

Article

How Does Population Shrinkage Affect Economic Resilience? A Case Study of Resource-Based Cities in Northeast China

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Abstract: By constructing an index system, this study analyzed the temporal and spatial characteristics of the economic resilience of 20 resource-based cities in northeast China after the financial crisis in 2008. On this basis, a mediation model was introduced to explore the mechanism of population shrinkage affecting economic resilience. The results show that: (a) from 2009 to 2019, the trend of the economic resilience of resource-based cities in northeast China was “ascending–descending–stable”. As time went by, the spatial difference of the economic resilience of resource-based cities gradually became obvious, indicating that the number of medium- and high-class cities was increasing. (b) By applying a correlation analysis, it was found that both a significant weak correlation and medium correlation existed between population shrinkage and economic resilience during the periods of 2011–2019 and 2013–2019. (c) Six mediation factors, namely industrial output, population consumption, resource dependence, urban innovation, cultural construction and environment quality, were chosen to apply the mediation model of population shrinkage affecting economic resilience. Among them, industrial output, population consumption, urban innovation, and cultural construction exerted a partial mediation effect on the process of population shrinkage affecting economic resilience, while the meditation effects of resource dependence and environment quality were not significant.

Keywords: northeast China; resource-based cities; shrinkage; economic resilience; mediation model



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1. Introduction

The term ‘resilience’ originates from physics, engineering and ecology [1]. Resilience emphasizes the ability of a system to maintain stability and to gradually recover to its original state in the face of external interference. Later, this concept evolved to include economic resilience after being introduced into economics and geography; now, resilience has become a new research hot spot. In the process of economic development, cities or regions are always subjected to various disturbances and shocks [2]. For example, shocks such as economic crises, natural disasters, epidemics and market changes pose great challenges to the development of an economic system. Economic resilience helps to explain why some regions can quickly recover or even realize growth after the shock, while other regions gradually decline after the impact of the shock [3]. Economic resilience is of vital importance for measuring the ability of a city to withstand various risks and to recover from damage, and also with regard to sustainable development and the formulation of policies.

In the planned economy era, the resource-based cities in northeast China exploited a large number of natural resources, which provided a solid guarantee for China’s economic development and energy supply [4]. Under the development mode of resource burning, resource-rich cities ushered in the spring of economic prosperity. However, at the same time, many hidden dangers were buried. The way in which these cities emphasized development over governance triggered a serious ‘man–land’ contradiction.

Moreover, the depletion of resources resulted in the gradual disappearance of the traditional advantages upon which resource-based cities rely. Thus, resources became the bottleneck, rather than the driving force, for the development of resource-based cities, leading to a series of urban problems, such as the resource curse [5]. Plagued by many factors, including resource exhaustion, a single industrial structure, lack of innovation and rigid administrative systems, the economic development level of resource-based cities in northeast China has fallen sharply. A large number of people have also lost their jobs, and the average wage is decreasing. These phenomena lead to a large level of population outflow, leaving the economy vulnerable to future economic shocks. The negative effects of this outflow are fed back to the urban economic system, deepening the existing social and economic problems even further.

It is commonly believed that population shrinkage tends to exert negative influences on the society and economy, but few have deeply studied its socioeconomic effects. In this article, the hypothesis that population shrinkage has negative effects on economic resilience is proposed and then confirmed with resource-based cities in China as research areas. The reasons why resource-based cities in northeast China are taken for empirical analysis in this study are as follows: (1) Resource-based cities in northeast China are plagued by location marginalization and resource exhaustion. They lack the endogenous impetus necessary for economic development, and thus, it is more likely that they will show poor economic resilience after economic shocks. (2) Resource-based cities in northeast China have socioeconomic problems that cannot be ignored. Most of these cities are suffering from severe population loss, which is a typical situation found when explaining and understanding shrinkage. (3) Compared with cities in other regions, resource-based cities in northeast China more clearly combine the two factors of low economic resilience and population shrinkage. As such, these cities serve as the subject of the question, “How does population shrinkage affect economic resilience?” To answer the question, the following research was conducted by building an index system of economic resilience and applying a mediation effect model. To thoroughly understand the impact of population shrinkage on economic resilience is an imperative prerequisite for transforming the economic development model of resource-based cities. Such understanding can provide a scientific basis for improving the economic resilience of resource-based cities in northeast China in the future.

2. Literature Review

2.1. Population Shrinkage

Population shrinkage is also known as population loss, depopulation or population decline. With the trend of an aging and declining population in Western countries, the phenomenon of population shrinkage is of wide concern. Most countries in Europe, North America and Asia, and Australia, have experienced significant population decline [6–9]. Against this background, many scholars are conducting extensive research on the definition, spatial characteristics, influencing factors and the socioeconomic effects of population shrinkage. In China, with population migrating on a large scale and the fertility rate continuously declining, the phenomenon of population shrinkage is becoming increasingly obvious [10]. For example, in the Pearl River Delta, Yangtze River Delta, Beijing–Tianjin–Hebei region and northeast China, the rapid population inflows and outflows indicate population shrinkage in some parts of these regions [11]. These studies have made beneficial contributions to the definition, trend and influencing factors of population shrinkage, but the positive or negative effects of population shrinkage need to be further explored [12]. In the context of China’s special administrative divisions, the concept of population shrinkage is significantly different from that of urban shrinkage [13]. The study of population shrinkage mainly focuses on population loss in urban administrative areas, while the study of urban shrinkage covers the declines of population, the economy, society and the environment in urban physical areas. Most population-related research pays more attention to ur-

ban shrinkage than population shrinkage [14]. Besides, existing studies on population shrinkage tend to cover all cities, rather than a certain kind of city in the region, as their research areas.

2.2. The Measurement of Economic Resilience

Two methods are used in measuring economic resilience currently. One is the sensitive index method and the other is comprehensive index method. The sensitive index method refers to a variable that can directly reflect the level of economic resilience for measurement. For example, Martin chose the employment rate to measure the economic resilience of various regions in the UK after the economic crisis [2]. Davies and Brakman used the unemployment number and GDP to measure the regional economic resilience of European countries after 2008 [15,16]. Bergeijk used the decline of global trade volume caused by the financial crisis to calculate the economic resilience of various countries [17]. The comprehensive index method is used to measure economic resilience by constructing an indicator system [18]. Briguglio was the first to measure economic resilience by the comprehensive index method [19]. Later, think tanks such as CLES, ARUP and IPPR North gave affirmation to this method and respectively proposed a variety of indicator systems to assess regional economic resilience [20–22].

There are certain negative aspects to using the sensitive index. First, to calculate economic resilience requires definition of a reference benchmark and the shock period, which is only applicable to large economic shocks and disturbances. When there are no shocks, the economic resilience of a city still exists, and this method will not be applicable. Second, similar economic shocks may not occur at the same time in different regions, and the measurement based on the same period is obviously inaccurate. Third, the selection of a sensitive variable does not cover all variables relevant to economic resilience. Therefore, this paper adopts the comprehensive index method covering more information to measure the economic resilience of resource-based cities in northeast China.

2.3. The Mediating Variables in the Process That Population Shrinkage Affects Economic Resilience

Few studies have deeply explored the impact of population shrinkage on economic resilience; nor have they examined the impact of economic resilience on population shrinkage, due to the complicated mechanisms of their interactions. In this paper, the effects of population shrinkage and the influencing factors of economic resilience are combined, and then the potential mediating paths via which population shrinkage affects economic resilience are proposed.

(a) Industry productivity

The economic effect caused by population shrinkage is often negative. Nelle and Ciccone believed that population shrinkage is not conducive to improving productivity [23,24]. The main explanation for this point is that population shrinkage is characterized by a reduction of the labor force and human capital, thus affecting the productivity of economic activities [25]. Productivity and economic resilience have been proved to be positively correlated [26]; the most resilient regions also tend to do better in industrial specialization and productivity [27]. The better the productivity of a region is, the higher the upper limit of its economic resilience is, indicating that a region of high productivity is more likely to exhibit resilient behaviors [28].

(b) Population consumption

Population shrinkage hinders the improvement of a city's consumption level. Two of the most important features of population shrinkage are the reduction in population size and the proportion of youth in the total population. Shrinkage in population size is bound to reduce the amount of overall consumption [29]. According to the overlapping generations (OLG) model [30], the consumption demand of the youth group is far

greater than that of the middle-aged and older groups. Besides, the youth group tends to pay more attention to high-quality consumption, which is something the middle-aged and older groups rarely pursue. If the proportion of youth is smaller than the other two groups, the middle-aged and older groups will be more inclined to increase savings and reduce consumption [31]. The change in consumption scale and structure caused by population shrinkage deeply affects a city's economic resilience. The negative effect from the changes in consumption scale and level is bad for economic growth, the upgrading of the industrial structure, the development of pillar industries and industry diversity [32,33].

(c) Resource dependence

Resource dependence refers to the mode in which cities rely on the comparative advantages of local natural resources; these resources are exploited and processed for economic development. An existing study has proved that resource dependence is greatly affected by population size. Specifically, the smaller the population size is, the stronger the resource dependence of a city will be [34]. Moreover, the lack of human capital caused by population loss can also reinforce resource dependence by dragging down long-term economic growth [35]. Resource dependence is bound to lead to higher wages and benefits for workers in resource-dependent sectors than workers in other sectors [36,37]. This phenomenon causes a squeezing effect and restricts the green development of urban economies [38,39]. To sum up, resource dependence exerts a negative influence on economic resilience.

(d) Innovation ability

Di Maria took developing countries as samples and found that population migration greatly reduces the level of human capital in the out-migration areas, thus weakening the innovation atmosphere in these areas [40]. Moreover, a new interpretation exists for the impact of population loss on innovation in China's unique institutional environment. The paradox of population loss and land expansion leads to a decline in the density of population and the economy [41]. This hinders the exchange of advanced production technologies and methods among all kinds of people and enterprises [42]. In terms of the impact of innovation on economic resilience, Martin emphasized for the first time that regional resilience depends on entrepreneurship and the ability to trigger changes [2]. Subsequently, Kogler proved that technological innovation has been widely identified as a key driver for regional growth [43]. The study found that technological innovation can help regions effectively cope with unpredictable recessions and increase the adaptive resilience of the region's economy [44]. All these findings indicate that innovation has an extraordinary impact on economic resilience.

(e) Culture construction

In the studies which find that population shrinkage and culture are related, culture construction is always considered to be a contributor to alleviating and reversing the situation of population shrinkage [45]. However, few existing studies have discussed whether population shrinkage will affect culture construction. This paper advocates that population shrinkage will affect culture construction through two aspects, namely community consciousness and government expenditure on cultural construction. Community consciousness is the basic unit for the formation of urban culture; population shrinkage undermines the network of community consciousness [46], and this is not conducive to culture construction. Although strengthening culture construction is regarded as an important means to alleviate shrinkage, in reality, most shrinking cities suffer from financial strain and lack what is required to improve the situation. Some cities even suffer a decline of their original cultural space. Culture contributes to the formation of economic resilience. First, institutions themselves are included in the range of culture, and they help guide economic

activities. Second, culture has the function of reducing transaction costs. Finally, culture's attitude toward change also predicts the potential of economic resilience [47].

(f) Environment quality

No consensus has been reached on whether population shrinkage has a positive or negative impact on environment quality. Blanco pointed out that many shrinking cities illegally dump construction waste and household garbage on vacant lands [48]. This is particularly typical in old industrial cities, which suffer from perennial pollution [49]. However, the impact of population shrinkage on the environment is not always negative. Some scholars have pointed out that population shrinkage in a number of European and American cities has brought about considerable ecological benefits [50,51], providing new opportunities to settle certain urban issues. A good environment is the key attribute for a city to continuously improve its economic resilience [52], because more foreign investment and new enterprises can be attracted. A city can realize long-term development through the organic combination of a good environment and industries.

3. Methods and Data

3.1. Study Area

Northeast China, including Liaoning Province, Jilin Province and Heilongjiang Province, is one of China's four major economic blocks. Having been adversely affected by resource exhaustion, the slow development of the market economy and other factors since the China's reform and opening up, cities in northeast China are now facing development problems, such as a sluggish economic trend, slow development speed and obvious spatial polarization. After the proposal aimed at revitalizing the old industrial base in northeast China, the decline of urban development was temporarily curtailed, and a brief period of prosperity was realized in northeast China. However, as China's overall economic development has entered a new period characterized by rapid change, structural optimization and momentum conversion, the socioeconomic development of cities in northeast China has encountered a new low. Resource-based cities are very typical, as they reflect the living state of most cities in northeast China. Research on resource-based cities can help us grasp the essence of the problems in northeast China. As shown in Figure 1, 20 resource-based cities in northeast China are taken as the study area. These cities were selected according to the national sustainable development plan for resource-based cities.

3.2. Research Methods

3.2.1. Measurement of Population Shrinkage

Based on a comprehensive consideration of the definition of population shrinkage, the total population change of a resource-based city in adjacent years is taken to measure whether or not that city shrinks. The formula is as follows:

$$C_{\delta} = \frac{P_i - P_{i-1}}{P_{i-1}} \quad (1)$$

where C_{δ} represents the population change rate of city δ in year i , and P_i and P_{i-1} , respectively, represent the total population of city δ in year i and year $i-1$ ($i = 2009, 2010, \dots, 2019$). If $C_{\delta} < 0$, then we identify city δ in year i as a shrinking city; if $C_{\delta} > 0$, then we identify city δ in year i as a growing city.

3.2.2. Measurement of Economic Resilience Based on Entropy Method

Economic resilience is essentially the ability of an economic system to adapt to the environment. The resilience is reflected in the whole process in which the urban economy responds to external disturbances and shocks. Martin proposed the concept of evolutionary resilience [2]. He believed that an economic system has the ability

to optimize its own structure, thereby minimizing the impacts of disturbances and even achieving its own transformation by taking advantage of external shocks. Martin was the first one to assess economic resilience by building indexes based on the phases of resistance and recovery. Based on Martin's definition of economic resilience, Boschma argued that economic resilience should not only include the ability to face short-term crises but also to resume long-term economic growth [53]. Therefore, following their definition of economic resilience, this paper proposes a pressure-state-response index system from the perspectives of resistance, regulation and response capacities (Table 1).

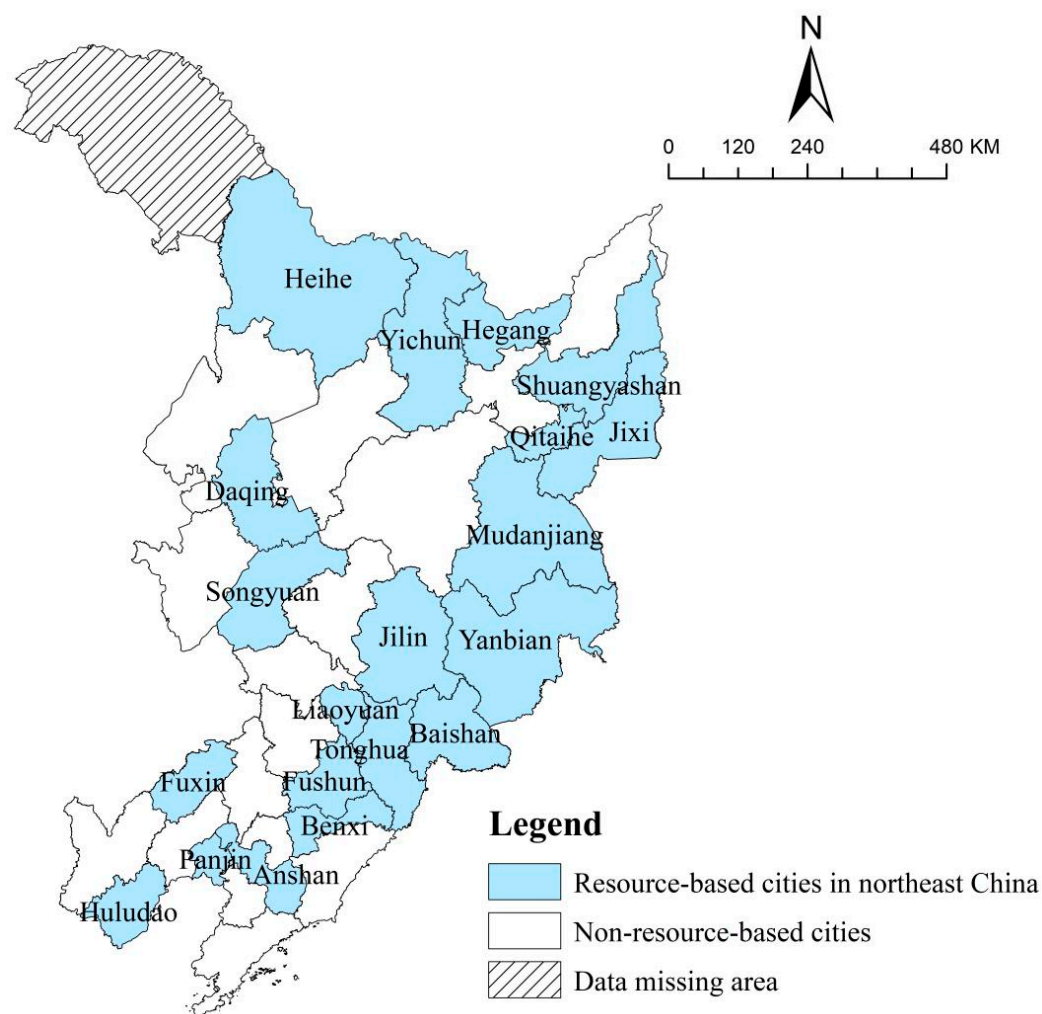


Figure 1. Distribution of resource-based cities in northeast China.

Resistance capacity refers to the capacity of a region to maintain its stable structure when facing an economic shock, and it is characterized by industrial structure, urbanization ratio, low unemployment and minor urban–rural disparities. Regulation capacity refers to certain changes in economy and society when an economic system of a city faces external disturbances, and it is characterized by employment vitality, consumption potential, population density and support for urban and economic renewal. Response capacity refers to the aftershocks of remedial measures that are taken by several economic forces, such as the government, society, enterprises, or individuals, and it is measured using the government's financial ability, enterprises' financial activities, the degree of trade openness and foreign collaboration.

In this paper, the entropy method is used to determine the index weight of economic resilience. Firstly, the original index values are transformed into $[0, 1]$ an interval using the extreme method, and the different orders of magnitude and dimensions are eliminated. The specific formulas used are as follows:

If the index is positive:

$$X'_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \quad (2)$$

If the index is negative:

$$X'_{ij} = \frac{\max(X_j) - X_{ij}}{\max(X_j) - \min(X_j)} \quad (3)$$

where X'_{ij} is a standardized index; X_{ij} is the original index, representing the value of index j of year i of a city; and $\max(X_j)$ and $\min(X_j)$ are the maximum and minimum values of the index j across all years, respectively.

Then, the entropy method is used to calculate the weight of each index and the economic resilience. The specific formulas used are as follows:

$$W_j = \frac{1 + k \sum_{i=1}^m \left(\frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \times \ln \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \right)}{\sum_{j=1}^n \left(1 + k \sum_{i=1}^m \left(\frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \times \ln \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \right) \right)} \quad (4)$$

$$R_{ij} = W_j \times X'_{ij} \quad (5)$$

$$R_i = \sum_j R_{ij} \quad (6)$$

where $k = -1/\ln m$ is a constant; m is the number of research areas, n is the number of indices; W_j is the weight of index j ; R_{ij} is the single index's calculation score; R_i is the comprehensive score of the year.

Table 1. Index system of economic resilience of resource-based cities in northeast China.

System Level	Criterion Level	Specific Factor Level	Measurement	Direction	Weight	Indicator Source	Data Source
Economic resilience	Resistance capacity	Industrial structure	Output of the second and third industry/GDP	+	0.0431	Man [54]	China City Statistical Yearbook
		Urbanization ratio	Urban population/Total population	+	0.0704	Wang [55]	China City Statistical Yearbook
		Unemployment	Number of unemployed	−	0.0086	Wang [55]	China City Statistical Yearbook
		Urban–rural disparities	Average income of urban population/Average income of rural population	−	0.0283	Sharifi [18]	China Statistical Yearbook for Regional Economy
	Regulation capacity	Employment vitality	Number of practitioners	+	0.1104	Chen [56]	China City Statistical Yearbook
		Consumption potential	Savings of urban and rural residents	+	0.1201	Bruneckiene [57]	China City Statistical Yearbook

Table 1. Cont.

System Level	Criterion Level	Specific Factor Level	Measurement	Direction	Weight	Indicator Source	Data Source
		Population density	Total population/area	+	0.1423	Pavel [58]	China Urban Construction Statistical Yearbook
		Support for urban and economic renewal	Investment in fixed assets	+	0.1687	Jiang, Wang and Zhao [59]	China City Statistical Yearbook
	Response capacity	Government's financial ability	Fiscal revenue	+	0.1401	Briguglio [60]	China City Statistical Yearbook
		Enterprises' financial activities	Loans from financial institutions	+	0.127	Wang [55]	China City Statistical Yearbook
		The degree of trade openness	Value of imports and exports	+	0.0214	Man [54]	China City Statistical Yearbook
		Foreign collaboration	Foreign direct investment	+	0.0195	Bruneckiene [57]	China City Statistical Yearbook

3.2.3. Mediation Model

Drawing on the literature review of the mediating variables in the process in which population shrinkage affects economic resilience, we speculate that complicated mechanisms exist between population shrinkage, economic resilience and mediating variables. Based on this framework, economic resilience is introduced as the explained variable. Population shrinkage is introduced as the explanatory variable. Industry productivity, population consumption, resource dependence, innovation ability, culture construction and environment quality are introduced as the mediating variables. More detailed descriptions of each variable are shown in Table 2. The specific formula of the mediation model is:

$$Y = \alpha_1 + cX + \varepsilon_1 \quad (7)$$

$$M = \alpha_2 + aX + \varepsilon_2 \quad (8)$$

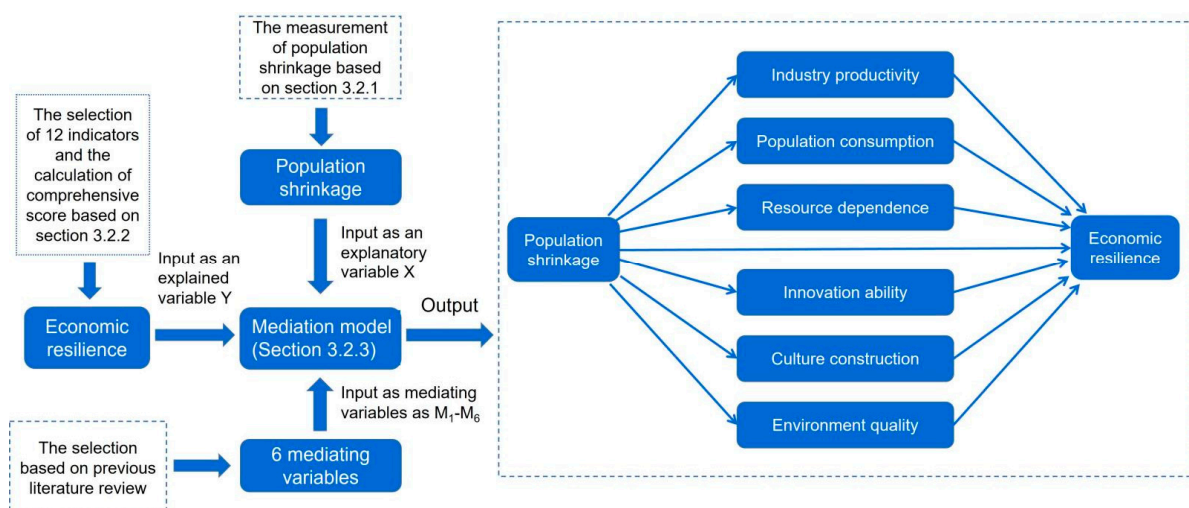
$$Y = \alpha_3 + c'X + bM + \varepsilon_3 \quad (9)$$

where Y is the economic resilience of each city, and X is the population shrinkage rate of each city; M represents the mediating variables, including industry productivity, population consumption, resource dependence, innovation ability, culture construction and environment quality. Then, α_1 , α_2 and α_3 represent the fixed intercepts; c , a , c' and b , respectively, represent the total effect, the configuration effect, the direct effect and the mediation effect generated by variables. Finally, ε_1 , ε_2 and ε_3 represent the random disturbance term. Equation (2) simulates the total effect of population shrinkage on economic resilience, and c stands for the total effect. Equation (3) simulates the configuration effect of population shrinkage on the mediating variables, and a stands for the configuration effect. Equation (4) simulates the direct effect and the mediation effect of population shrinkage on economic resilience; c' and ab , respectively, stand for the direct effect and the mediation effect. The relationship between each effect is $c = c' + ab$. Bootstrap was used to assist in testing the mediation effect.

A flowchart (Figure 2) is added to help explain how different parts of the research method are linked to each other.

Table 2. Description of variables.

Variable Type	Variable	Variable Indicator	Variable Abbreviation	Data Source
Explained variable	Economic resilience	/	ER	Calculated in Section 3.2
Explanatory variable	Population shrinkage	/	Pop Change	Calculated in Section 3.2
	Industry productivity	Average GDP	AGDP	China City Statistical Yearbook
	Population consumption	Per capita social retail sales	PCSR	China City Statistical Yearbook
	Resource dependence	Proportion of employees in resource industries	RD	China City Statistical Yearbook
	Innovation ability	Innovation index	INNOV	The Center for Enterprise Research of Peking University
Mediating variables	Culture construction	Baidu Index of “City name + Culture”	CI	The Baidu Index platform
	Environment quality	Air quality index	AQI	The data center of the Ministry of Ecology and the Environment of the People’s Republic of China

**Figure 2.** The flowchart of research process based on Sections 3.2.1–3.2.3.

4. Characteristics of the Economic Resilience of Resource-Based Cities in Northeast China

4.1. Temporal Characteristics

Based on the proposed index system, the economic resilience of each city is calculated from 2009 to 2019 (Figure 3). As can be seen from the figure, the overall trend of the economic resilience of resource-based cities in northeast China was first upward trend, then downward, and finally stable, with 2013 and 2016 as the dividing years. From 2009 to 2013, China released policies to help northeast China fight the economic crisis. Cumulative fiscal transfer payments, as well as the reforms of the markets and functions of the governments from The Twelfth Five-Year Plan all contributed to the improvement of the ability of resource-based cities in northeast China to resist economic risks. From 2013 to 2016, the New Northeast Phenomenon emerged. This means the overall economy of cities in northeast China was weak, and its transformation power was insufficient in the face of the deepening social and economic transformation in China. Against this background, the original development models of resource-based cities in northeast China could not satisfy the demands at that time from their society and economy, leading to the continuous

decline of their economic resilience. From 2016 to 2019, many resource-based cities in northeast China began to transform and expand the external effects of transformation. For example, industrial and mining cities tried to develop complementary industries, such as equipment manufacturing, ship supporting or industry-and mine-based tourism. Forestry cities managed to start forestry economy, pension industry based on ecology and ice-snow tourism industries. Even if resource-based cities had made progress to a certain extent during the process of transformation, there is still room for improvement. In general, during the past 11 years, the economic resilience of resource-based cities in northeast China has shown obvious stage characteristics, which are, to a large extent, closely related to national policies. Their endogenous factors are not sufficient for urban development.

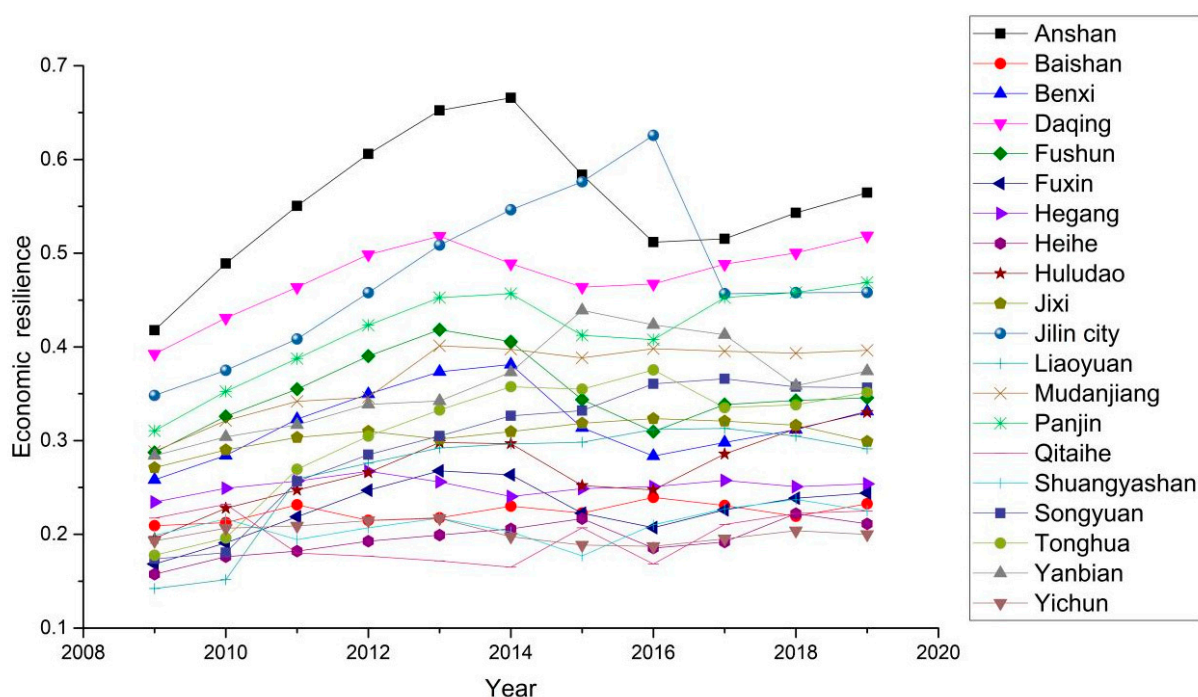


Figure 3. Change of economic resilience of resource-based cities in northeast China.

4.2. Spatial Characteristics

The years 2009, 2014 and 2019 were chosen for the analysis of the spatial differentiation of the economic resilience of resource-based cities in northeast China (Figure 4). Three classes of economic resilience have been divided for comparison purposes, namely low class (0–0.3), medium class (0.3–0.5) and high class (0.5–0.7). From 2009 to 2019, the spatial gradation of economic resilience gradually became obvious. The number of cities with medium and high economic resilience increased; these cities are mainly located along the Hunchun–Ulanhot Expressway and the Hegang–Dalian Expressway. Five cities on the border of Heilongjiang Province, Baishan and Liaoyuan in Jilin Province, and Fuxin in Liaoning Province were in a state of low economic resilience. In 2009, the overall economic resilience of resource-based cities in northeast China was low. Most cities (except for Daqing, Jilin, Panjin and Anshan) had low economic resilience, indicating that most cities took a hit during the economic crisis. In 2014, the differentiation among the three classifications was more obvious than in 2009. The economic resilience of many cities had improved, as a result of the support of national policies. Among these cities, Jilin and Anshan were of high economic resilience in 2014; several cities with medium economic resilience are closely distributed around these two cities. Meanwhile, the cities with low economic resilience are mainly distributed near the border of northeast China. In 2019, the grading characteristics were similar to those in 2014, with the economic resilience grades of Jilin and Jixi declining, Daqing and Huludao improving, and the economic resilience grades of the rest unchanged.

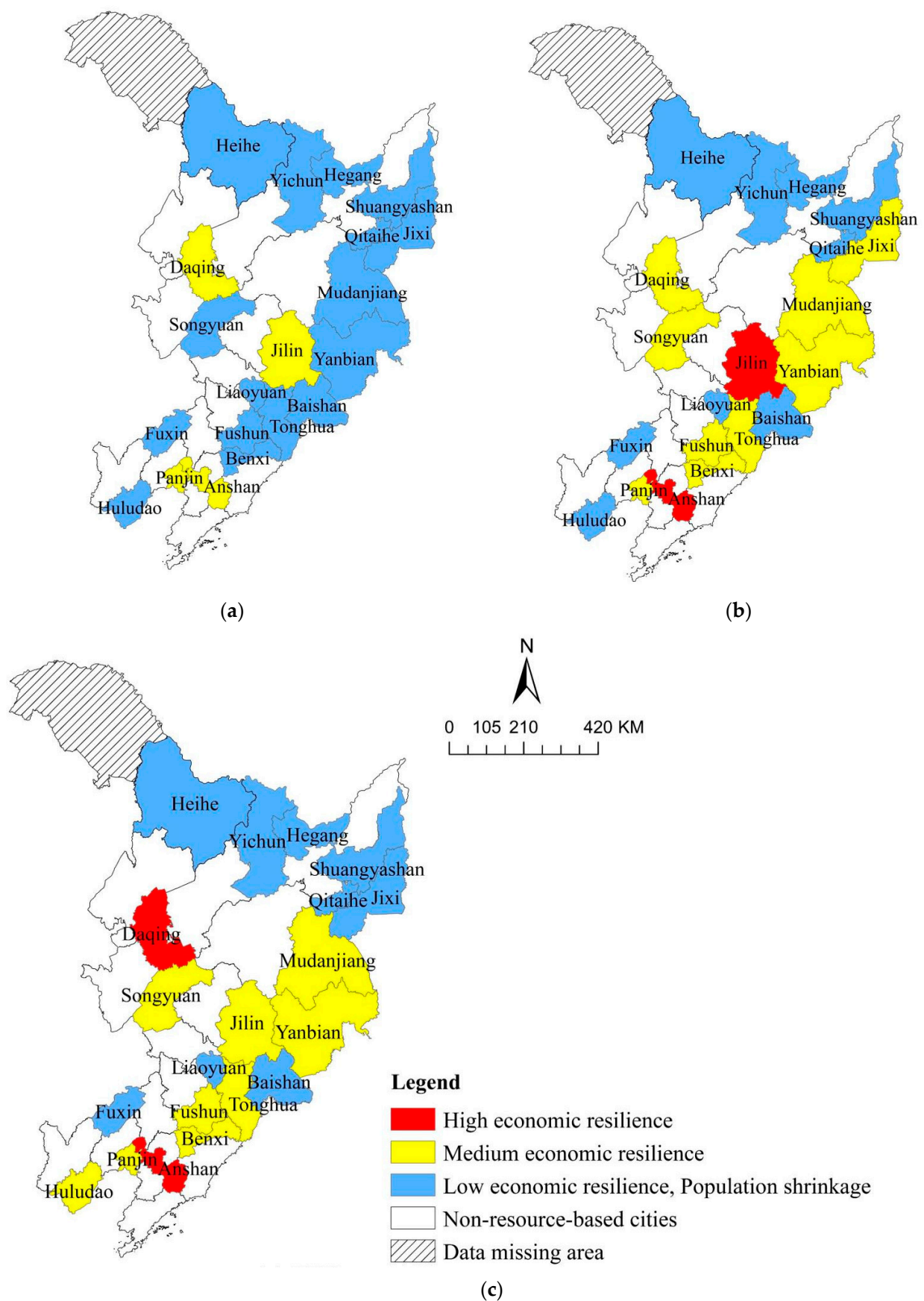


Figure 4. Spatial differentiation of the economic resilience of resource-based cities in northeast China. (a) 2009; (b) 2014; (c) 2019.

5. Impact of Population Shrinkage on the Economic Resilience of Resource-Based Cities in Northeast China

5.1. *The Relationship between Population Shrinkage and the Economic Resilience of Resource-Based Cities in Northeast China*

5.1.1. The Spatial Matching of Population Shrinkage and Economic Resilience

Based on population shrinkage and the classification of economic resilience, there are five spatial types (Figure 5). Analyzing the trend of each type, from 2009 to 2019, one can see that small changes occurred in the numbers of cities whose economic resilience belonged to the medium class. The population of those cities increased, while the cities whose economic resilience belonged to the high class saw their populations shrink. There were major changes in the numbers of cities: (1) whose economic resilience belonged to the low class and the populations of which shrank, (2) those whose economic resilience belonged to the low class and the populations of which increased, and (3) those whose economic resilience belonged to the medium class and the populations of which shrank. As can be seen from the figure, these three types of cities with major changes are distributed in an inverted “L” shape around Jilin, Anshan, Fushun and Daqing. The number of cities whose economic resilience belonged to the low class and the populations of which shrank changed from five in 2009, to eight in 2014 and 2019. The number of cities whose economic resilience belonged to the low class and the populations of which increased experienced a drastic change. There were 11 such cities in 2009, and just one such city in 2014 and 2019. The number of cities whose economic resilience belonged to the medium class and the populations of which shrank also experienced a major change. There were only two such cities in 2009, but that figure increased to eight in 2014, and seven in 2019. Cities whose populations shrank tended to have lower levels of economic resilience if judged solely from the perspective of the number change in spatial types. However, is this a reasonable conclusion? Did a relationship exist between population shrinkage and economic resilience? If so, what are the mechanisms between them? The following research will answer these questions.

5.1.2. The Correlation between Population Shrinkage and Economic Resilience

In response to the question in the previous section, “Did a relationship exist between population shrinkage and economic resilience?”, a Spearman correlation analysis was applied to quantify the relationship between them (Table 3). It is generally believed that when the correlation coefficient falls between 0 and 0.2, two variables are irrelevant. When the correlation coefficient falls between 0.2 and 0.4, the correlation is weak; when the coefficient falls between 0.4 and 0.6, the correlation is moderate; when the coefficient falls between 0.6 and 0.8, the correlation is strong, and when the coefficient falls between 0.8 and 1, the correlation is high. As can be seen from Table 3, the correlation between population shrinkage and the economic resilience of resource-based cities in northeast China increased with time. Since 2011 and 2013, a significant weak correlation and moderate correlation has been shown between them; this is also consistent with the number trajectory of regional resource-based cities’ shrinkage and growth (Figure 6). Since 2011, the number of resource-based cities that are shrinking has maintained at a high level, indicating that the prerequisite for the correlation to be significant is that the number of shrinking cities stays at a stable level. The relationship between population shrinkage and economic resilience is complicated; they are the cause and effect of each other. This study mainly focuses on how population shrinkage affects economic resilience. In order to ensure the significance and sufficiency of the samples for the following model, the period from 2013 to 2019, with moderate correlation and relatively sufficient samples, was selected.

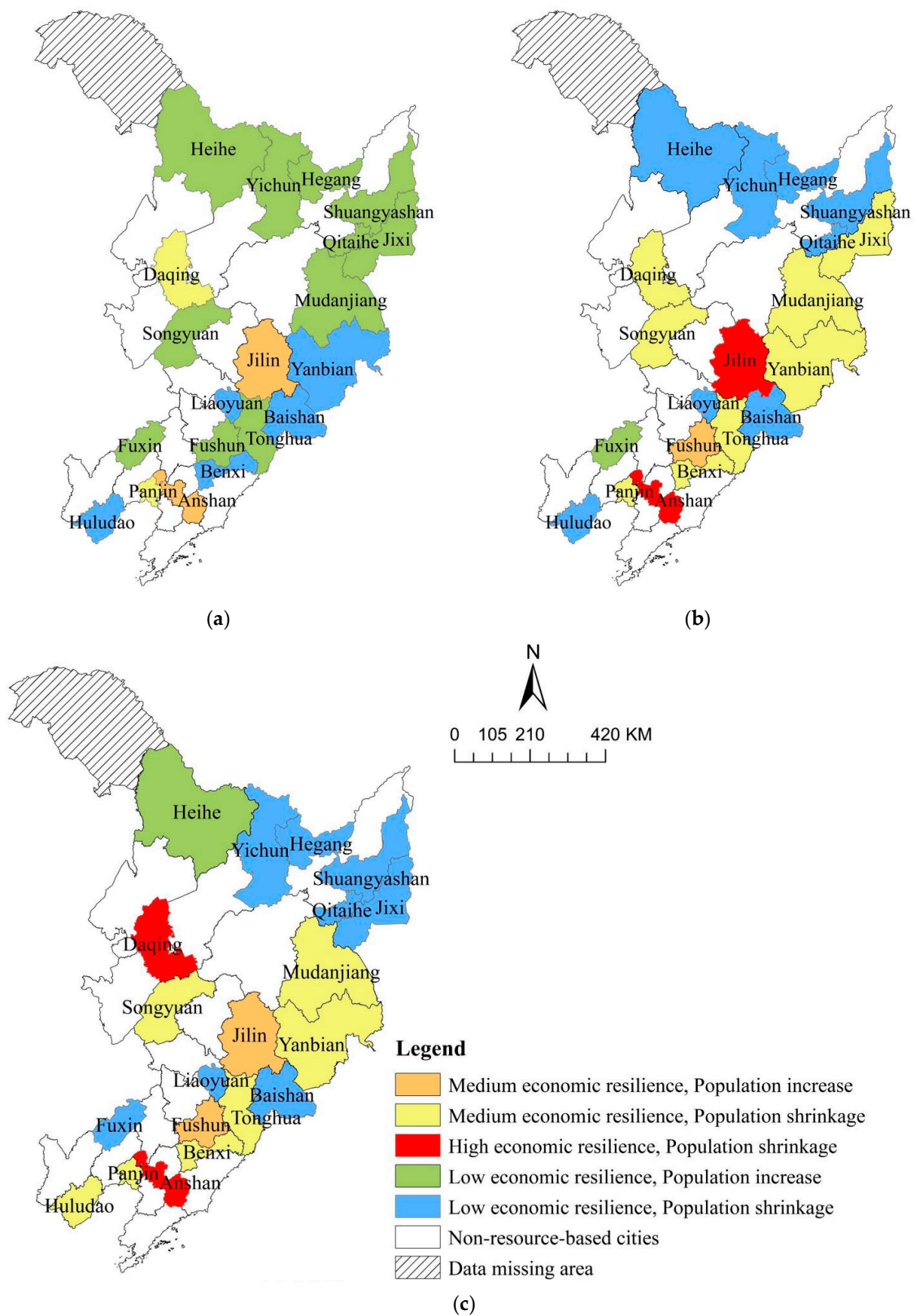
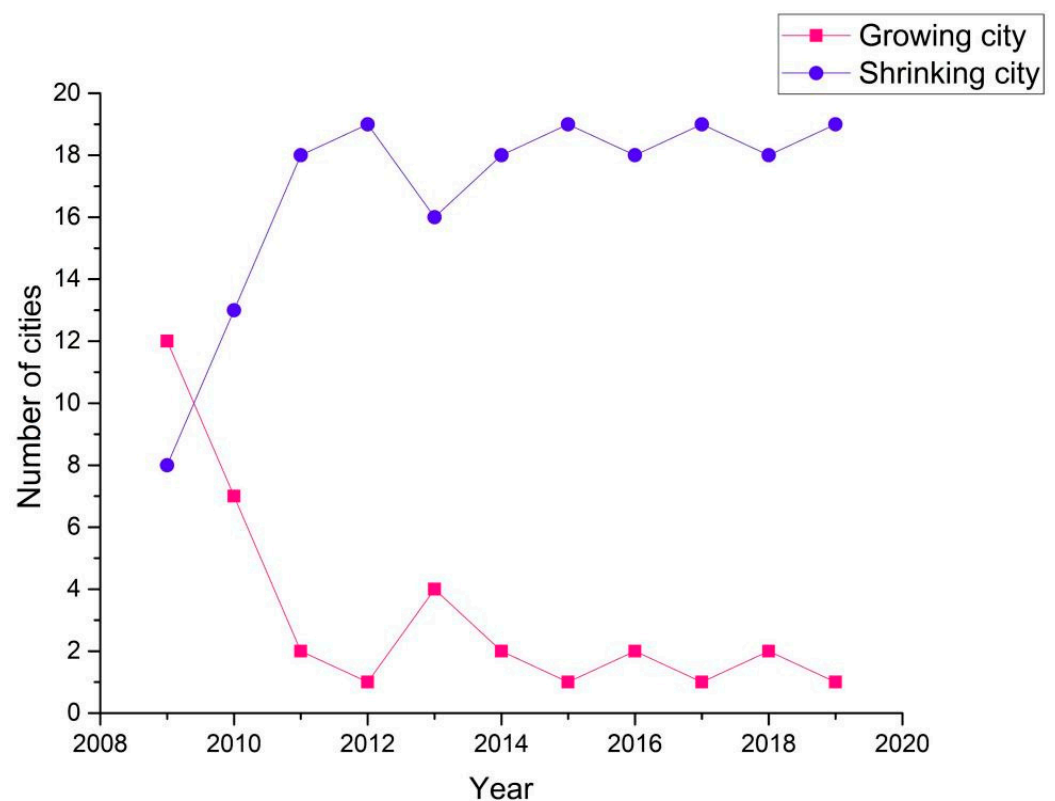


Figure 5. The matching types of population shrinkage and economic resilience of resource-based cities in northeast China. (a) 2009; (b) 2014; (c) 2019.

Table 3. The correlation between population shrinkage and the economic resilience of resource-based cities in northeast China.

Period	Spearman Coefficient	Sig.	Sample Size
2009–2019	0.129	0.057	220
2010–2019	0.238 **	0.001	200
2011–2019	0.315 **	0.000	180
2012–2019	0.372 **	0.000	160
2013–2019	0.420 **	0.000	140
2014–2019	0.449 **	0.000	120
2015–2019	0.518 **	0.000	100
2016–2019	0.510 **	0.000	80
2017–2019	0.428 **	0.000	60
2018–2019	0.534 **	0.000	40
2019	0.405	0.077	20

** means that the influence is significant at 0.01 level.

**Figure 6.** Number trajectory of the population shrinkage and growth of resource-based cities in northeast China.

5.2. The Paths by Which Population Shrinkage Affects Economic Resilience

A mediation model was used to examine the paths by which population shrinkage affects the economic resilience of resource-based cities in northeast China. As shown in Table 4, population changes have a significant positive effect on economic resilience, based on the total effect (the regression value is 3.797, passing the 1% test of significance). That is, against the background that most resource-based cities shrink, the more the population shrinks, the lower is the economic resilience. In addition, population shrinkage has significant negative effects on industry productivity, population consumption, innovation ability and culture construction. Population shrinkage also strengthens these cities' dependence on their natural resources, whereas the relationship between population shrinkage and environment quality is not significant. For this paper, six mediating variables were put into the mediation model, first one-by-one and then together. The results are shown in

Table 5. Industry productivity, population consumption, innovation ability and culture construction exerted positive partial mediation effects on the influencing paths; the mediation effects of resource dependence and environment quality were not obvious. By comparison, the mediation effect value of innovation ability was the highest (0.726), followed by those of industry productivity (0.655), culture construction (0.571) and finally population consumption (0.491).

Table 4. The allocation effects of population shrinkage on mediating factors.

Variable	Total Effect	Allocation Effect					
	ER	AGDP	PCSR	RD	INNOV	CI	AQI
Pop. shrinkage	3.797 ** (4.353)	4.699 ** (3.248)	5.145 ** (3.025)	−4.866 ** (−2.848)	4.849 * (2.584)	4.170 * (2.354)	1.866 (1.572)
Constant	0.364 **	0.244 **	0.417 **	0.193 **	0.325 **	0.245 **	0.290 **
Sample size	140	140	140	140	140	140	140
Adj R ²	0.114	0.064	0.055	0.049	0.039	0.032	0.01

** and * mean that the influence is significant at 0.01 and 0.05 levels, respectively.

Table 5. Regression results of population shrinkage impacting on mediating variables and economic resilience.

Variable	The Direct Effect of Population Shrinkage on Economic Resilience after the Introduction of Mediating Factors							Mediation Effect	Conclusion
	AGDP	PCSR	RD	INNOV	CI	AQI	All Introduced		
	ER	ER	ER	ER	ER	ER	ER		
Pop. shrinkage	2.081 ** (2.880)	1.830 ** (3.038)	3.344 ** (3.776)	1.985 ** (3.725)	2.308 ** (3.755)	3.471 ** (4.046)	1.091 * (2.322)	/	/
AGDP	0.365 ** (8.909)	/	/	/	/	/	0.139 ** (3.579)	0.655 ** [0.015~0.124]	Partial mediation
PCSR	/	0.382 ** (13.090)	/	/	/	/	0.096 * (2.549)	0.491 ** [0.008~0.096]	Partial mediation
RD	/	/	−0.093 * (−2.172)	/	/	/	−0.030 (−1.152)	0.145 ** [−0.013~0.045]	Not significant
INNOV	/	/	/	0.374 ** (15.829)	/	/	0.150 ** (4.031)	0.726 ** [0.019~0.119]	Partial mediation
CI	/	/	/	/	0.357 ** (12.331)	/	0.137 ** (3.869)	0.571 ** [0.016~0.099]	Partial mediation
AQI	/	/	/	/	/	0.175 ** (2.869)	0.063 (1.796)	0.118 ** [−0.002~0.032]	Not significant
Constant	0.275 **	0.205 **	0.382 **	0.243 **	0.277 **	0.314 **	0.196 **	/	/
Sample size	140	140	140	140	140	140	140	/	/
Adj R ²	0.435	0.604	0.138	0.685	0.577	0.158	0.788	/	/

** and * mean that the influence is significant at 0.01 and 0.05 levels, respectively.

Population is the body of economic activities, and population shrinkage has a great impact on urban economic systems. First, population shrinkage significantly constrains the innovation abilities of resource-based cities, leading to a reduction of economic resilience. The regression results show that population change has a positive effect on innovation ability (4.894), and innovation ability is positively correlated with economic resilience (0.374). In reality, a loss of the youth population leads to the phenomenon of population aging. This is significant, because the elderly have passed the golden age of learning and working. Their relatively low innovation consciousness affects all kinds of economic activities, and the economic system tends to lack the ability to make a correct and positive response when facing all kinds of risks.

Population shrinkage will lead to a significant decrease in industry productivity (4.699), and further, will lessen economic resilience (0.365). A large population loss means the personnel engaged in production activities will be unceasingly reduced, resulting in the frequency and density decline of all kinds of aggregated economic activities. This is not conducive to the sustainable development of an economy and is in reality a threat to an economy's stability and vitality. Subsequently, the low level of the economic resilience of resource-based cities means the population's overall income cannot be guaranteed, thus causing further population loss and creating an endless vicious circle.

Population shrinkage is not conducive to culture construction (4.107). While rarely quantified as a factor, culture plays an irreplaceable role in improving economic resilience (0.357). As has been widely discussed, institutional and cognitive lock-ins are the most important reason that the development of resource-based cities in northeast China is stuck in the current dilemma [61]. Essentially, a region's institutions and cognition belong to the category of regional culture. Population shrinkage seriously affects the institutional transformation and the construction of a good social ethos, while institutions play a very important role in the economic development of northeast China. The complexity of government–enterprise relationships and subsequent power rent-seeking are not only unable to promote the transformation of economic structure, but will also strengthen resource input in pillar industries, resulting in surplus production. In addition, the public's cognitive lock-in, and the social ethos of entering the administrative system, will undoubtedly limit any local economic vitality and development potential.

The decreasing population will change the overall consumption scale and structure of residents (5.145), in turn causing an irreversible impact on economic resilience (0.382). The phenomenon of a low birth rate and an aging population in shrinking resource-based cities is very obvious. Compared to the youth group, the elderly's consumption of food, clothing, housing, transportation, travel, shopping and entertainment is far lower. Their daily consumption is often just the basic needs of life; the overall level of social consumption is reduced, subtly changing the industrial structure by means of the supply–demand relationship. This situation is not conducive to increasing the sustainability of economic resilience.

In addition, the regression results show that the overall mediation effects of resource dependence and environment quality are not significant. Previous studies have confirmed that population shrinkage will exacerbate the economic dependence on resources. However, many resource-based cities have also managed to seek and find industrial replacements and the means to sustainably develop their economy against the current background of economic structure optimization and the transformation of momentum in China. From this perspective, resource-based cities' dependence on resources is gradually being lowered. Therefore, the mediation effect of resource dependence is not significant. Another effect, namely the mediation effect of environment quality, is also not significant. From the direction of the mediation effect, the impact of population shrinkage on environment quality is positive, indicating that population shrinkage leads to poor management in terms of the urban environment and pollution remediation. This will further lead to the decline of environment quality. However, the fact that the effect did not pass the significance test also suggests that the effect's positive impact (the decrease of population alleviates the pressure on the environment system) offsets part of its negative impact. This validates the bidirectional effects through which population shrinkage impacts environment quality.

6. Discussion

6.1. *The Perspective That Population Shrinkage Affects Economic Resilience*

In terms of the effects of population shrinkage, most believe that its negative effects outweigh its positive effects. Panagopoulos and others found that the average age of urban population is negatively correlated with government's financial expenditure: this means the extra cost of infrastructure maintenance will be paid by the rest of the residents, which is not conducive to the improvement of those residents' quality of life [62–65]. Rocak believed that the socioeconomic status of urban residents in a shrinking city is usually low, and lack of knowledge of urban governance and expecting little of the shrinking city may lead to further population loss [66]. Audiracetal's study found that population shrinkage could lead to poverty and racial problems in rust-belt cities [67]. Having studied urban wasted land, Lange pointed out that population loss would further lead to environmental health issues [49]. In fact, population shrinkage brings positive effects too. A few scholars pointed out that population shrinkage will bring unexpected opportunities for a city to optimize its public space and ecological environment [50,68,69]. In this paper, we find that population shrinkage has a significant negative impact on economic resilience.

The influencing factors of economic resilience have been widely discussed. To sum up, most believe that the factors affecting economic resilience mainly include industrial structure, social capital, policy, institutional environment, innovation and culture [70,71]. Culture, as an important factor affecting economic resilience, is usually difficult to quantify and an effective method for measuring culture is not yet available. In this paper, the Baidu index based on Python script was used to quantify a city's culture construction. It is imperative to select culture as a mediating factor for this study, because resource-based cities in northeast China face the situation of serious cognitive and political lock-ins. Studying this factor is the first step to unlock the lock-ins.

Except the above two aspects, the most important contribution of this paper is the proposal of the mediating paths by which population shrinkage affects economic resilience, from the perspective of combining the effects of population shrinkage and the influencing factors of economic resilience. Many factors help transmit the effects of population shrinkage on economic resilience during the whole process. Correct understanding and utilization of these paths is essential to improve economic resilience.

6.2. *Inspirations for Policy Making to Mitigate the Impact of Population Shrinkage on Economic Resilience*

The United States, Germany, France, Japan, Central and Eastern Europe have formed their own governance models to counter the phenomenon of shrinkage. These models can be summarized into three types: (1) The local governance represented by the United States [72]. This type advocates local leadership, community planning, and the integration of stakeholders' resources through public–private partnerships (including NGOs, community organizations, local enterprises and local governments, etc.). (2) The central governance represented by France and Japan [73,74]. Through formulating guiding policies at the national level, and coordinating the relationship among capital, government, organizations and citizens, sustainable urban renewal and shrinkage governance can be achieved. (3) The transformative governance represented by Central and Eastern Europe [75]. This type is the combination of local governance and central governance, with the policy formation and implementation led by local governments and the funds or policy resources coming from the central government. As for China, the issue of shrinkage has not yet reached the national level. Considering China's current political system, shrinkage governance in China should follow the examples of central governance in the future, but it should be noted that the shrinkage situations vary in different parts of China. The results of this paper can cast light on the shrinkage governance of resource-based cities in northeast China.

The current problems that resource-based cities in northeast China are exhibiting can be systematically summarized from the perspective of population shrinkage impacting economic resilience. Using this perspective can help to inspire policy making for these resource-based cities.

First, population shrinkage is a reality that resource-based cities in northeast China must face. The cities' governments need to learn to accept population shrinkage; at the same time, however, they should also take positive measures to attract talents and avoid further population loss.

Second, population shrinkage can affect a city's economic resilience through various mediating factors, so it is very important to cut off the transmission of these negative effects. In this case, the measures to cut off the transmission include: upgrading industries to get rid of resource dependence, adding supports to guarantee urban consumption, increasing investment in science and technology innovation to enhance cities' competitiveness, developing industry related to culture to shape the urban soft environment, and attaching greater importance to environment renovation, to solve the problems of historical pollution.

Finally, administrative insurances need to be taken to enhance economic resilience. Governments should manage risks and shocks more flexibly, reinforcing infrastructure construction to ensure the reliability of urban daily functions. Apart from that, governments should also cooperate with each other more frequently, in order to strengthen the resilience redundancy of a single resource-based city, and to explore the resilience correlation of multiple resource-based cities. By doing so, regional network resilience can come into formation through the division of labor and the cooperation of these cities.

6.3. Limitations and Future Research Direction

This study does make a beneficial attempt to answer the question, "How does population shrinkage affect economic resilience?" However, the study still has some limitations. First, this paper uses statistical data to build an index system to measure economic resilience, meaning this research is still on the macro level. Subject to the availability of data, this paper only evaluates the overall economic resilience of cities; the urban and rural economic resilience are not explored. Second, this paper applies a mediation model to explore how population shrinkage affects economic resilience. Although this model shows good interpretability in terms of explaining the relationship of the independent variable, the dependent variable and the intermediate variables, there is still the limitation of neglecting latent variables and model endogeneity. Third, though taking resource-based cities in northeast China as the sample to conduct the study is very typical, the sample cannot characterize all resource-based cities in China. After all, the ways population shrinkage impacts economic resilience may change, due to regional heterogeneity or other factors.

With the rapid development of big data and remote sensing, a potential forward-looking topic would be the study of economic resilience from the micro level perspective in the future. The problems of economic resilience can be better solved from the joint perspective of macro and micro levels. In addition, population shrinkage, mediating factors, and economic resilience interact with one another, but this paper only explores how population shrinkage impacts economic resilience. More effective methods should be applied to explore the interaction system of population shrinkage and economic resilience in the future. Finally, a deep understanding of the relationship between population shrinkage and economic resilience is of great significance for improving cities' economic resilience. Therefore, exploring the relationship of population shrinkage and economic resilience in different regions would be an important direction for future research.

7. Conclusions

In this paper, the temporal and spatial characteristics of economic resilience are explored, as well as the mechanisms by which population shrinkage affects economic resilience. They are of vital importance to the transformation and sustainable development of resource-based cities in northeast China. First, the definition of population shrinkage and the measurement of economic resilience were introduced. Then, the temporal and spatial characteristics of economic resilience and the relationship between population shrinkage and economic resilience were discussed. Finally, on these bases, a mediation model was used to test the mediation paths of six variables during the process of population shrinkage and the subsequent impact on economic resilience. The main conclusions are as follows:

- (1) The temporal and spatial characteristics of economic resilience were measured by an index system. The results show that, from 2009 to 2019, the overall trend of the economic resilience of resource-based cities in northeast China was first upward, then downward, and finally stable, with 2013 and 2016 as the dividing points. The national support policies implemented after the economic crisis, the changes in external market demand and the momentum of economic growth, as well as attempts at transformation, are all important factors that explain the periodic changes of resource-based cities' economic resilience in northeast China.
- (2) Based on the measurements of population shrinkage and economic resilience, the relationship between population shrinkage and economic resilience was analyzed. From the perspective of spatial matching, cities that shrank also tended to be cities that showed low economic resilience. From the perspective of correlation, a significant positive correlation has existed between population shrinkage and economic resilience since 2011. Based on the correlation analysis, 2013–2019 was taken as the regression period of the subsequent mediation model, considering the significance and sample size of this model.
- (3) The hypothesis that population shrinkage affects economic resilience through both direct and indirect ways was proposed. The indirect ways include mediating factors, such as industry productivity, population consumption, resource dependence, innovation ability, culture construction and environment quality. Then, these variables were quantified for empirical analysis. The mediation model showed that there are two ways in which population shrinkage impacts on economic resilience. One is that population shrinkage directly inhibits economic resilience. The other is that population shrinkage transmits its negative effect through various mediating factors, which will further undermine economic resilience. Four mediating factors, namely industry productivity, population consumption, innovation ability and culture construction, play a significant partial mediation effect. Against the background of population shrinkage, the governments of shrinking resource-based cities should try their best to eliminate the negative effects of population shrinkage, so that these effects cannot be transmitted to economic resilience through mediating factors.

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