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# Are Medium-Sized Cities in China Shrinking from 2010 to 2020? An Empirical Analysis with a Multi-Dimensional Model

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**Abstract:** Urban shrinkage has emerged as a worldwide concern, which is increasingly prevalent in developing countries like China, particularly in medium-sized cities (MSCs). Compared to large cities and counties, MSCs find themselves in a national policy blind spot and have been neglected both in policy and research. Previous studies, based on population changes, have shown that urban shrinkage in China is not severe. However, urban shrinkage is not just about population decline, and it has not been adequately discussed from a multi-dimensional perspective. This paper adopts a multi-dimensional model, considering population, economy, and space dimensions to analyze shrinkage patterns in 164 MSCs in China from 2010 to 2020. Findings reveal that 6.1% of MSCs experienced population shrinkage, and 24.4% faced shrinkage in economic or spatial dimensions. Shrinking MSCs are spatially distributed in the Northeast as well as in the areas surrounding large cities. Industrial restructuring, job losses, and healthcare disparities contribute to urban shrinkage, and the impact of aging will be further felt. As large cities consistently attract population and resources and digitization has dramatically affected population mobility, more MSCs will shrink in the future. This paper contributes to the understanding of shrinkage of MSCs among scholars and policymakers, urging a shift towards more balanced and digital urban governance.

**Keywords:** mid-sized cities; shrinking cities; population decline; urbanization; governance

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## 1. Introduction

Since the turn of the millennium, urban shrinkage has increasingly reached global dimensions [1]. Urban shrinkage is not only an issue in European and North American cities [2,3]. East Asian cities are also experiencing complex and varied shrinkage [4–7]. Even in rapidly urbanizing China, urban shrinkage has gained increasing attention from scholars and policymakers [8–10]. Unlike in developed countries and regions, most shrinking cities are MSCs in China [11]. During the first decade of the 21st century, migration was highly polarized, with 44% and 47% of the new urban population in large and small cities, respectively, and less than 9% in MSCs [12]. The population of larger cities and smaller towns is proliferating, while the population of MSCs is growing slowly and even shrinking. This paper focuses on the shrinkage of China's MSCs under rapid urbanization.

Rapid urbanization in China is characterized by urban–rural hypermobility [13]. The income gap and public service inequality have been the major drivers of rural–urban migration [14]. Thus, the willingness of migrants to settle in large cities is higher. The percentage is even lower in MSCs, at only 17.3% [15]. International studies have confirmed that rural migration towards metropolises in France produced MSCs as "French desert" [16]. As China's urbanization enters the middle and later stages, migration has shifted from predominantly rural-to-urban to urban-to-urban, which will exacerbate population outflow from MSCs with less employment opportunities [17,18].

MSCs have been neglected by national policies for a long time in China. Since reform and opening in 1978, the government has allowed the agricultural population to relocate to small towns and cities, significantly fostering the growth of small cities in China. The increased emphasis on special economic zones and development zones in coastal areas has also significantly boosted the development of large coastal cities [19]. The neglect of MSCs inevitably leads to urban shrinkage. Many MSCs have developed rapidly in the past, relying on resource-based industries. However, with resource depletion and industrial transformation, these cities have faced vulnerabilities, such as population loss and economic decline, like many resource-depleted cities around the world [20]. Resource-based cities and MSCs on the periphery of metropolitan areas are among the first to encounter growth difficulties and turn to shrinkage [9,21].

In early studies, the extent of urban shrinkage in China was considered severe. Demographic shrinkage is the indicator commonly used to define urban shrinkage, meaning a decrease in the number of the total residents of a city over a period of time. However, recent studies have challenged this view and concluded that urban shrinkage in China is not severe. They argued that two major shortcomings of the previous literature were the use of administrative boundaries rather than physical urban areas and the use of administrative populations rather than urban populations, which led to far higher numbers than were in fact the case [22,23]. Using urban (chengqu) population data and physical urban areas, there were only a few, 48 to be exact, shrinking cities in China from 2010 to 2020 [18]. This certainly goes a step further in accurately identifying China's shrinking cities via the population dimension.

Merely examining urban shrinkage via the population dimension is insufficient. The decline in urban populations is one of the common features of shrinking cities globally [1,2]. However, scholars have reflected on the concept of urban shrinkage and proposed the idea that it is a multi-dimensional process [4]. Population change alone may not reflect all aspects of urban shrinkage. Researchers have used economic shrinkage and spatial shrinkage to measure urban shrinkage along with population shrinkage [24–27]. Economic shrinkage signifies a decline in the city's economy, which does not necessarily lead to population decline, and vice versa [26]. Spatial shrinkage refers to the reduction of urban space and the abandonment of buildings, such as vacant houses and abandoned infrastructure [25]. Furthermore, China's cities exhibit significant regional disparities in economic development, industrial structure, spatial expansion, and urbanization. Therefore, examining shrinking cities from a multi-dimensional perspective may better capture urban dynamics in different regions.

This paper will rethink the phenomenon of shrinkage in China's MSCs from a multi-dimensional perspective, exploring the spatiotemporal characteristics of shrinkage from 2010 to 2020 and further analyzing factors influencing urban shrinkage. The study aims to answer the following questions: What is the shrinkage situation of MSCs from different dimensions? What factors have led to the shrinkage of some MSCs in China? This will help to better understand their status and provide a reference for policy optimization and governance practices in shrinking cities.

The paper is structured as follows. Following this introduction, Section 2 reviews the evolution, theoretical explanation, and multi-dimensional perspective of urban shrinkage. Section 3 introduces the methodology, including the typology, data sources, and processing. Section 4 reports on the empirical results and multi-dimensional factors. Section 5 presents discussion about the explanation of shrinking cities in different dimensions and the underlying causes. Section 6 draws the conclusions.

## 2. Literature Review

For the definition of MSCs, the classification of MSCs based on the urban population is currently the most common method used by countries [28]. Different countries and regions have different criteria for the population size of MSCs due to different geographical contexts and their total population [29,30]. MSCs in China have been defined until 2014

as having a population of between 200,000 and 500,000. With the rapid development of urbanization and the increase in urban population, the definition of city size does not meet the reality of urban development [19,31]. In 2014, the national city size standard was adjusted, and the population definition of MSCs was changed to 500,000–1,000,000.

In addition to quantitative changes, the new standard replaces "urban and suburban areas" with "urban (chengqu) areas" regarding city boundaries. An urban (chengqu) area is defined by the neighborhood councils and other areas in the municipal district to which the physical construction of the municipal seat connects, which is closer to the actual physical urban area [31]. The demographic statistics also use the urban (chengqu) resident population instead of the non-agricultural population. The urban (chengqu) resident population is the population within the urban (chengqu) area, which reflects the actual changes in the urban population more closely. We use 500,000–1,000,000 urban (chengqu) resident population in our definition of MSCs.

Scholars worldwide have extensively discussed the emergence, definition of, and theoretical explanations for urban shrinkage. In the late 1970s, shrinking cities appeared for the first time to define the process of industrial decentralization in cities suffering population losses in Germany [32]. Theoretical explanations for the dynamics of urban shrinkage are diverse. Some scholars have argued from urban life-cycle theory that urban shrinkage is an inevitable process [33,34]. Manchester, Liverpool, and Leipzig saw regrowth after shrinkage [35,36]. Some have focused on the accumulation of capital and argued that urban shrinkage is the spatial manifestation of the crisis of overaccumulation, with capital and labor surplus as the primary triggers [4,37]. According to post-Keynesian regional growth theory, some have argued that urban shrinkage is a continuous downward process that cannot be reversed [38]. Regardless of the pathway, urban shrinkage is context-specific and different for different sizes of cities in different countries.

MSCs generally face unique challenges, with a greater risk of shrinkage. World-renowned cities, like London, New York, Paris, and Shanghai, attract the most attention globally, and policy interests have historically prioritized large cities, leading to insufficient support for MSCs [39]. Faced with globalization and economic crises, MSCs often exhibit greater vulnerability. Industrial MSCs often struggle to transition from traditional manufacturing industries and continually face population outflows [30,37]. Small cities are more dependent on surrounding large and medium-sized cities and are not the first to bear the brunt of risks. Therefore, MSCs face long-term higher unemployment rates, low income, real estate development management issues, isolation, cultural enclaves, and loss of urban identity, making them more vulnerable to shrinkage risks [16].

The factors affecting the shrinkage of MSCs are various and can be summarized as global and local factors [40]. Further analysis of MSCs in different countries with different backgrounds helps to better understand the complexity of urban shrinkage [4,41]. Aging caused Spain's MSCs to shrink [30]. Deindustrialization and population outflows are the main reasons for shrinking MSCs in Germany [42]. Nearly half of the MSCs in France are experiencing urban shrinkage, mainly due to the outmigration of young people with higher education [43]. Shrinkage in MSCs in Eastern Europe and the former Soviet Union is largely due to the collapse of socialist regimes and institutional factors [44,45].

Compared to developed countries, we need to analyze the unique shrinking path in China's MSCs. MSCs in China differ from those in developed regions in terms of globalization, economy, natural environment, social factors, and regional policies [21,37,46,47]. Specifically, some scholars have emphasized that China's urban shrinkage is actually a consequence of rapid urbanization [22]. China's MSCs have different urbanization and economic levels in different regions. MSCs are experiencing population flows to larger cities due to their industrial restructuring. In addition, the population of nearby rural areas certainly prefers to move to large cities, leading to difficulties in the growth or even shrinkage of MSCs. There are relatively few studies on the causes of shrinkage in MSCs.

There is no consensus on the definition of urban shrinkage yet [25,48]. In a narrow sense, urban shrinkage refers to a decrease in the urban population. Many studies have

been conducted on identifying China's shrinking cities based on census data [10,47,49]. However, considering only population change cannot fully examine the overall changes in cities [3,50]. In particular, some MSCs have not experienced population loss but have experienced economic decline and stagnation or spatial shrinkage. The uncertain relationship between population loss and urban shrinkage raises doubts about relying solely on population change to test urban shrinkage in China [51]. In classical urban studies, population change, economic performance, and geographic expansion of urban areas have been widely considered as three aspects of urban change [52,53]. The connections between these dimensions are complex and vary in different regional contexts [26].

Demographic, economic and spatial changes are not necessarily parallel. In Spain, cities with population shrinkage are spatially growing, because real estate is used more as an asset than as housing [54]. In some East German cities, the population decline did not bring about an economic downturn; instead, the urban industry shifted from labor-intensive to knowledge-intensive, contributing to an increase in the productivity of the urban economy [55]. The challenge to the parallelism between population and economic shrinkage is supported by additional evidence that some cities in the Ruhr region of Germany are experiencing steady population growth, but their economies are declining [24]. The two Canadian cases also confirm that urban shrinkage is not strictly parallel in terms of demographic and economic shrinkage [25]. Thus, urban shrinkage has become a multi-dimensional phenomenon rather than explained by a single demographic change.

In conclusion, urban shrinkage around the world is a diverse phenomenon. Although there is much discussion about urban shrinkage, the discussion of the multi-dimensional dynamics of MSCs' shrinkage and the associated factors is still insufficient. Moreover, considering urban shrinkage solely from the perspective of population change cannot fully depict the multidimensional changes in urban shrinkage. Different from literature that only examines urban shrinkage from the perspective of population change, this paper aims to establish a multi-dimensional analysis model to analyze the degree of shrinkage in MSCs from different dimensions and explore the factors influencing the shrinkage of these cities.

## 3. Methodology

### *3.1. Typology of Shrinking MSCs*

This paper adopts the current definition of MSCs with urban (chengqu) resident populations of 500,000 to 1,000,000. Then, we identify 91 (in 2010) and 135 (in 2020) MSCs. A total of 164 MSCs in 2010 and 2020 are the subject of this paper (of which Laiwu City is excluded due to it being abolished and becoming a district of Jinan City). In addition, MSCs include both prefecture-level cities and county-level cities. This paper argues that some cities that have been abolished as counties and established as districts have transformed their rural and town population into an urban population in situ.

For the definition of shrinkage cities, urban shrinkage is a multi-dimensional process involving not only population change but also economic and spatial change [1,11,26,27]. This study examines urban shrinkage from three dimensions: population, economy, and space, represented by the urban (chengqu) resident population, gross regional production (GRP), and urban built-up area, respectively.

It is necessary to determine whether each dimension has experienced shrinkage, and then these dimensions are combined for classification. In terms of population, a decrease in the urban population of a city is considered as population shrinkage. In terms of economy and space, particularly, nearly all cities in China are experiencing economic growth and spatial expansion [37,47]. However, there are significant differences in growth rates among cities, and some studies suggest that relative shrinkage occurs when a city's economic or spatial growth is significantly lower than the average [2,11,27]. Therefore, we follow the approach of Liu et al. [26], considering economic or spatial shrinkage to occur when a city's GRP growth rate or built-up area is less than one standard deviation from the mean of all MSCs.

Furthermore, combining the typological approach of Turok and Mykhnenko [2] and He et al. [27], the following classifications are made from three different dimensions: (1) Growth cities: Population, economy, and space all experience growth throughout the period; (2) Population shrinking cities (P-shrinking cities): These cities experience population decline while the economy and space continue to grow; (3) Economic shrinking cities (E-shrinking cities): These cities experience economic decline while population and space continue to grow; (4) Spatial shrinking cities (S-shrinking cities): These cities experience spatial shrinkage while population and economy continue to grow; (5) P-E-shrinking cities: These cities experience both population loss and economic decline, but urban space is expanding; (6) P-S-shrinking cities: These cities experience both population loss and spatial shrinkage, but the economy is growing; (7) E-S-shrinking cities: These cities experience both economic decline and spatial shrinkage, but population is growing; (8) P-E-S-shrinking cities: These cities experience simultaneous population loss, economic decline, and spatial shrinkage.

### *3.2. Data and Methods of Analysis*

#### 3.2.1. Data Sources and Processing

Urban shrinkage has proved to be a very diverse and complex phenomenon [56]. Demographic, economic, and social public service changes have been the primary drivers of urban shrinkage. We have selected factors that have been discussed internationally and are unique to China, based on the experiences of MSCs and the unique context of China. This study thus classifies the drivers of urban shrinkage into three dimensions: demographic factors, economic factors, and social factors.

As for demographic factors, urban shrinkage is closely related to the drop in fertility levels, the rise in the aging population, and changes in population structure (which can be categorized into changes in the share of population under 15 years old and the share of population over 60 years old) [25,30,57]. We use the indicators "Proportion of population aged below 15 years" and "Proportion of population aged over 60 years" to represent the proportions of children and the degree of aging, respectively. Since fertility rates are not available for some cities, we follow Ao and Liang [58] in measuring the fertility rate as the average number of children born alive to women aged 15–64. We continue to consider the special case of China, where the loss of young labor is a causal factor in urban shrinkage. The outflow of young people to larger cities is the leading cause of population loss in small and medium-sized cities [47]. We examine the migration rate of young people by the proportion of people born during the 1990s. This is attributed to this population having a more vital willingness to migrate between 2010 and 2020 [15]. Moreover, the population decrease in this age group due to natural death is relatively small, so the statistical change is mainly attributed to population migration.

Regarding economic factors, changes in the proportion of employment in different industries represent the transformation of urban economic structure, where cities undergoing industrial transformation see a shift of employment from the secondary to the tertiary sector. Industrial transformation has a crucial impact on urban shrinkage, with a higher proportion of the tertiary sector indicating a greater likelihood of shrinkage [47]. Additionally, the labor force participation rate is an important indicator of economic change in shrinking cities [25]. The decrease in the number of enterprises corresponds to the reduction of jobs in the city and is related to urban shrinkage [27,30].

Among social factors, the decline in the level of infrastructure services is also an important factor in urban shrinkage. In addition to seeking better jobs with higher salaries, better healthcare and housing are also important considerations for China's migrant population. This study uses housing areas and housing conditions to represent changes in housing infrastructure service levels. The housing condition indicator is composed of the average ratio of whether the house has piped water, kitchen, toilet, and bathing facilities. The change in the number of medical beds is also an indicator, as pursuing better quality healthcare is also a driver of outmigration [15].

The above data sources mainly include the Sixth and Seventh Population Censuses, City Statistical Yearbooks, as well as some missing data from local statistical bulletins. The census data include China Census Data by County 2010 and 2020, and Census Labor Force Data 2010, In addition to the three dependent variables of population, economy, and space, 11 indicators were selected representing demographic, economic, and social factors (Table 1).

**Table 1.** Description of variables.

| Categories | Variables | Abbreviation |
|---|---|---|
| Dependent variables | Urban resident population | URPCAGR |
| | Gross regional production | GRPCAGR |
| | Urban built-up area | UBACAGR |
| Demographic factors | Fertility rate | FRCAGR |
| | Proportion of population aged below 15 years | PB15CAGR |
| | Proportion of population aged over 60 years | PO60CAGR |
| | Youth migration rate | YMRCAGR |
| Economic factors | Labor participation rate | LPRCAGR |
| | Share of employment in the secondary industry | SE2CAGR |
| | Share of employment in the tertiary industry | SE3CAGR |
| | Number of enterprises above designated size | NECAGR |
| Social factors | Housing conditions | HCCAGR |
| | Per capita living space | PCLCAGR |
| | Number of medical beds | NMBCAGR |

Note: The data for all the above variables are derived from the Sixth and Seventh Population Census, City Statistical Yearbooks 2011, 2014 and 2021. Fertility rates are replaced by the average number of live births of women of appropriate age. The youth migration rate is the percentage change in people born in the 1990s. Labor participation rates have been adjusted according to the sampling fraction of different cities. The number of enterprises above the designated size had an annual main business income of more than 20 million yuan in 2013 and 2020.

In addition, the Compound Annual Growth Rate (CAGR) represents compound growth over discrete periods. It is an important method with which to study the change in the average annual growth of two (or more) time indicators. This method has been widely used in urban shrinkage studies [30,46,59]. The formula to calculate the CAGR is as follows:

$$CAGR_i = \left(\frac{P_{t_a}}{P_{t_o}}\right)^{\frac{1}{t_a - t_o}} - 1 \quad (1)$$

where $CAGR_i$ donates the compound annual growth rate of the $i$ indicator, $P_t$ represents the value of the indicator in $t$ year, and $t_a$ and $t_o$ represent the final and initial years, respectively.

#### 3.2.2. Partial Least Squares Regression

Partial least squares is a class of regression estimation method initially developed by Wold [60,61]. Partial least squares regression analysis combines the advantages of principal component analysis, typical correlation analysis, and multiple linear regression analysis, commonly used in forecasting studies. PLS has been applied to studies of shrinking cities, population, and ecology [20,62–64]. PLS regression can effectively address the presence of multicollinearity in variables and offers strong explanation of analytical models with small sample sizes.

The method will extract the latent variables (integrated variables) $t_i(u_i)$ from $X(Y)$ variables and make $t_i(u_i)$ represent the original information in $X(Y)$ as much as possible. After the first component has been extracted, partial least squares regression is implemented to regress $X$ on $t_1$ and $Y$ on $u_1$, respectively. If the regression equation has reached satisfactory accuracy, the algorithm terminates; otherwise, a second round of component extraction is performed using the residual information from the interpretation of $X$ by $t_1$ and the residual information from the interpretation of $Y$ by $u_1$. This is repeated until more satisfactory accuracy can be achieved. If a total of m components $t_1$, $t_2$,..., $t_m$, the

regression of $y_k$ to $t_1$, $t_2$,..., $t_m$ is performed, and then expressing it as a regression of $y_k$ on the original independent variables' $x_1$, $x_2$,..., $x_p$ regression equation. We directly adopted the Simca-P14.1 software, developed by Umetrics (Malmö, Sweden), to perform PLS calculations.

In the first step, normalization is performed on the data matrix $X$, $Y$. Then, extract the first pair of components $t_1$, $u_1$ of the two matrices, respectively, and maximize their correlation.

$$u_1 = Yv_1,\ t_1 = Xw_1 \tag{2}$$

In order to satisfy $||w_1|| = ||v_1|| = 1$, this corresponds to maximizing $\mathrm{cov}(t_1, u_1) = w_1^T X^T Y v_1$. Using the Lagrange multiplier method, the problem is transformed into a calculation of the matrix $M = X^T Y Y^T X$. $w_1$ is the unit eigenvector corresponding to the largest eigenvalue of $M$. $v_1$ is the unit eigenvector corresponding to the largest eigenvalue of $Y^T X X^T Y$. $w_1$ is the weight of the factor $t_1$. The vector obtained when the sample observations are brought to $t_1 = Xw_1$ is called the score vector for factor $t_1$.

Next, build a regression of $X$ on $t_1$ and a regression of $Y$ on $t_1$, for which the regression model is:

$$X = t_1 c_1^T + E_1,\ Y = t_1 d_1^T + F_1 \tag{3}$$

where $c_1 = X^T t_1 / t_1^T t_1, d_1 = Y^T t_1 / t_1^T t_1$ are the vectors of coefficients in the regression models $X$ to $t_1$ and $Y$ to $t_1$, respectively. $E_1$, $F_1$ are the residual arrays of the regression models, respectively. $c_1$ is the loading of factor $t_1$.

If the absolute value of the elements in the residual array $F_1$ is approximately 0, this means that the regression equation established with the 1 component meets the accuracy requirement. Otherwise, repeat the above steps by replacing $X$ and $Y$ with residual array $E_1$ and $F_1$, respectively.

Assuming that the rank of $X$ is $r$, there is a series of component pairs $(t_i, u_i)$ and the vector of regression coefficients is $c_i, d_i$ $(\mathrm{i} = 1, \ldots, r)$. This yields two regression equations:

$$X = t_1 c_1^T + t_2 c_2^T + \cdots + t_r c_r^T + E^r, Y = t_1 d_1^T + t_2 d_2^T + \cdots + t_r d_r^T + F^r \tag{4}$$

Since $t_r$ is a linear combination of the standardized variables $x_r^*$, we can finally obtain a multiple linear regression equation for each dependent variable $y_i$ on the independent variables $x_p$.

The principle of cross-validity was used to determine the number of components to be extracted, *h*. $y_i$ is the original data and $t_1, t_2, t_3, \cdots, t_h$ are the components in the partial least squares regression. $\overline{y}_{h_i}$ is the fitted value for the $sample_i$ after using all sample points and taking $t_1, t_2, t_3, \cdots, t_h$ components for the model. $\overline{y}_{h(-i)}$ is the value of the fit computed from this model after deleting the $sample_i$ from the modeling and taking $t_1, t_2, t_3, \cdots, t_h$ components to model.

$$PRESS = \sum_{i=1}^{n} \left( y_i - \overline{y}_{h(-i)} \right)^2 \tag{5}$$

where $y_i$ is the original data, $y_i - \overline{y}_{h(-i)}$ is the model, according to which the model calculates the fitting value after deleting the $sample_i$ during modeling and taking $t_1, t_2, t_3, \cdots, t_h$ components for the model. The variable PRESS is taken to be the smallest indicating the best fit of the model, in which case the number of components *h* extracted is the best number of components.

An important indicator can be obtained from PLS regression, i.e., variable importance in the projection (VIP), which measures the explanatory power of each independent variable over the dependent variable. The formula to calculate the VIP is:

$$VIP_j = \sqrt{p \sum_{k=1}^{ncomp} \left( PV_k \times \left( W_{jk} / \parallel W_k \parallel / \sum_{k=1}^{ncomp} PV_k \right) \right)} \tag{6}$$

where $VIP_j$ donates the importance of the $j$ predictor variable, $p$ represents the number of predictor variables, *ncomp* represents the matrix of response and predictor variables, $W$ is the response variable weight, and $PV_k$ represents the $k$ component's variance for the corresponding variable's explanatory variables.

## 4. Results

### *4.1. Spatial Distribution and Characteristics in MSCs*

Rapid urbanization accompanied by general growth and partial shrinkage is a characteristic feature of MSCs overall (Figure 1). In general, from 2010 to 2020, 45 cities experienced at least one dimension of shrinkage in terms of population, economy, or space, accounting for 27.4% of the total sample of 164 MSCs. Specifically, only 10 cities experience a decrease in urban population, with an average population decline rate of 13.3%, accounting for approximately 6.1% of the total sample cities. The remaining 154 cities saw population growth, representing the majority of China's MSCs at 93.9%. A total of 23 cities are experiencing economic recession, accounting for 14% of all cities. Among them, only 15 cities experienced economic recession without population or spatial shrinkage, 4 cities jointly experienced population shrinkage and economic recession, and 3 cities experienced economic recession and spatial shrinkage. A total of 21 cities experienced spatial shrinkage, with 17 of them shrinking only in spatial dimension, and no cities experiencing simultaneous population and spatial shrinkage. Additionally, 1 city experienced shrinkage in all three dimensions. When examining the relationship between the three dimensions of MSCs (Figure 2), we find that changes in population and economy generally follow a positive correlation. However, changes in space do not always align with changes in population or economy.

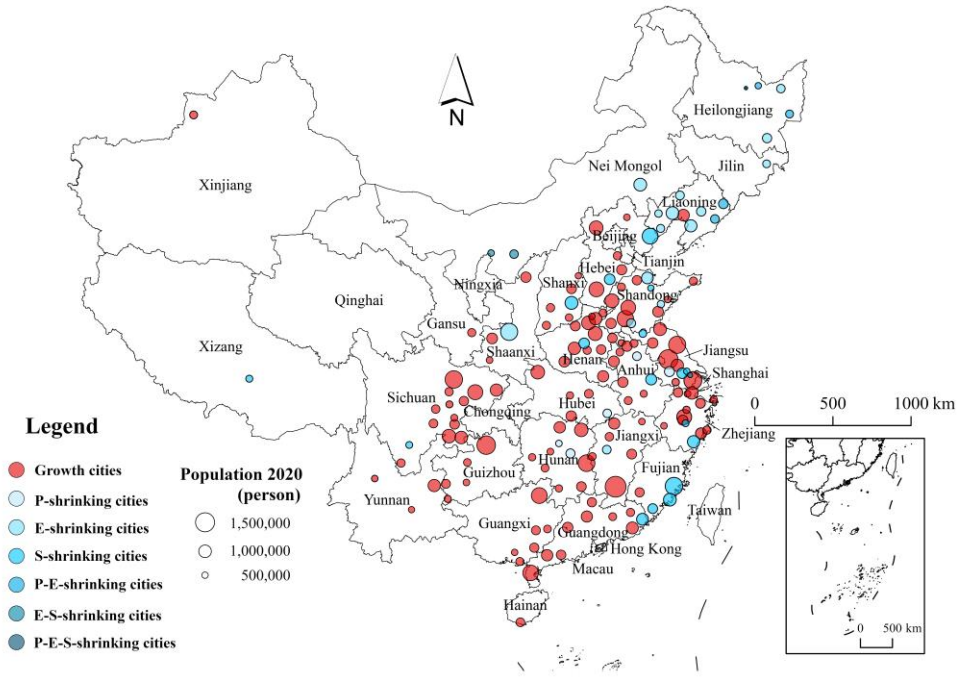



**Figure 1.** Spatial distribution of different typologies of MSCs in China from 2010 to 2020.

From a population perspective, the growth and shrinkage of MSCs are spatially uneven. In the eastern areas, many MSCs in 2010 surpassed a population of 1 million by 2020, becoming large cities, and numerous small cities in 2010 have developed into MSCs. The number of MSCs in Zhejiang Province increased from 5 to 12, and in Guangdong Province increased by 4. Except for Zhenjiang, other cities in the eastern region maintained population growth. In the central region, many cities have experienced rapid urbanization

over the decade, resulting in the emergence of a large number of MSCs. However, 4 MSCs experienced population shrinkage, as residents were attracted to more developed eastern regions. In the western region, Yining City, Lhasa City, and Tianshui City emerged as MSCs. In the northeast region, 4 out of 13 MSCs became P-shrinking cities in 2020. In terms of the extent of population shrinkage, the northeast region is the most severe, with the most severe population loss in Yichun City exceeding half. The degree of urban shrinkage in the central and eastern regions is less than 12% (Table 2). Examining the population changes in all 164 MSCs, it is found that the urban population increased by approximately 40 million, while shrinking cities reduced by 950,000, with a contribution rate of population decline of only 2.38%. Not only are there few P-shrinking cities, but the absolute number for population decrease is also low. They also do not exhibit spatial segregation, as there are some growing cities near P-shrinking cities, highlighting the spatial unevenness between shrinking and growing cities.

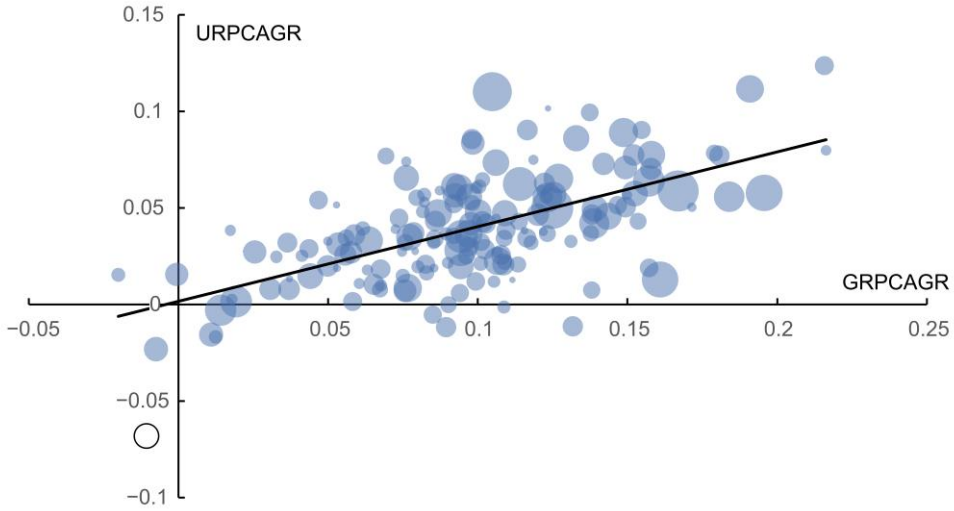



**Figure 2.** Population, economic, and spatial changes in MSCs from 2010 to 2020. Note: Bubbles represent MSCs, the x-axis represents the change in the economic dimension, the y-axis represents the change in the population dimension, and the size of the bubble represents the change in the spatial dimension, with the hollow example as negative.

From an economic perspective, a total of 23 (14%) cities experienced economic recession. These cities are concentrated spatially in the northeast region, with 14 cities located in the northeast, 5 in the central region, and 4 in the eastern region. Among them, Liaoning Province experienced the most severe economic recession, with 8 MSCs experiencing various scales of economic recession. In terms of the scale of economic recession, 4 cities experienced a decline over the decade, all located in the northeast region, with Jiamusi City experiencing the most severe economic decline, with an 18.4% decrease in total GDP over the decade.

From a spatial perspective, a total of 21 (12.8%) cities experienced spatial shrinkage. Unlike population and economic dimensions, S-shrinking cities are concentrated in the eastern region, with only Yichun City in the northeast, over half (11 cities) of the S-shrinking cities located in various eastern provinces, and the rest distributed in the central and western regions. Jiangsu Province had the most severe spatial shrinkage, which may be related to the fact that urbanization in the area is in the middle to later stages, and urban expansion has almost been completed. S-shrinking cities in the central and western regions, as well as in Fujian Province, may be related to local mountainous terrain, where spatial expansion is difficult. In terms of the scale of shrinkage, Yichun City is the only city where the urban built-up area experienced a decline. The growth of built-up areas in other S-shrinking cities is slow.

**Table 2.** The 10 P-shrinking MSCs from 2010 to 2020.

| MSCs | Province | Region | Urban Resident Population 2010 | Urban Resident Population 2020 | Population Change Rate |
|---|---|---|---|---|---|
| Zhenjiang | Jiangsu | Eastern | 841,577 | 797,942 | −5.18% |
| Huangshi | Hubei | Central | 673,171 | 672,423 | −0.11% |
| Yiyang | Hunan | Central | 518,773 | 511,966 | −1.31% |
| Bengbu | Anhui | Central | 772,367 | 689,398 | −10.74% |
| Xiangtan | Hunan | Central | 806,696 | 716,064 | −11.23% |
| Dandong | Liaoning | Northeast | 705,200 | 684,563 | −2.93% |
| Hegang | Heilongjiang | Northeast | 588,942 | 502,649 | −14.65% |
| Jixi | Heilongjiang | Northeast | 741,324 | 626,019 | −15.55% |
| Benxi | Liaoning | Northeast | 968,505 | 765,932 | −20.92% |
| Yichun | Heilongjiang | Northeast | 600,250 | 296,258 | −50.64% |

### *4.2. Influencing Factors for Shrinking MSCs*

Urban shrinkage is driven by socioeconomic development. This study analyzes the factors influencing urban shrinkage and, based on previous academic viewpoints, selects 11 elements as the demographic, economic, and social factors to explore the drivers of urban shrinkage. We first conducted descriptive statistics on the relevant elements. Table 3 shows the average and standard deviation of 14 types of data for 164 MSCs in 2010 and 2020, as well as data for 10 P-shrinking cities, 23 E-shrinking cities, and 21 S-shrinking cities.

**Table 3.** The 10 P-shrinking MSCs from 2010 to 2020.

| Tables | MSCs (n = 164) | | P-Shrinking (n = 10) | | E-Shrinking (n = 23) | | S-Shrinking (n = 21) | |
|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| URPCAGR | 0.0389 | 0.0281 | −0.0157 | 0.0199 | 0.0114 | 0.0248 | 0.0389 | 0.0332 |
| GRPCAGR | 0.0963 | 0.0441 | 0.0524 | 0.0534 | 0.0239 | 0.0196 | 0.0911 | 0.0504 |
| UBACAGR | 0.0613 | 0.0261 | 0.0503 | 0.0488 | 0.0520 | 0.0368 | 0.0219 | 0.0236 |
| FRCAGR | −0.0018 | 0.0066 | −0.0060 | 0.0059 | −0.0037 | 0.0061 | 0.0022 | 0.0064 |
| PB15CAGR | 0.0060 | 0.0135 | −0.0001 | 0.0183 | −0.0013 | 0.0160 | 0.0095 | 0.0140 |
| PO60CAGR | 0.0451 | 0.0134 | 0.0498 | 0.0100 | 0.0528 | 0.0103 | 0.0431 | 0.0125 |
| YMRCAGR | −0.0191 | 0.0341 | −0.0317 | 0.0188 | −0.0242 | 0.0244 | −0.0004 | 0.0335 |
| LPRCAGR | −0.0115 | 0.0098 | −0.0105 | 0.0082 | −0.0080 | 0.0065 | −0.0073 | 0.0087 |
| SE2CAGR | 0.0367 | 0.0366 | 0.0045 | 0.0338 | 0.0107 | 0.0265 | 0.0149 | 0.0341 |
| SE3CAGR | 0.0634 | 0.0285 | 0.0425 | 0.0150 | 0.0431 | 0.0190 | 0.0461 | 0.0245 |
| NECAGR | 0.0344 | 0.0693 | −0.0197 | 0.0823 | 0.0270 | 0.0112 | 0.0259 | 0.0192 |
| HCCAGR | 0.0341 | 0.0217 | 0.0289 | 0.0141 | 0.0319 | 0.0104 | 0.0294 | 0.0163 |
| PCLCAGR | 0.0318 | 0.0138 | 0.0347 | 0.0122 | −0.0347 | 0.0702 | 0.0259 | 0.0713 |
| NMBCAGR | 0.0673 | 0.0344 | 0.0305 | 0.0418 | 0.0340 | 0.0321 | 0.0638 | 0.0395 |

Next, we construct a partial least squares (PLS) regression equation with the SIMCA-P14.1 software. We use changes in population, economy, and space as dependent variables and the other 11 socioeconomic factors as independent variables to build the regression equation. Cross-validation Q2 is negative when three components are extracted. The cross-validation effectiveness Q2 (cum) is highest when two PLS components are extracted, so we extract 2 PLS components. The resulting partial least squares regression model in three dimensions is:

$$\begin{aligned} URPCAGR = \; & 0.0233 + 0.0534FRCAGR + 0.0507PB15CAGR \\ & -0.1862PO60CAGR + 0.1269YMRCAGR - 0.0352LPRCAGR \\ & +0.0783SE2CAGR + 0.0487SE3CAGR + 0.1657NECAGR \\ & -0.0027HCCAGR - 0.0099PCLCAGR + 0.2175NMBCAGR \end{aligned} \quad (7)$$

$$\begin{aligned} GRPCAGR = \; & 0.0566 + 0.0406FRCAGR + 0.0631PB15CAGR \\ & -0.2322PO60CAGR + 0.1024YMRCAGR - 0.0906LPRCAGR \\ & +0.1857SE2CAGR + 0.1403SE3CAGR + 0.2955NECAGR \\ & +0.0591HCCAGR + 0.0263PCLCAGR + 0.3281NMBCAGR \end{aligned} \quad (8)$$

$$\begin{aligned} UBACAGR = \; & 0.0487 - 0.0210FRCAGR - 0.0034PB15CAGR \\ & +0.0121PO60CAGR - 0.0458YMRCAGR - 0.0292LPRCAGR \\ & +0.0543SE2CAGR + 0.0504SE3CAGR + 0.0492NECAGR \\ & +0.0423HCCAGR + 0.0267PCLCAGR + 0.0243NMBCAGR \end{aligned} \quad (9)$$

PLS regression resulted in the values of VIP in the model (Figure 3). VIP measures the explanatory power of each independent variable on the dependent variable. It is generally accepted that a value of VIP greater than 1 indicates that the independent variable is essential for the dependent variable, while a value less than 0.5 is not necessary [62,63]. According to the regression results, the VIP values for NECAGR, NMBCAGR, and SE2CAGR are 2.23, 1.54, and 1.24, respectively, all greater than 1. This indicates that changes in the number of enterprises and the number of medical beds, as well as the proportion of employment in secondary industry, have a significant impact on the dynamics of MSCs.

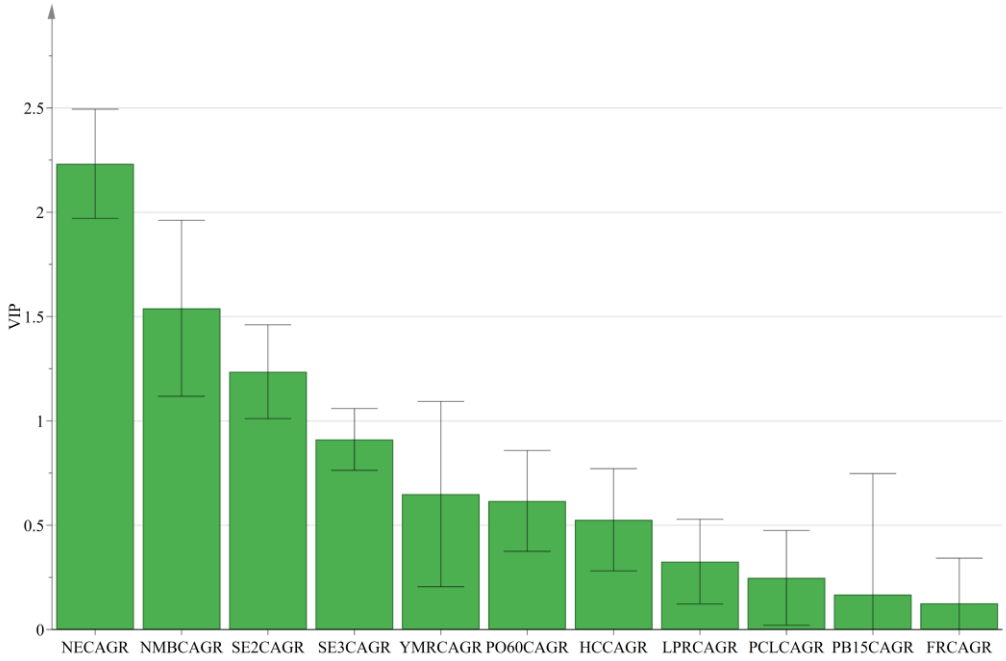



**Figure 3.** VIP value of influencing factors in MSCs.

SE3CAGR, YMRCAGR, PO60CAGR, and HCCAGR have VIP values of 0.91, 0.65, 0.62, and 0.53, respectively. This suggests that changes in the proportion of employment in tertiary industry, young population migration, aging, and changes in housing conditions are relatively important. Other factors have no significant impact on shrinkage in MSCs.

Examining the standardized coefficients of the PLS equation (Figure 4), we find that, among the factors with VIP values greater than 1, changes in the number of enterprises, the number of medical beds, and the proportion of employment in secondary industry are significantly positively correlated with changes in urban population and economy, while the aging rate is significantly negatively correlated with population and economic dimensions. Furthermore, the permutation test helps to assess the risk that the current PLS model is spurious, e.g., the model just fits the training set well but does not predict Y well for new observations. The plot shows (Figure 5), for a selected Y-variable, on the vertical axis, the values of R2 and Q2 for the original model far to the right, and of the Y-permuted models further to the left. If all blue Q2-values to the left are lower than

the original points to the right or the blue regression line of the Q2-points intersects the vertical axis (on the left) at, or below zero, the plot above strongly indicates that the original model is valid. Permutation test results show that, when the number of permutations is 200, the regression line slopes for the R2 and Q2 of the three dimensions of population, economy, and space are positive, with intercepts of −0.089, −0.117, and −0.051 for the Q2 regression line, respectively, indicating that the model is not overfitting and has good explanatory power.

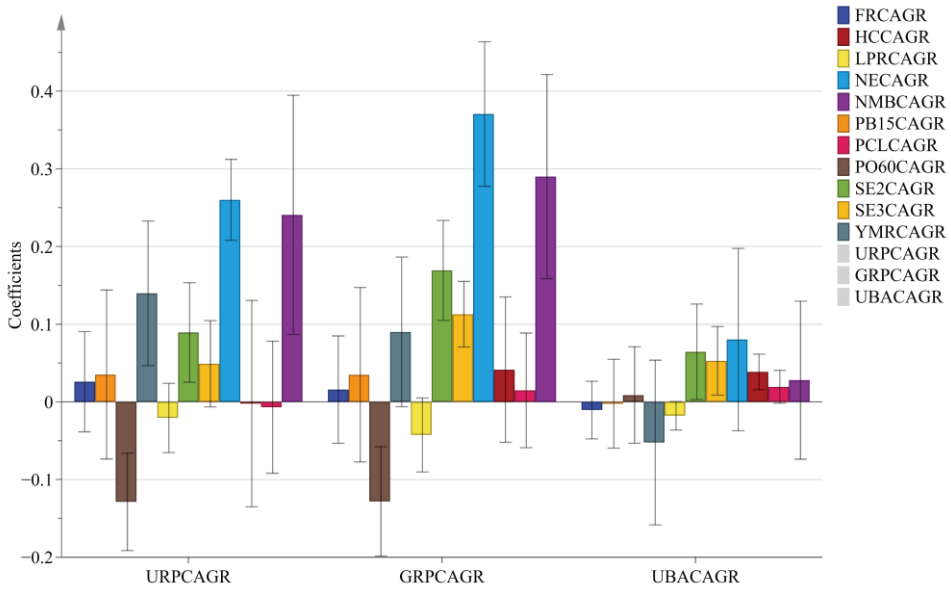
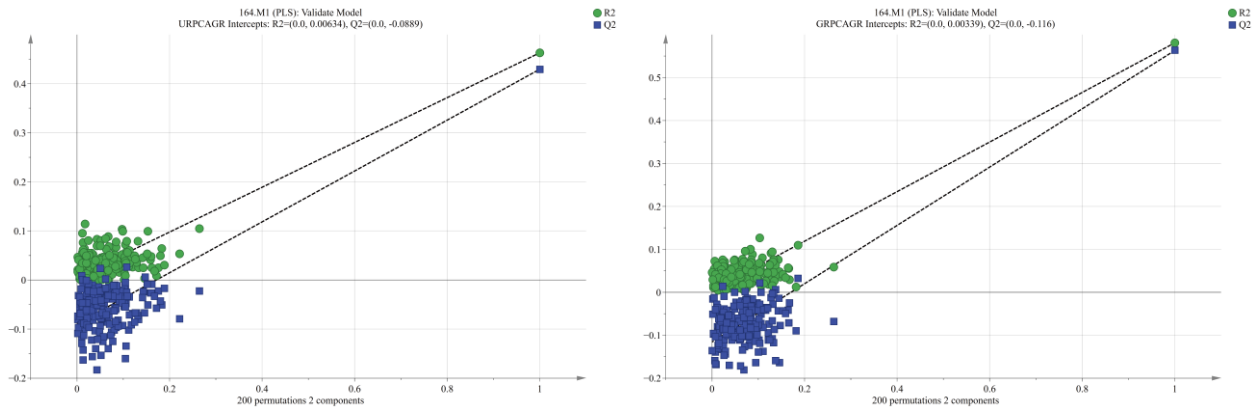



**Figure 4.** Coefficient overview plot of influencing factors in MSCs.




(**a**) (**b**)

**Figure 5.** Permutation test of PLS in MSCs.

There is another plot used to explain the applicability of the PLS: the $t_1/t_2$ scatter plot (also called be $T^2$ oval plot) [62,65]. In the $T^2$ oval plot, $t_1$ and $t_2$ are the integrated or latent variables extracted from the $X$ variables. They can represent the key information of $X$ variables as far as possible and have a strong capacity to explain the $Y$ variables as far as possible. Except for five cities, the $t_1/t_2$ relationship of the sample data is almost all included in the oval (Figure 6), so these sample data are homogeneous and good and can be accepted perfectly.

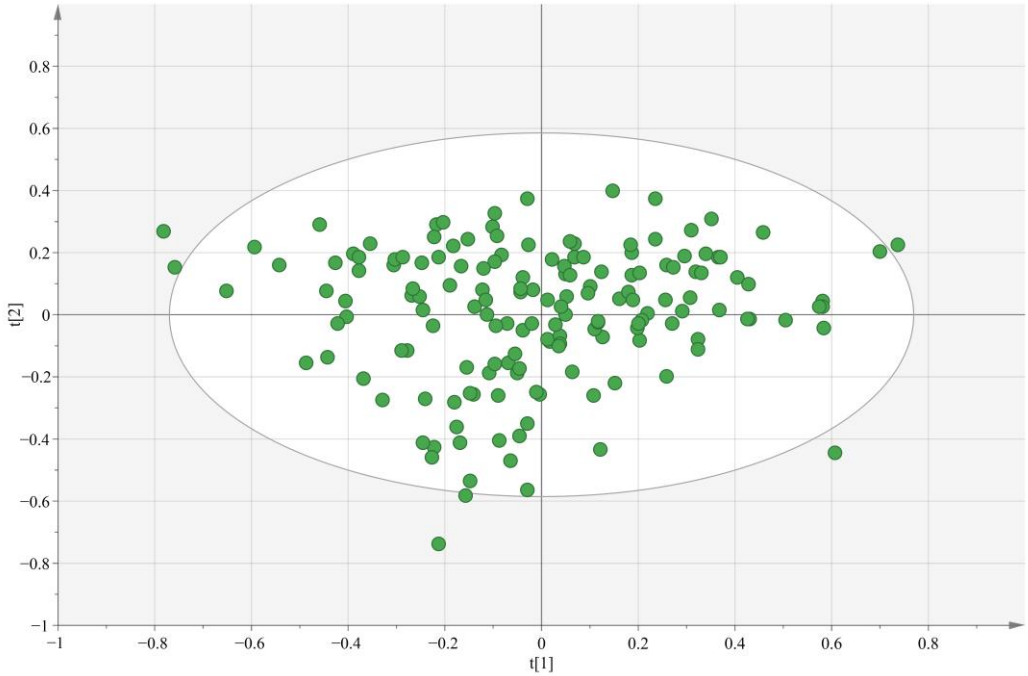



**Figure 6.** $T^2$ oval plot of MSCs.

## 5. Discussion

### *5.1. Complexity of Population–Economic–Spatial Shrinking MSCs*

Identifying shrinking cities from a multi-dimensional perspective confirms the diversity and complexity of urban shrinkage in China's MSCs. While population change constitutes an important aspect of shrinking cities, examining economic and spatial changes diversifies our perspective. Past international and Chinese research has also confirmed that population decline, economic recession, and spatial contraction often do not exhibit strict parallel relationships [24,26,27,59]. We identified a total of seven types of shrinking MSCs (Figure 1). However, the majority (71.1%) of shrinking cities only shrink in one dimension, indicating that, even in the process of urban development, shrinkage occurs only in certain aspects. This further illustrates that those cities experiencing population shrinkage do not necessarily shrink in terms of economy and space, and cities experiencing economic recession and spatial contraction do not necessarily lose population. Although the complexity of population decline, economic recession, and spatial contraction has been discussed in many literatures, our research has found several points worth mentioning.

It has been confirmed that the loss of urban population in MSCs is not severe [18,26]. Previous literature that emphasized the severity of urban shrinkage mostly used the administrative district population to identify shrinkage [10,47,49]. Therefore, we can more accurately identify the direction of population flow in China from 2010 to 2020, with more people moving from villages and towns rather than from small and medium-sized cities to large cities. Liu et al. also confirmed the accelerating decline in the total rural population in China [66]. The 10 cities with P-shrinking are cities at the forefront of China's industrialization. In the past, they relied on the advantages of industrialization to attract a large urban population, but with the decline in industry, and the lack of local employment opportunities in these cities, the population outmigration intention is strong, and the willingness of rural populations to migrate is very weak, gradually leading to urban shrinkage. Cities in the northeastern region of China, as the old industrial base of China, are representative of such cities. This also explains the phenomenon that shrinking cities in China are concentrated in the northeastern region.

Economic recession in MSCs often accompanies shrinkage in other dimensions. Four cities suffered from both population decline and economic recession, three cities expe-

rienced economic recession and spatial shrinkage, and 1 city experienced shrinkage in all three dimensions. Most MSCs with significant economic recession are located in the northeastern region, and most of which are resource-based cities. These cities generally face the exhaustion of resources, and economic development needs to find new growth points [46]. They not only have a declining attractiveness for the surrounding rural population but, more importantly, the continuously decreasing number of job opportunities will also cause population loss. This can be seen from the significantly decreasing proportion of employment in secondary industry. The two cities with the largest changes, Hegang and Yichun City, reached a decrease of around 10%, compared to an average increase of 7.85% in growing cities. This also confirms that the direct cause of economic recession in shrinking cities is the decrease in employment in secondary industry.

The geographical distribution of spatial shrinkage in MSCs is quite different from that of the population and economic dimensions. Only one city in the northeastern region, where population and economic shrinkage are serious, has experienced spatial shrinkage. Jiangsu and Fujian provinces in the eastern coastal region are the provinces with the most serious spatial shrinkage. Most (81%) of the S-shrinking cities only shrink in one spatial dimension. When we reviewed these cities, we found that their growth performance in population and economic dimensions was only slightly weaker than that of growing cities. Population shrinkage does not necessarily lead to spatial "shrinkage". Therefore, population shrinkage can coexist with spatial growth [54]. Similarly, we explored this issue in the case of China and found that very few cities are shrinking in both the demographic and spatial dimensions. Therefore, the reasons for the emergence of S-shrinking cities have become very interesting. We tentatively estimate that these cities have expanded to a fairly large scale, as the built-up area of the 21 spatially shrinking cities in 2010 was 35.3% higher than the average of all MSCs. These cities are in the later stages of urbanization and are more economically developed cities, which have limited new available urban space and restrictions on the real estate market. Thus, we use the example of China also to demonstrate a pluralist world of urban shrinkage, and the fact that the three dimensions do not occur simultaneously [4].

### *5.2. The Underlying Causes of Shrinking MSCs*

Urbanization is an important background factor for the shrinkage of MSCs in China [22,48]. In the decades since the reform and opening up, a large number of rural people have migrated to cities, which has not only brought about population growth, but also contributed to the development of the urban economy as well as the expansion of urban land area. However, this growth has brought different results to cities of different sizes (Figure 7). Between 2000 to 2010, large cities and small cities (towns) increased their population by 44% and 47%, respectively, while MSCs by less than 9% [12]. This trend continued during the 2010–2020 period, and we used the 2010 and 2020 census data to find that MSCs account for only 11.4% of all urban population additions. While people prefer to move to large cities or nearby counties and small cities, MSCs are places where people neither want to go nor to stay. As a result, MSCs have seen less immigration on the one hand, and a large outflow of people to larger cities on the other. MSCs have had to fall into shrinkage.

MSCs in China tend to be resource-based cities or in marginal locations within the overall urban agglomeration. China's resource-based cities have been urbanized and industrialized earlier. As a result, a significant proportion of workers in these cities are already aging. In addition, with the depletion of resources and the rise of new industries, these cities have suffered a considerable loss of labor. This explains why aging, the rate of out-migration of the young population, the decline in the number of firms and the restructuring of industries are important explanatory factors for the shrinkage of MSCs. MSCs located at the margin of urban agglomerations are subject to the siphoning effect of large cities and are more likely to shrink, because these cities are not replenished by

the population of smaller cities and counties even as they continue to lose population to large cities.

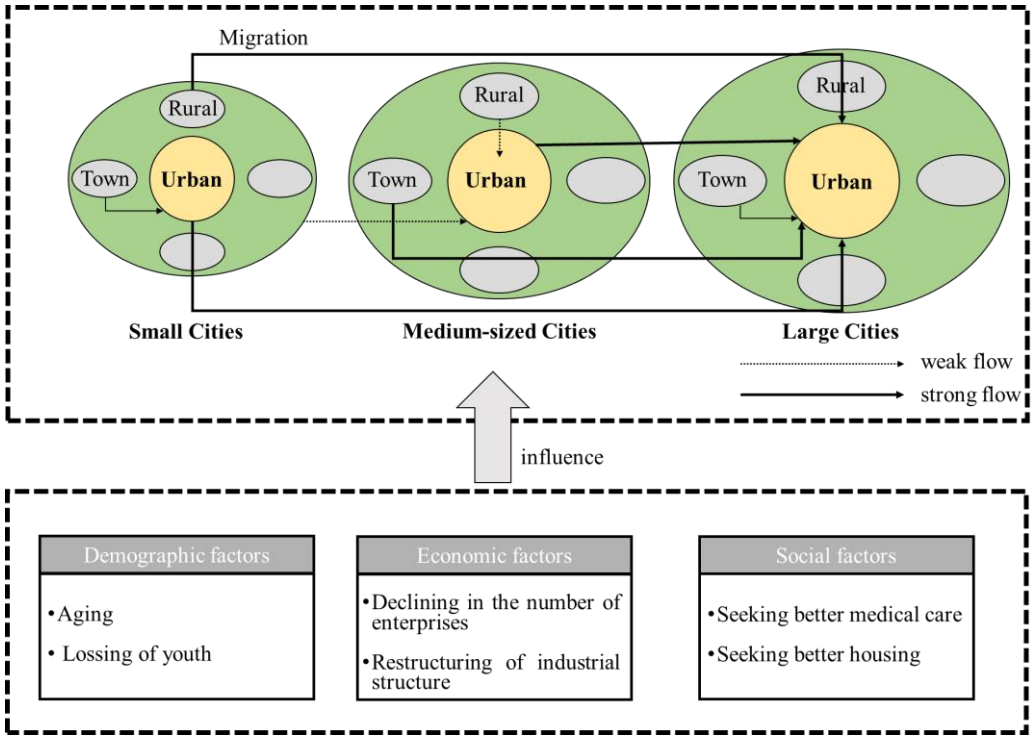



**Figure 7.** Influencing factors for MSCs' urban shrinkage.

In terms of the hierarchy of population migration, medium-sized cities should absorb the population of small cities and counties and gradually become regional centers of larger urban regions. However, due to China's policy favoring large cities, the gap between urban and rural areas in China is too wide, and the gap between large cities and MSCs is also quite large. The development in large and medium-sized cities is uneven. A large number of rural people have migrated to big cities in search of a better life. MSCs have not been able to develop as they should within this general trend of population mobility.

Aging, loss of young population, decline in the number of enterprises, restructuring of industry, and seeking better medical care and housing in large cities are all significant, as the three dimensions of demographic, economic, and social factors affect urban shrinkage in China's MSCs to varying degrees.

Aging has impacts on urban shrinkage. The international literature, especially in Europe, confirms that aging is a key factor in urban shrinkage [30,33,67]. In China, with rapid urbanization and a hypermobility background [13], most of the shrinking cities are not only affected by the aging of their population structure, but also by the outmigration of the young population [68]. To validate our findings, the average migration rate of the young population across 164 MSCs is −26.79%, indicating a decrease of 26.79% in population in this age group over 10 years, and it is even more severe in the P-shrinking cities, with an average of −40.54%.

Changes in the structure of industrial employment and the number of enterprises significantly affect MSC shrinkage. The majority of shrinking cities see slow growth or continuous decline in employment in secondary industry, combined with the reduction in the number of registered enterprises, suggesting that the shrinkage of MSCs is more likely to be due to the reduction in the number of enterprises and the lack of job opportunities, leading to population loss. In some resource-based cities in China, the important impact of industrial restructuring on urban shrinkage is indisputable [17]. The decline in industry

has had a noticeable "crowding out effect" on the urban population employed locally, and has led to the economic and spatial decline of cities [69].

Changes in medical conditions are an important factor in urban shrinkage. PLS regression effectively explained the impact of changes in the number of hospital beds on urban shrinkage. Although medical conditions have improved in almost all MSCs (161 out of 164), there is also a huge disparity in the change in medical conditions among cities. The number of hospital beds in growth cities increased by 82.77%, while the growth rate in shrinking cities is less than half of that in growth cities. Insufficient improvement in medical conditions in shrinking cities leads to less attractiveness compared to growing cities or larger cities. We need to be cautious in arriving at conclusions about the dynamics of housing conditions and shrinkage. International studies have confirmed the important relationship between housing vacancies and population loss, and changes in the number of housing and vacancy rates are more indicative of housing changes in shrinking cities [54]. However, it is difficult to obtain these two indicators for China's cities.

In summary, during the decade of rapid urbanization, a large rural population was able to enter cities. However, in 2022, China's total population experienced negative growth for the first time in decades, and this trend continued in 2023. We also found that the aging and migration rate of the young population in MSCs has a significant impact on urban shrinkage. Due to the imbalanced development policies implemented by the Chinese government in different regions, large cities have attracted a large number of young migrant workers. In contrast, small cities are encouraged by "county urbanization" policies. Compared with small and large cities, MSCs will be the first to face urban shrinkage in the future.

## 6. Conclusions

This paper confirms the multi-dimensional complexity of urban shrinkage using examples of MSCs in China [41,56]. Compared to previous studies, this paper analyzes the quantity, types, and spatial distribution of shrinkage in China's MSCs from 2010 to 2020 based on a multi-dimensional perspective of population, economy, and space. The paper employs PLS regression models to explore the influencing factors for multi-dimensional urban shrinkage. A total of 45 shrinking cities of seven types were identified, with an additional 119 growth cities. Specifically, there are 10 population-shrinking cities, 23 economic-shrinking cities, and 21 spatial-shrinking cities. The majority (71.1%) of cities only undergo shrinkage in one dimension. From a geographical distribution perspective, the northeastern region is the most severely affected area by population and economic shrinkage, while cities experiencing spatial shrinkage are mainly located away from the northeastern region, primarily in the eastern region near large cities.

Building upon the revelation of shrinkage phenomena in China's MSCs, this study further elucidates the factors influencing the shrinkage of these cities. The important factors explaining urban shrinkage are ranked as follows: reduction in the number of enterprises, decrease in hospital beds, decline in employment in secondary industry, migration of young population. These factors indicate that the direct factors driving MSC shrinkage from 2010 to 2020 are the weakening of urban attractiveness. Furthermore, future low fertility rates and aging will further exacerbate urban shrinkage. China implemented the two-child and three-child policies in 2015 and 2021 respectively, but the effects of these policies have been weak, with the birth rate decreasing from 1.20% in 2015 to 0.68% in 2022. In the long run, natural population changes will further impact urban shrinkage.

This study can assist governments and planning practitioners in transitioning from planning centered on urban growth. MSCs not only need to retain existing populations but also enhance their attractiveness to rural populations. On the one hand, strengthening inter-regional connections and introducing more enterprises to solve employment issues are necessary; on the other hand, efforts to improve the level of public services and enhance urban attractiveness are crucial. These measures require a correct understanding of urban

shrinkage and more focus on MSCs that have been neglected by policies, moving towards sustainable and people-centered urban governance.

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