in China, regional urban shrinkage has become a typical type of urban shrinkage.

### Identification of Regional Urban Shrinkage and Data Usage

The identification and measurement of regional urban shrinkage is the first step to understand this relatively new urban phenomenon. The definition of urban shrinkage originated in Germany and traditionally refers to an area with a severe decrease in population (Audirac 2018). For example, the Shrinking Cities International Research Network (Wiechmann 2008; Martinez-Fernandez et al.

2012; Hollander et al. 2009) defined shrinking cities as urban areas with a population of more than 10,000 that had experienced population loss for at least two continuous years together with a local economic transformation and crisis. Shrinking cities are also defined as urban areas that experience population loss of more than 3% in 15 years (Delken 2008) or a population loss of 25% in 40 years (Schilling and Logan 2008). All these definitions are largely embedded in the Western context and are difficult to apply to the context of developing countries such as China given the enormous differences in the types of urban areas, populations, and development status between Chinese and Western cities (Yang and Sun 2015). For example, Berlin as the largest German city had a 3.5 million population and a total area of 891 $km^2$ in 2016 (Statistical Office for Berlin-Brandenburg 2016), and this population is only one-third of the total population of Wuhan City (the largest capital city in Central China) and only one-tenth of its total urban area (Wuhan Municipal Bureau of Statistics 2018a). Thus, there is a pressing need to identify urban shrinkage in China through a more comprehensive approach targeted to the Chinese context rather than through a universal definition that is based on population loss. For example, if a Chinese megacity experienced a population loss of 1%, it might not have a significant effect, but a decrease of the absolute number of people this 1% loss might have a profound influence on a European city. A further example is that of population loss in a short period. This factor is considered a criterion of urban shrinkage in Western cities (Delken 2008), but in China, population loss in a short period might be triggered by large-scale urban regeneration and planned human resettlement in Chinese cities. Thus, a rapid decrease of population in some urban areas may be the consequence of regional redevelopment or government-driven migration rather than of economic decline and land abandon. As a result of these confounding factors, researchers in the Chinese context have defined and distinguished actual and potential urban shrinkage in consideration of multiple dimensions (e.g., population, economy, and land use) (Du and Li 2017b; Li et al. 2015). Actual urban shrinkage might be manifested through population loss in concert with economic decline, a decrease of land supply for urban construction, and a growing aging population. Potential urban shrinkage might be manifested by a slow increase of population, a minor economic decline, and a slow increase of land supply (Du and Li 2017b). However, such identification of urban shrinkage is underaddressed in the literature and suffers from a lack of empirical research. Despite there being some case studies conducted in the Chinese context, these have been published in Chinese but rarely in English and are therefore not widely disseminated.

To identify urban shrinkage, previous research has commonly used population data (e.g., census data with socioeconomic and demographic information), land-supply data (e.g., land supply for urban construction or land-use intensity), and economic data (e.g., GDP) (Du and Li 2017b; Li et al. 2015). Population and land-supply data are usually available at the jiedao (i.e., the subdistrict as the basic building block of a city proper in China) level in Chinese cities, but data on GDP at the jiedao level are not available. Thus, researchers have used night-time light data to gauge the economic activity of a subdistrict (Du and Li 2017b). It has been demonstrated that GDP in an area is significantly correlated with the degree of lighting in that area (Elvidge et al. 2001; Ghosh et al. 2009). Previous research has considered night-time light data sufficient to capture the economic intensity of an area (Han et al. 2012; Cai et al. 2015) and its accuracy has been evaluated and calibrated with other socioeconomic data (Ghosh et al. 2009).

## Study Context, Data, and Methodology

### Study Context

As the capital city of Hubei Province located in the central plain of China, Wuhan City had an urban residential population of 11.06 million in 2018, including an 8.54 million hukou (registered) population (Wuhan Municipal Bureau of Statistics 2018a). Its total area within the municipal boundary was 8,494.41 $km^2$ in 2018, with 13 administrative districts, including 6 districts within the major urban area and 7 county-level districts located remotely in the periurban area. Wuhan had a GDP of RMB1484.73 billion (Chinese Yuan) in 2018, making the city the largest economy in Central China (Wuhan Statistics Bureau 2018a). As the most important political, economic, transport, educational, and cultural center in Central China, Wuhan has experienced rapid urbanization and significant economic growth since the early 2000s; however, since the early 2010s, the city has also been experiencing slowing population growth and even population loss within its municipal boundary (Liu and Zhang 2017). We use Wuhan for our empirical study for four reasons. First, as the most important and largest capital city in Central China, Wuhan represents some common characteristics of hinterland cities in China in relation to its geographic location, industrial structures, and development trajectories. Second, Wuhan has experienced slowing population growth and even population loss in some areas within its municipal boundary alongside an overall population growth (Liu and Zhang 2017). This coexistence of rapid growth and regional shrinkage in Wuhan is a common urban phenomenon that has been observed in other hinterland cities in China. Third, Wuhan has been defined as the central city at the national level and the only subprovincial city in Central China, and it has profound effects on surrounding provinces. Fourth, Wuhan has rich multidimensional data that are reliable in quality, quantity, and ease of access. Thus, Wuhan serves as a good test case for the examination of regional urban shrinkage in the "new normal" era.

### Data and Methodology

Our study collected population, land-supply, and night-time light data at the jiedao level of 2000, 2010, and 2015. We selected 2000, 2010, and 2015 as the key time points for several reasons. The year 2000 marked the beginning of the twenty-first century and the commencement of China's 15th economic plan (Chinese Bureau of Statistics 2000), and in this year, Wuhan had an annual GDP increase of 12% and began the rapid economic growth it would experience in the following decade (Wuhan Statistical Bureau 2018a). The year of 2010 was the last year in which China's national census was conducted (the sixth census of population and housing, Chinese Bureau of Statistics 2010) and was also the year in which the important Chinese four trillion infrastructure investment policy was implemented (Wang and Lu 2009). The year 2015 was when Wuhan's GDP dropped to 8.8% and was the year available for the city's latest population-sampling data and land-supply data through open auction (Chinese Bureau of Statistics 2015; Wuhan Municipal Bureau of Statistics 2018a). Table 1 presents the data and data sources employed in the study.

A comprehensive mixed methodology including quantitative identification and qualitative investigation was employed in this study. We began by selecting one indicator for each of the three dimensions of urban shrinkage to identify areas in which shrinkage had occurred. That is, we employed the dimensions of demography (measured through the indicator of population), economy (measured through the indicator of night-time light), and land use (measured through the indicator of land supply through open

**Table 1.** Data usage and data sources in three dimensions

| Dimension | Data | Data sources |
|---|---|---|
| Population | Fifth census of population in 2000; Sixth census of population in 2010; and population-sampling data in 2015 | Chinese Bureau of Statistics; Wuhan Statistics Bureau |
| Land supply | Land for urban construction data (auction in the open market) in 2000, 2010, and 2015 | Wuhan Natural Resources and Planning Bureau |
| Economy | Night-time light remote sensing images in 2000, 2010, and 2013[a] | US National Geophysical Data Center |

[a]Night-time light remote sensing images was retrieved from DMSP-OLS. DMSP-OLS data have been processed to remain pixels with the gray scale of 0–63 by removing clouds and diminishing background noises and short exposure. It has the capability to identity weak light sources and to reflect the distribution of surface light accurately. The DMSP-OLS data were only available before 2013 since the US National Geophysical Data Center lodged a new satellite in National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPP/VIIRS) in 2013. Given there is a considerable disagreement between these two data sources, we used DMSP-OLS data to cover three key time frames in 2000, 2010, and 2013.



auction) to identify areas of urban shrinkage. First, population was selected because it is a typical indicator of urban shrinkage widely used in current scholarship. Second, night-time light rather than GDP was selected as a measure of the economy given that GDP data were not available at the jiedao level. Night-time light data from the Defence Meteorological Satellite Program Operational Linescan System (DMSP-OLS) available at 1 km by 1 km resolution provide accurate and continuous measures of economic activities at the jiedao level. Third, land supply was selected despite the fact that its use as a dimension may be questioned by the previous scholars because of their opinions that a decrease of urban land supply may be not induced by urban shrinkage but by a series of compact land-use policies. However, such compact land-use policies may matter more to a previous sprawl of industrial land but less to land supplied through open auction in a free market for the purpose of residence, commerce, and services. As the focus of our study, land supply through open auction can be considered a sufficient indicator of actual urban construction activities in Chinese megacities. Moreover, to reduce bias introduced by reliance on a single indicator, we first examined results of urban shrinkage identified by each of the three indicators separately and then compared to the results identified by all three indicators combined in each jiedao of Wuhan. The comparison of identifications of urban shrinkage by single and combined indicators was made to demonstrate that a result indicating shrinkage in one dimension may not reflect true urban shrinkage; thus, combined indicators provided more realistic and reliable results.

For the demographic dimension, we used urban residential population as the measurement of urban shrinkage. Urban residential population refers to the population living within the administrative boundary of a city, including both hukou (registered) population and temporary residents or migrants who are not registered in that city but have been living there for a while (Zhou and Ma 2005). It is noteworthy that an urban residential population is greatly different from a nonagricultural population, which has been widely used in previous studies (Zhou and Ma 2005). The nonagricultural population refers to people with nonagricultural hukou, which was used by the government as an equivalent measure of the urban residential population before the implementation of China's Reforms and Opening-Up policy in 1978; however, during the period of the economic reform since that time, many rural migrants have entered major Chinese cities but have not acquired nonagricultural status. Thus, currently, the nonagricultural population is usually a great deal smaller than the urban residential population when based on where people live as different from when based on where people are registered (Zhou and Ma 2005).

**Table 2.** Comprehensive classification of urban growth and shrinkage based on the combined measures in three dimensions

| Classification | Population | Land supply | Economy |
|---|---|---|---|
| Type I | Increase | Increase | Increase |
| Type II | Increase | Increase | Decrease |
| Type III | Increase | Decrease | Increase |
| Type IV | Increase | Decrease | Decrease |
| Type V | Decrease | Increase | Increase |
| Type VI | Decrease | Increase | Decrease |
| Type VII | Decrease | Decrease | Increase |
| Type VIII | Decrease | Decrease | Decrease |

Note: Increase indicates urban growth, while decrease indicates urban shrinkage.

Population change was calculated for two periods (2000–2010 and 2010–2015) as follows:

$$\mathrm{Pop}_{change}(\%) = \frac{(\mathrm{Pop}_{end} - \mathrm{Pop}_{start})}{\mathrm{Pop}_{start}} \quad (1)$$

where $\mathrm{Pop}_{start}$ = number of the population in the starting year; and $\mathrm{Pop}_{end}$ = number of the population in the ending year. If $\mathrm{Pop}_{change} > 0$, it is defined as population increase; otherwise, it is defined as population decrease, which reflects urban shrinkage.

Land-supply change was also calculated for two periods (2000–2010 and 2010–2015) over the entire study period (2000–2015) as follows:

$$\mathrm{LU}_{change}(\mathrm{ratio}) = \frac{\mathrm{LU}_{period}}{\mathrm{LU}_{2000-2015}} \quad (2)$$

where $\mathrm{LU}_{period}$ = mean value of the land converted to use for urban construction through open auction during the period; and $\mathrm{LU}_{2000-2015}$ = mean value of the land converted to use for urban construction through open auction from 2000 to 2015. If $\mathrm{LU}_{change} > 1$, it is defined as the acceleration of land conversion; otherwise, it is defined as the deceleration of land conversion, which reflects urban shrinkage.

Economic change was measured through change in night-time light at the pixel level and also calculated for two periods (2000–2010 and 2010–2015) as follows:

$$\mathrm{GrayScale}_{change}(\%) = \frac{(\mathrm{GrayScale}_{end} - \mathrm{GrayScale}_{start})}{\mathrm{GrayScale}_{start}} \quad (3)$$

where $\mathrm{GrayScale}_{start}$ = gray scale at a certain pixel at the starting year of that period; and $\mathrm{GrayScale}_{end}$ = gray scale at a certain pixel in the ending year of that period. If $\mathrm{GrayScale}_{change} > 0$, it is defined as an increase in economic activity; otherwise, it is defined as a decrease in economic activity, which reflects urban shrinkage.

Next, we comprehensively identified urban shrinkage combining the three dimensions. Based on the measurements conducted in the preceding step, we classified 142 jiedaos (there are 178 jiedaos in Wuhan, but 36 were excluded because they have missing data) into 8 categories (Table 2) based on increase or decrease in each dimension (e.g., $\mathrm{Pop}_{change} > 0$, or $\mathrm{LU}_{change} > 1$, or $\mathrm{GrayScale}_{change} > 0$ is classified as an increase, otherwise a decrease). We were particularly interested in the categories that had population decrease (i.e., Type V to Type VIII) because population decrease was the primary indicator for urban shrinkage in most of

**Table 3.** Changing tendency in each single dimension across two periods of time

| Period | | Population | | | Land supply | | | Economy | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Increase | Decrease | Missing data | Increase | Decrease | Missing data | Increase | Decrease | Missing data |
| 2000–2010 | No. | 79 | 53 | 46 | 37 | 141 | 0 | 157 | 10 | 11 |
| | % | 44.38 | 29.78 | 25.84 | 20.79 | 79.21 | 0.00 | 88.20 | 5.62 | 6.18 |
| 2010–2015 | No. | 118 | 59 | 1 | 148 | 30 | 0 | 115 | 35 | 28 |
| | % | 66.29 | 33.15 | 0.56 | 83.15 | 16.85 | 0.00 | 64.61 | 19.66 | 15.73 |

Note: The total number of jiedaos in Wuhan is 178. % is calculated as the number of jiedao in each type divided by the total.



the literature (Wiechmann 2008; Martinez-Fernandez et al. 2012; Hollander et al. 2009). Type V is a decrease in population but an increase in land supply and economy, which means that the population decrease in these areas might be caused by the forced immigration and planned resettlement widely observed in the urban regeneration process occurring in Chinese cities, rather than by an actual urban shrinkage. Thus, our later analyses focused on Type VI to Type VIII areas.

After classifying the 142 jiedaos, we conducted a qualitative investigation of Qianshan District (a typical shrinking area) as a pilot study to explore the mechanisms and causality of regional urban shrinkage through archive searching and narrative description.

## Regional Urban Shrinkage Identified through Three Dimensions

### Identification by a Single Dimension Separately

Table 3 shows that in the dimension of land use, the annual average land supply for urban construction in Wuhan was 1854 ha in the period 2000–2015, 1,286 ha in the period 2000–2010, and sharply increased three times to 3,105 ha in the period 2011–2015. This indicates that the implementation of the Chinese four trillion infrastructure investment policy in 2008 profoundly increased land supply and the real estate market in Wuhan (Wuhan Natural Resources and Planning Bureau 2018). This infrastructure investment policy was implemented in November 2008 by the Chinese Government in response to the onset of the GFC in September 2008. The policy aimed to facilitate domestic needs of construction and stimulate economic growth stably by implementing 10 key economic incentives, for example, increasing investment on infrastructure in villages, increasing availability of affordable housing, constructing railways and airports, improving the ecological environment, transforming industry, and upgrading technology.

The spatial patterns of urban shrinkage identified by the indicators in each of the three dimensions are presented in Fig. 1. In the demographic dimension, 53 jiedaos were observed to experience population loss from 2000 to 2010, and these were mainly concentrated on the fringes of the municipality and in newly developed areas. For example, Huangpi District experienced 19% population loss, and Caidian, Hanyang, Jianghan, and Jiangxia Districts all experienced 10%. The number of jiedaos with population loss increased to 59 by 2015, and this was observed to be in concert with urban decline. In the economic dimension, the night-time light data demonstrated that 157 jiedaos experienced an enormous increase in economic activity from 2000 to 2010 and only 10 jiedaos experienced an economic decline in the same period, all of which were slight. However, after the effects of the GFC became clear in the period 2010–2015, 35 jiedaos were observed to experience an economic decline to various degrees (Table 3).

### Identification by Three Dimensions Combined

Table 4 presents the number of jiedaos in each of the eight categories classified according to the three dimensions combined. As stated, we were particularly interested in Type IV and Type VI to Type VIII because these types are identified through at least two indicators as experiencing urban shrinkage. From 2000 to 2010, there were 39 jiedaos identified as shrinking areas with spatial distribution [Fig. 2(a)]. From 2010 to 2015, there were 68 jiedaos experiencing an increase in all 3 dimensions (demography, land use, and economy), but only 3 jiedaos experiencing a decrease in all 3 dimensions. This means that by the end of the study period (2015), Wuhan remained in a stage of experiencing overall urban growth, with regional urban shrinkage sporadically appearing in the main urban area [Fig. 2(b)]. Meanwhile, we observed that the number of Type V jiedaos (i.e., decrease in population but an increase in land supply and economy) substantially increased after 2010, indicating there were many areas with increasing land supply and economy but decreasing population. This may have been caused by the forced migration and planned resettlement of residents during the process of government-driven urban regeneration or real estate redevelopment. These areas of urban regeneration in Wuhan mainly appear along the third transport circle as the main route for daily commuting [Fig. 2(b)], which is in alignment with the main areas targeted for future urban expansion where there is a concentration of ongoing urban regeneration programs. These factors related to urban regeneration contributed to a temporary population loss but an increase in the land supply and economy.

From 2010 to 2015, there were 16 shrinking jiedaos (Types VI–VIII), accounting for approximately 9% of all the jiedaos in Wuhan. We observed some common characteristics in these shrinking jiedaos: population loss, deceleration or stagnation of the economy, and a decrease in land supply for urban construction. These 16 shrinking jiedaos were mainly concentrated in the main urban area and the newly developed area. Although the night-time light data indicated some areas with increasing economic activity in the Type VII jiedaos from 2010 to 2013, the increase rate was extremely low. For example, there was a 0.8% annual increase in the economy in the industrial park of the Wuhan Iron and Steel Company (WISCO) and a 5% increase in the economy in Huaqiao Street from 2010 to 2013.

We further compared the shrinking jiedaos identified by the combined three dimensions and by the single dimension of population in the period 2010–2015 (Fig. 3) because this period after the GFC contained domestic and international triggers of urban shrinkage that will be discussed further in the examination of the case study. From 2010 to 2015, 9% of all the jiedaos in Wuhan were identified as experiencing urban shrinkage when considering the combined dimensions, which is far less than the 41% identified by population loss alone. The main difference between shrinkage identifications by the combined dimensions and by population was seen in Type V jiedaos (i.e., jiedaos with population loss but


**Fig. 1.** Urban shrinkage identified by one indicator in a single dimension: (a) 2000–2010 economy dimension; (b) 2010–2013 economy dimension; (c) 2000–2010 population dimension; (d) 2010–2015 population dimension; (e) 2000–2010 land supply dimension; and (f) 2010–2015 land supply dimension.

**Table 4.** Number of jiedaos within each of the eight categories classified in the combined dimensions across two periods of time

| Period | Type I | Type II | Type III | Type IV | Type V | Type VI | Type VII | Type VIII | Null |
|---|---|---|---|---|---|---|---|---|---|
| 2000–2010 | 9 | 1 | 63 | **5** | 8 | **1** | **36** | **2** | 53 |
| 2010–2015 | 68 | 17 | 11 | **5** | 33 | **10** | **3** | **3** | 28 |

Note: Bold numbers are the number of shrinking jiedaos identified by at least two indicators in the combined dimensions.

increase in land supply and economy), which should not be treated as representing urban shrinkage. Such results demonstrate that multidimensional identification captures actual urban shrinkage more accurately and realistically than the single-dimensional identification.

## Mechanisms and Causality of Regional Urban Shrinkage

The Chinese literature provides various explanations of the mechanisms of urban shrinkage in Chinese cities, for example, the decline of regionally dominant industries, bankruptcy of leading enterprises, lack of capital investment in communities, weakening attraction of neighborhoods, population aging, and regional climate change (Liu and Yang 2017; Liu and Zhang 2017; Yang and Sun 2015; Zhou et al. 2017a; Fan 2019; Yang et al. 2015; Wu and Sun 2017; Zhang and Li 2017; Zhou and Qian 2015; Li et al. 2015; Du and Li 2017b; Wu et al. 2015). These factors have been acknowledged as drivers of population change but might be not sufficient to explain the regional urban shrinkage in the urban fringe or in old industrial areas in hinterland cities in China (Gao et al. 2019).

This study now explores the mechanisms of urban shrinkage on a global scale by virtue of the international experience and findings from the Western context. Through comprehensive consideration of geographic patterns and locations, urban history, socioeconomic features, and institutional and political resolutions, we selected three perspectives—antiglobalization, industrial transformation, and capital circuits—to explain the mechanisms of urban shrinkage in Wuhan. These perspectives were chosen for the following reasons. First, antiglobalization is an important global trigger of change in industry, economy, and society at the local level (Lin 2019) and these changes are directly related to the industrial

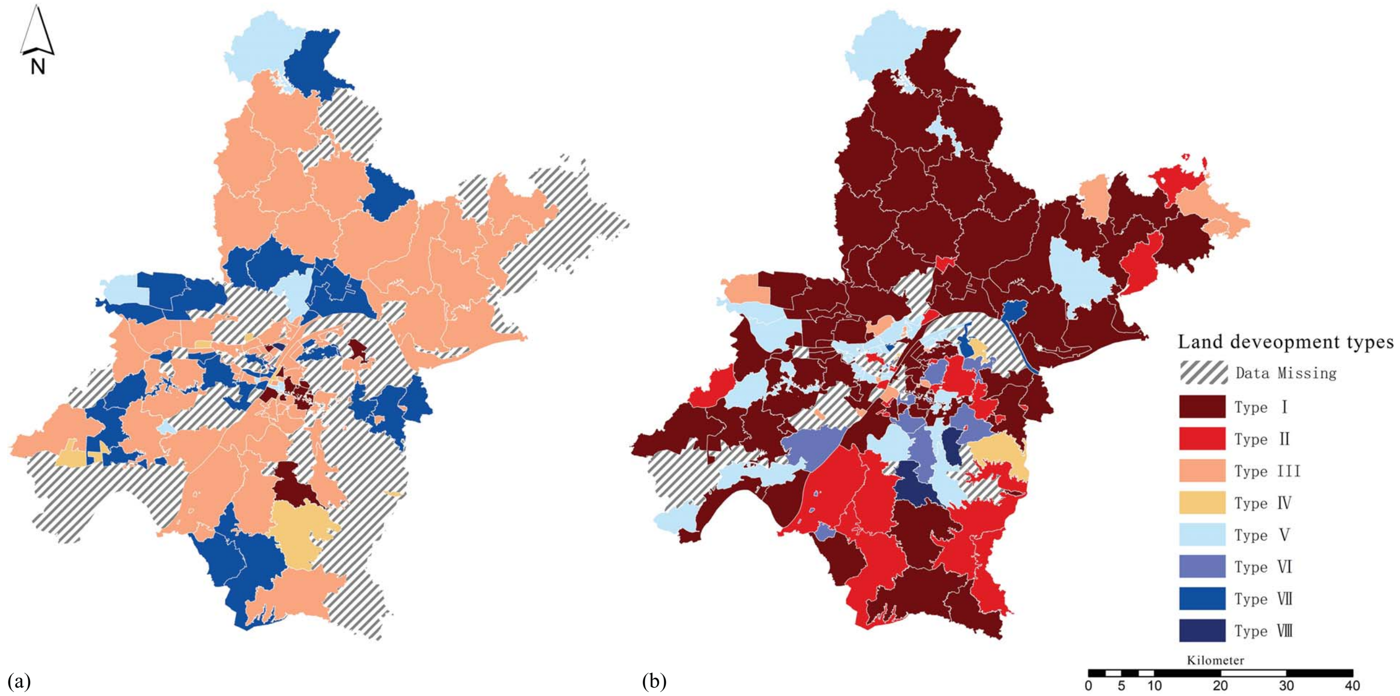


**Fig. 2.** Eight types of land development identified by combined indicators in multiple dimensions: (a) 2000–2010; and (b) 2010–2015.

transformation captured by the second perspective. Second, industrial transformation broadly reflects changes in the production, manufacturing, and working environments and modes. In particular, the industrial transformation of state-owned enterprises with strong Chinese characteristics has been a profound and dominant driver of economic change in China and has had long-term effects on economic growth in China. This is particularly true for Wuhan as one of the oldest heavily industrial cities in China. The shrinking areas of Wuhan identified thus far in our study are largely industrial areas, which further supports the importance of considering industrial transformation as a potential driver of urban shrinkage. Third, capital circuits have been widely discussed as a typical driver of urban shrinkage. Capital inflow leads to urban regeneration and gentrification; in contrast, capital outflow may result in urban shrinkage in urban areas. Thus, capital circuits provide an important explanation of urban shrinkage and an innovative perspective that previous case studies conducted in China have generally ignored (Liu and Zhang 2017; Zhang and Li 2017; Zhou and Qian 2015; Li et al. 2015; Du and Li 2017b; Wu et al. 2015; Zhou et al. 2017b).

## Antiglobalization

It has been widely recognized that the impact of globalization on international collaboration is powerful, inevitable, and irresistible, which renders many nations borderless and with less self-control and advantage in geographic locations (Friedman 2005). The onset of the GFC marked a global entry into a postcrisis era. A series of strategies and policies implemented by President Donald Trump of the United States since 2016 and arising from Brexit (i.e., Britain's exit from the European Union) decelerated the progress of globalization, creating unprecedented effects on China and Chinese enterprises as highly important advocates of and participants in globalization (Lin 2019). A US Government report published in March 2018 (Liu and Woo 2018) claimed the existence of unfair trade practices between the two largest economies in the world: the United States and China. The report advocated that increasing tariffs and other trade barriers aimed to force China to take action and manage bilateral issues such as growing trade deficits, theft of intellectual property, Chinese overinvestment in US companies, and the transfer of US technology to China (Liu and Woo 2018). This US Government report marked the commencement of the US–China trade war. Since then, the adverse effect of the trade war on Chinese enterprises has been clear in the short term and the instability that the trade war causes in the long term may create more damage to the Chinese economy (Lee 2019). The investigation by the American Chamber of Commerce in China (2018) found that as a consequence of the US–China trade war, one-third of all US companies in China (more than 430) had moved out of China or were considering moving their factories to other offshore locations, primarily in Southeast Asia. Further, Japan's Nikkei Research (2018) organization investigated 240 managers in 428 large- and medium-sized Japanese companies and discovered that in early 2018, 3% of Japanese companies were concerned about their decreasing exports to China and the decreasing needs of Mainland China, and this percentage increased to 33% by the end of 2018. Thus, the US–China trade war and increasing automatic machine generation in China have diminished the advantages experienced by manufacturing industries in China, which had hitherto relied on foreign investment, postprocessing, and low labor costs. This change of Chinese manufacturing accelerates industrial transformation, facilitates the migration of labor forces and population loss, and further triggers regional urban shrinkage.

## Industrial Transformation

China's state-owned enterprises have been in a deep transformation period since 2000, and it has been necessary to expand their upstream and downstream industrial chains to overseas locations as a strategy for future development (Li et al. 2010). However, such expansion has not achieved the expected results and has encountered failures in investment and transformation, which have further led to regional urban shrinkage in China as a spatial manifestation of the unsuccessful transformation of these state-owned enterprises

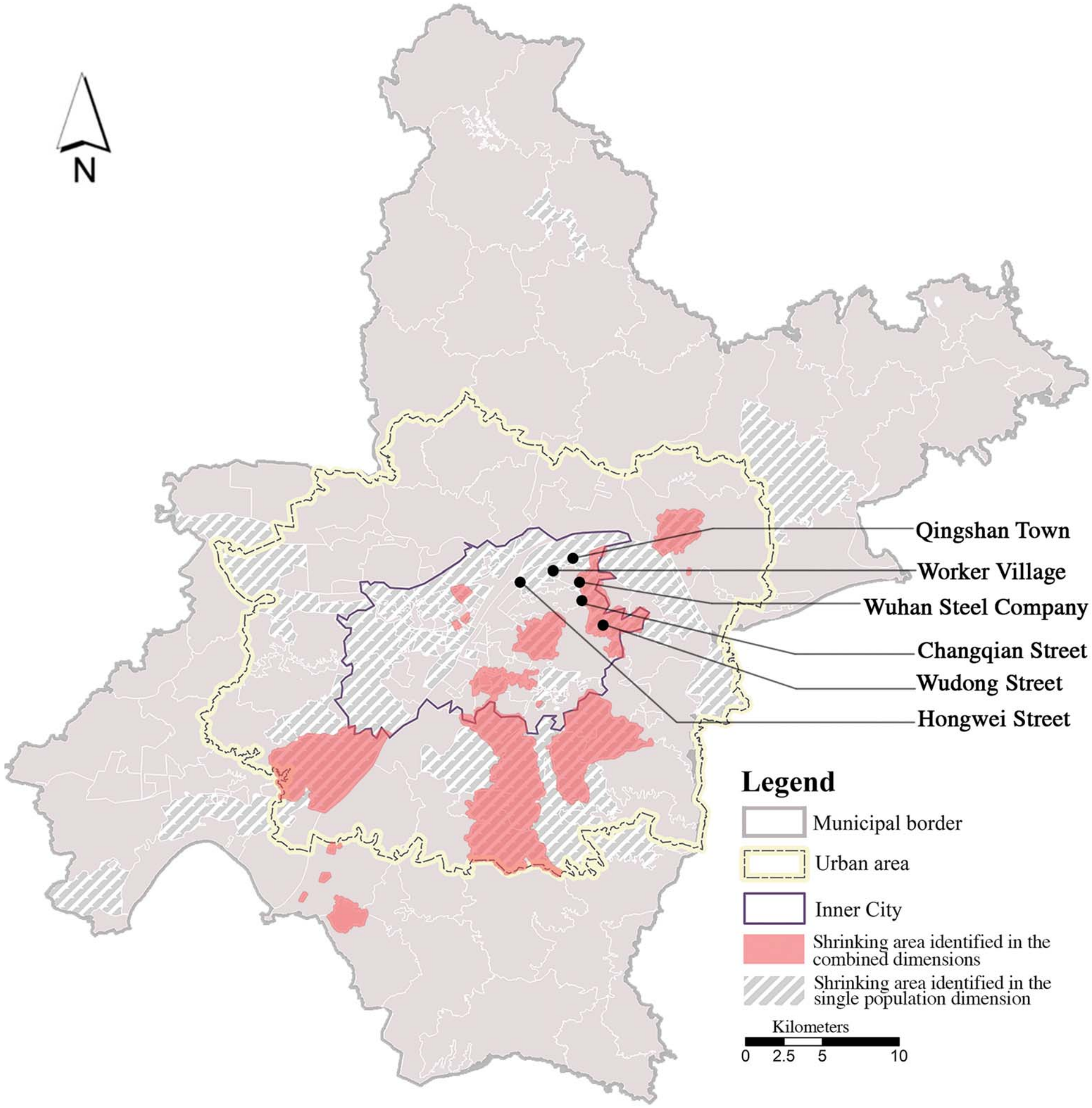


**Fig. 3.** Shrinking areas identified by indicators in combined dimensions and in single population dimension in 2010–2015.

(Yang and Wei 2013). The study now employs the case of WISCO as an example to understand the transformation of state-owned enterprises and the effect of such transformation on the regional shrinkage of Qingshan District in Wuhan. Established in 1958, WISCO was the first joint-venture steel company to be established after the foundation of the People's Republic of China in 1949. In the late 1950s, WISCO and its cooperating companies (e.g., State-owned No. 460 and 471 factories) established a large-scale industrial park with more than 20,000 employees in Qingshan District, historically known as the City of Steel (Editor Committee of History of Wuhan Steel Factory 1988). The establishment of the WISCO meant that the spatial formation of Qingshan District was predominantly driven by the work-unit-based WISCO, combined with residential and manufacturing spaces as part of the WISCO industrial park. From the early twenty-first century, WISCO's revenue continued to increase annually and its net revenue achieved a peak level of RMB6.53 billion in 2007, which greatly increased the GDP of Qingshan District, making it the district of Wuhan with the largest GDP (Gao et al. 2019). However, in the late 2000s, WISCO encountered great challenges and difficulties, experiencing a sharp decrease in annual revenue, leading it to be integrated into Shanghai Baoshan Steel Company in 2016. One of the critical reasons for the WISCO's decline may have been the company's failure to implement strategies for overseas investment and its merging with other companies without full preparation and consideration (Gao et al. 2019). The report produced by Southern Weekend (2016) stated that with 80% of its iron ore imported from overseas, WISCO commenced its overseas investment in 2005 so that it could ensure larger and more stable supplies of raw materials. WISCO opened its first branch in Australia and founded the Wheelarra Joint Venture in 2005. Since that year, WISCO has invested in multiple projects in Canada, Brazil, Australia, and Libya through purchasing mining rights and through engaging in equity, joint venture, sole proprietorship, and shareholding investments. WISCO's foreign investment achieved a peak in 2012, with storage of mining resources of more than 40 billion tons. However, most of the iron ore purchased overseas was of low quality, resulting in an enormous deficit of market demand when the market price of iron ore dropped to USD88 per ton in 2012 and further to USD40 per ton in 2015. In fact, the unsuccessful transformation of WISCO and the failure of its overseas investments occurred not only with WISCO and the steel industry but also with other state-owned Chinese companies, possibly because of the inefficiency and inflexibility of investment strategies and project management (Gao et al.

2019). In addition, the rise of antiglobalization posed further difficulties for state-owned companies in implementing transformational strategies. These factors affecting the transformation of Chinese state-owned companies have also contributed to an increase in regional urban shrinkage. Thus, the regional urban shrinkage that has been observed in Qingshan District of Wuhan is a spatial manifestation of these unsuccessful transformations. According to the Wuhan Statistical Yearbook (Wuhan Municipal Bureau of Statistics 2018a), Qingshan District ranked last among Wuhan's six major districts in relation to GDP and population and economic growth. Moreover, almost half of the jiedaos in Qingshan District encountered severe population loss from 2000 to 2016; specifically, there was an 81.82% population loss in Changqian Street, a 42.8% population loss in Qingshan Town, and more than 20% population loss in Hongwei Road and Worker Village (Fig. 3). In addition, population aging also contributed to the regional urban shrinkage experienced in Wuhan. For example, from 2000 to 2016, the percentage of people aged 65 or older in Baiyushan Street increased from 4.94% to 17.13%, while the percentage of people aged 15 and younger decreased from 14.46% to 6.17% (Wuhan Municipal Bureau of Statistics 2018b).

### *Capital Circuits*

The concept of capital circuits initially proposed by Harvey (1982) explained the interrelationship between capital flow and urban development. Harvey (1982) described three phases of the circulatory process of capital: capital invested in the production process, capital invested in the built environment, and capital invested in science and technology. In the first phase (i.e., capital invested in the production process), the primary circuit of capital is created by increasing output and using machines and workers to make products. Excessive competition forces capitalists to produce as much as they can; however, when commodities are overproduced and supply and demand become unequal, capitalists must utilize any excess capital (e.g., labor forces) to avoid a reduction in profits. Capitalists then reinvest in the built environment, thus beginning the secondary circuit of capital. The second phase of the circulatory process of capital (i.e., capital invested in the built environment) is particularly related to consumption because in this phase overaccumulated capital that is not used in the production process is invested into fixed assets (e.g., houses, durables, and machinery) in the built environment. Thus, the urban built environment is affected by capital flow and control. The decline of the urban environment (e.g., through regional urban shrinkage on the fringe of metropolitan areas and in old industrial areas) is a consequence of capital overflow and relocation (Audirac et al. 2010). In the case of WISCO, the international price of steel was substantially decreased after the GFC and the Steel Price Index, also known as the Commodity Research Unit (CRU) Index, dropped by 52.34% (CRU 2008). From 2010, productivity in the steel industry in China became excessive, substantially decreasing WISCO's gross revenue from RMB6.53 billion in 2007 to RMB7.51 billion in 2015 (WISCO 2016). Correspondently, China's investment in the steel industry dropped from RMB14.82 billion in 2007 to RMB1.40 billion in 2015. Although WISCO had undergone industrial transformation and laid off many employees (i.e., 35,504 employees were fired from 2010 to 2015), the recession in the broad steel industry and the multiple failures in WISCO's investments eventually led to it restructure and integrate with Shanghai Baoshan Steel Company in 2016. When the productivity of WISCO become excessive and profits fell in the primary circuit of capital (i.e., capital invested in the production process), capital escaped from the original environment (the middle and eastern part of Qingshan District) and moved to other urban spaces where there was more demand for labor and higher profits in production. What was left over from this capital overflow and relocation was the decline of the material space, ultimately resulting in the occurrence of regional urban shrinkage.

## Discussion and Conclusion

The identification of regional urban shrinkage in Chinese cities is the starting point to creating understanding of this relatively new urban phenomenon. Unlike previous studies that identify urban shrinkage based on the single dimension of population, which is argued to reflect actual urban shrinkage (Hollander et al. 2009; Martinez-Fernandez et al. 2012; Audirac 2018), our study measured regional urban shrinkage through the dimensions of demography, economy, and land use; investigated the changes in these three dimensions across 2000, 2010, and 2015; and explored the mechanisms of regional urban shrinkage in relation to antiglobalization, industrial transformation, and capital circuits.

The examination found antiglobalization to be the external cause of regional urban shrinkage and industrial transformation in the form of the transformation of China's state-owned companies to be the internal cause. Urbanization in China has been deeply rooted in globalization (Li et al. 2017); thus, antiglobalization has inevitably caused demographic and economic changes in China's urban development, manifesting in regional urban shrinkage.

In addition, in the late 2000s, both private and state-owned Chinese companies encountered crises with industrial transformation in some Chinese cities, contributing to urban shrinkage. For example, this has occurred in Dongguan City, which predominantly has private companies (Du and Li 2018) and in Qingshan District in Wuhan, which predominantly has state-owned companies (Gao et al. 2019). It is possible that the regional urban shrinkage identified in Qingshan District of Wuhan City is profound and is long-lasting because of the difficulties encountered by state-owned companies during the transformation process (e.g., the firing of many employees and the loss of the solid foundation of bureaucratic institutions). These difficulties cannot be simply resolved by the power of free market but require the construction of new industrial institutions and a systematic transformation of state-owned companies, alongside a plan for guided "smart shrinkage" (Min et al. 2015, p. 9).

The study also examined considered antiglobalization (as the external driver) and transformation of state-owned companies (as the internal driver) collectively with capital relocation and overflow, which was also found to be a critical cause of regional urban shrinkage. As Smith (1979) noted, gentrification is caused by the influx of capital to inner cities, rather than by the inflow of population to these areas. Similarly, we assert that the regional urban shrinkage seen in Chinese cities has also be caused by the decline of the material space triggered by capital relocation and overflow, while population loss has been found to be a reflection of capital relocation, rather than a driver of urban shrinkage as is asserted in studies conducted in the Western context (Hollander et al. 2009; Martinez-Fernandez et al. 2012).

Our study makes four key contributions. First, we expand the research paradigm of urban shrinkage from the Western context (Lang 2012; Elzerman and Bontje 2015; Haase et al. 2016; Bernt 2016; Audirac 2018) to Eastern society by adding an empirical study that identifies and explains the causes of regional urban shrinkage in the Chinese context. Second, our study provides comprehensive understanding of regional urban shrinkage as a relatively new urban phenomenon characteristic of the Chinese context. Unlike existing literature on Chinese urban shrinkage





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(Liu and Zhang 2017; Zhang and Li 2017; Zhou and Qian 2015; Li et al. 2015; Du and Li 2017b; Wu et al. 2015), our study explores the mechanisms of regional urban shrinkage on a global scale by considering economic–political trends and global events, which have not been discussed in previous research. Third, our study employs novel methodology to define and identify areas of regional urban shrinkage by utilizing population, land-supply, and night-time light data to employ the dimensions of demography, land use, and economy in the examination of their singular and combined effect of regional urban shrinkage. Our approach of considering a combination of dimensions provides more realistic and reliable identification of areas where urban shrinkage has occurred than the identification provided by previous studies that use population as the only indicator of urban shrinkage (Delken 2008; Schilling and Logan 2008; Wiechmann 2008; Hollander et al. 2009; Martinez-Fernandez et al. 2012; Audirac 2018). Fourth and most importantly, our study offers empirical evidence that urban shrinkage exists in areas of a growing Chinese city, thus shedding light on the coexistence of urban expansion and urban shrinkage that should be considered in current urban planning. The shift of the focus from urban expansion to urban shrinkage in urban planning calls for a new framework that urban planners and policy makers can follow to re-evaluate land-use types and intensity and to revise planning regulations. This framework has been provided in a preliminarily form through our identification of the spatial patterns of urban shrinkage, and exploration of the types and mechanisms of this urban shrinkage. However, future research must aim to provide further theory and empirical evidence to guide policy in relation to managing regional urban shrinkage.

While this study represents a valuable initial examination of regional urban shrinkage in a hinterland city of Central China, there are some limitations that can be addressed in future research. First, the night-time light data can be improved from the DMSP-OLS data (available before 2015) to the latest Suomi National Polar-orbiting Partnership Visible Infrared Imaging Radiometer Suite data to enable more accurate measurement of economic activity. Second, the current identification of urban shrinkage is subject to the spatial boundaries of jiedaos (subdistricts), which inevitably encounter areal unit problems and cannot realistically depict the actual space of urban shrinkage within jiedaos. There is a need to employ a standardized areal unit (i.e., grid) to capture urban shrinkage at a smaller spatial scale. Moreover, the change of the number of jiedaos and adjustment of administrative boundaries of Wuhan City from 2000 to 2015 leads to different amounts of data missing in different periods, although jiedaos with missing data accounted for only a small proportion of the total number of jiedaos and exerted a limited effect on the results. Third, the three mechanisms proposed in our study are reformulated from the perspectives of production of space (Harvey 1982) and decentralization and anti-globalization (Lin 2019). Such mechanisms have been partially discussed in some existing studies as reasonable causes contributing to urban shrinkage (Du and Li 2017a); however, they have not been robustly proven as causality yet. As such, we encourage future scholars to investigate the causal factors of regional urban shrinkage by quantitative reasoning and statistical analyses and to provide concrete implications on urban planning, policy making, and environmental design in the *new normal* era.

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## Data Availability Statement

All data, models, or code generated or used during the study are available in a repository online in accordance with funder data retention policies. Population data can be found at http://tjj.wuhan.gov.cn/newslist.aspx?id=2012111010461248; land supply data can be found at http://zrzyhgh.wuhan.gov.cn/pt-317-2.html; night-time light data can be found at http://www.ngdc.noaa.gov/dmsp/download.html.

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

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