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Research on Urban Contraction of Liaoning Province Based on Population Influencing Factors

Guanghui He

School of Architecture and Artistic Design, University of Science and Technology Liaoning, Anshan, 114051, China

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Abstract: In the process of urbanization in China, the problem of urban contraction in Liaoning Province has become increasingly prominent. In this paper, through the preprocessing of the data of 30 cities in Liaoning Province from 2009 to 2020, an one-dimensional classification model is established by using population factors, and 23 shrinking cities are identified, accounting for 76.7%. Furthermore, considering the changes of total population and GDP, combined with comprehensive influencing factors, a multi-dimensional classification model is established, and 30 cities are divided into absolute growth type, population aggregation type, intelligent contraction type and absolute contraction type. The results show that the cities of Liaoning Province generally show a shrinking trend from 2009 to 2020, among which the population contraction trend of Lighthouse City and Linghai City is particularly obvious. In addition, the economic development of shrinking cities in Liaoning Province tends to slow down, or even decline. Combining the analysis results of the two identification methods, it is found that Anshan City, Donggang City, Fengcheng City, Dashiqiao City, Tiefa City and Kaiyuan City are six cities with a large degree of contraction.

1. Introduction

At a time when China's economy has entered the "new normal" and the demographic structural pressure has gradually become prominent, the localized urban contraction is gradually coming into people's view [1]. Population decline and economic weakness are the concrete manifestations of urban shrinkage.

Urban shrinkage exists widely at home and abroad, and is also an economic and social phenomenon with significant regional characteristics. It has been noted that under the influence of globalization, deindustrialization and resource depletion, many cities have experienced population loss and economic decline. This phenomenon is also common in Europe and the United States, the transition countries of Eastern Europe, Central and South America and Asian countries.

Nowadays, China's economy is advancing by leaps and bounds, urbanization is developing rapidly, industry and regional development is unbalanced, and the problem of urban shrinkage has aroused people's attention in recent years. Through the study of the old industrial zone in northeast China, the traditional heavy industry city in central China, the developed urban circle in eastern China and the

remote areas in western China, there are local and different degrees of urban shrinkage, and the urban shrinkage in the three eastern provinces is the most significant.

Liaoning, as the national traditional heavy industry base, is also the first province to start industrialization and urbanization. At present, Liaoning has 2 sub-provincial cities such as Shenyang and Dalian, 12 prefecture-level cities such as Anshan, and 16 county-level cities such as Xinmin, a total of 30 cities, which are also facing the problem of urban shrinkage.

The definition of shrinking cities can be roughly divided into two categories: the definition based on the change of single population number index and the definition with comprehensive multi-index change. A single population indicator, such as: a shrinking city is defined as having a population decline for three consecutive years; A city that has lost population for more than two years and experienced a structural economic crisis can be defined as a shrinking city; A city with a population loss of at least 10% of the total population or an average annual population loss rate greater than 1% can be defined as a shrinking city. The categories of urban shrinkage are mild, moderate and severe. Based on multiple indicators such as simultaneous population and urban GDP changes, cities are classified into four types: absolute growth (both growth), population agglomeration (population increase, urban GDP decrease), smart contraction (population decrease, urban GDP increase) and absolute contraction (both contraction).

This paper classifies 30 cities in Liaoning Province, uses the definition method to identify shrinking cities, and establishes the classification model.

2. Research Method

First of all, we judge according to the data given in the title, which can be divided into one-dimensional population urban shrinkage type and joint comprehensive index urban shrinkage type according to the definition.

This is a shrinking city with a shrinking population for three consecutive years.

Cities with a population loss of more than two years and experiencing a structural economic crisis; cities whose population loss accounts for at least 10% of the total population or with an average annual population wastage rate of more than 1%; combined with population and urban GDP changes, cities are divided into four types: absolute growth (double growth), population agglomeration (population increase, urban GDP decrease), smart contraction (population decline, urban GDP increase) and absolute contraction (both contraction).

After analyzing the two types, first fill in the missing data to ensure the integrity of the data.

Then, according to the definition and data, the shrinking type of the city with one-dimensional population is calculated, and the city in the shrinking state is obtained.

After the shrinking cities are obtained, the shrinking cities are further classified by the joint comprehensive index (GDP, demographics).

3. Model establishment and solution

3.1 Data Preprocessing

In order to ensure the integrity of the data, we preprocessed the data and processed the missing values of the missing data by Lagrange interpolation and Newton interpolation.

3.1.1 Lagrange interpolation method

(1) Set to the corresponding year, for the corresponding number of people in the corresponding year. $y_i x_i$Find the basis function of the point pair.$(x_1, y_1), (x_2, y_2) \ldots (x_n, y_n)$.

$$l_i\left(x_j\right)=\prod_{j=0,j\neq i}^{n}\frac{x-x_j}{x_i-x_j} \tag{1}$$

(2) Find the $(x_1,y_1),(x_2,y_2)\ldots(x_n,y_n)$interpolation polynomial of the known 11 point pairs.

$$L(x)=\sum_{i=0}^{n}y_i\prod_{j=o,j\neq i}^{n}\frac{x-x_j}{x_i-x_j} \tag{2}$$

(3) Substitute the points corresponding to the missing function value into the interpolation polynomial to get the missing value approximation$L(x)$.

3.1.2 Newton interpolation method

(1) Formula for finding all order difference quotients of known n point pairs $(x_1,y_1),(x_2,y_2)\ldots(x_n,y_n)$.

$$f[x_1,x]=\frac{f[x]-f[x_1]}{x-x_1}=\frac{f(x)-f(x_1)}{x-x_1} \tag{3}$$

$$f[x_2,x_1,x]=\frac{f[x_1,x]-f[x_2,x_1]}{x-x_2} \tag{4}$$

(2) Combine the above difference quotient formula to establish the following interpolation polynomial$f(x)$.

$$\begin{aligned}f(x)=f(x_1)+(x-x_1)f[x_2,x_1]+(x-x_1)(x-x_2)f[x_3,x_2,x_1]+\\(x-x_1)(x-x_2)(x-x_3)f[x_4,x_3,x_2,x_1]+\cdots+\\(x-x_1)(x-x_2)\cdots(x-x_{n-1})f[x_n,x_{n-1},\cdots,x_2,x_1]+\\(x-x_1)(x-x_2)\cdots(x-x_n)f[x_n,x_{n-1},\cdots,x_1,x]\end{aligned} \tag{5}$$

(3) The point corresponding to the missing function value is substituted into the interpolation polynomial to get the approximate value of the missing value $f(x)$.

3.1.3 Data Processing Result

Two methods 3.1.1 and 3.1.2 were used to calculate the missing data and outliers with MATLAB, and the results were shown in Table 1.

Table 1: Urban population of Liaoning

Regions	TIELING	CHAOYANG
Frequency	years	years
Units	Million	Ten thousand
2009	44.7	59.8
2010	44.59	57.59
2011	44.57	60.7
2012	44.1	60.68
2013	43.86	60.65
2014	43.8	61.16
2015	43.52	61.11
2016	43.44	61.39
2017	42.9	61.19
2018	42.6	61.35
2019	42.2	61.46
2020	41.46	61.11

3.2 Identification of shrinking cities by single population factor and its identification results

3.2.1 Single population factor shrinks city identification

One of the most important characteristics of urban shrinkage is population shrinkage, so population shrinkage is regarded as the core and key index to define urban shrinkage [2]. The definition of the change of a single population number index is diverse. This paper divides it into two stages according to the time series, from 2009 to 2018 and from 2019 to 2020, and analyzes the shrinking cities of Liaoning Province in the two stages. According to the criteria of mild shrinkage (-5% < SSD < 0), moderate shrinkage (-10% < SSD≤ -5%) and severe shrinkage (SSD≤ -10%), the shrinking trends of different cities were analyzed.

3.2.2 Research methods

(1) Standardized data:

$$\begin{cases} \text{forward: } X'_{ij} = \frac{X_{ij} - minX_j}{maxX_j - minX_j} \\ \text{backward: } X'_{ij} = \frac{maxX_j - X_{ij}}{maxX_j - minX_j} \end{cases} \tag{6}$$

(2) Calculate the weight of the desired index:

$$W_j = \frac{1 + \frac{1}{\ln n}\sum_{j=1}^{n}\left(\frac{X'_{ij}}{\sum_{j=1}^{n} X'_{ij}} \ln \frac{X'_{ij}}{\sum_{j=1}^{n} X'_{ij}}\right)}{m + \sum_{i=1}^{m}\left(\frac{1}{\ln n}\sum_{j=1}^{n}\frac{X'_{ij}}{\sum_{j=1}^{n} X'_{ij}} \ln \frac{X'_{ij}}{\sum_{j=1}^{n} X'_{ij}}\right)} \tag{7}$$

(3) Calculate the development index of the JTH city:

$$Z_i = \sum_{j=1}^{m} W_j \times X'_{ij} \tag{8}$$

(4) Calculate shrinkage SSD:

$$SSD = (Z_{it2} - Z_{it1}) \times 100\% \tag{9}$$

The formula (6) - (9) represents the difference between the original value X_{ij} and the standardized value X'_{ij} prime of evaluation index j for evaluation unit i. Here, $maxX_j$ and $minX_j$ denote the maximum and minimum values of evaluation index j, respectively. Z_i refers to the urban development index of evaluation unit i, while W_j represents the weight assigned to evaluation index j. Additionally, n denotes the number of samples, m signifies the number of evaluation indicators, SSD stands for city shrinkage, and t indicates the time year [3].

3.2.3 Analysis of results of shrinking cities by single population factor

The population dimension changes of 30 cities in Liaoning Province during 2009-2018, 2019-2020 and 2009-2020 are obtained, and according to SSD evaluation, when the value is negative, they are judged as shrinking cities. The collective judgment results are shown in Figure 1.

According to the formula in 3.2.1, entropy method, index weight and development index are respectively applied to finally represent the shrinkage SSD. From 2009 to 2018, 22 of the 30 cities in Liaoning Province contracted, namely: Fushun, Benxi, Dandong, Fuxin, Tieling, Huludao, Xinmin, Wafangdian, Zhuanghe, Haicheng, Donggang, Fengcheng, Linghai, Beizhen, Gaizhou, Dashiqiao, Lighthouse, Tiaobingshan, Kaiyuan, Beipiao, Lingyuan and Xingcheng. In 2019-2020, the number of shrinking cities in Liaoning Province increased from 22 to 28, and all of them were shrinking cities

except Shenyang and Dalian. From 2009 to 2020, the number of shrinking cities is 23, which are: Anshan, Fushun, Benxi, Dandong, Fuxin, Tieling, Huludao, Xinmin, Wafangdian, Zhuanghe, Haicheng, Donggang, Fengcheng, Linghai, Beizheng, Gaizhou, Dashiqiao, Lighthouse, Tiaobingshan, Kaiyuan, Beipiao, Lingyuan and Xingcheng.

According to three different contraction degrees, from 2009 to 2018, among the 22 contracted cities, 13 were mildly contracted cities, namely Fushun, Dandong, Fuxin, Tieling, Huludao, Xinmin, Wafangdian, Zhuanghe, Donggang, Beizhen, Dashiqiao, Lingyuan and Xingcheng; There are 7 moderately shrinking cities, respectively: During 2019-2020, 28 contracting cities are also mildly shrinking. Among the 28 cities that contracted between 2009 and 2020, the contraction was also mild. Among the 23 contracted cities from 2009 to 2020, Linghai and Lighthouse are the two cities with severe contraction. Moderate shrinkage of 14 cities, namely: Benxi, Fuxin, Panjin, Huludao, Xinmin, Zhuanghe, Fengcheng, Beizhen, Gaizhou, Dashiqiao, Tiaobingshan, Kaiyuan, Beipiao and Xingcheng; And 7 mild cities, respectively: Anshan, Fushun, Dandong, Huludao, Zhuanghe, Donggang, Lingyuan.

Index	Urban population shrinkage in Liaoning															
area	SHENYANG	DALIAN	ANSHAN	FUSHUN	BENXI	DANDONG	JINZHOU	YINGKOU	FUXIN	LIAOYANG	PANJIN	TIELING	CHAOYANG	HULUDAO	XINMIN	
frequentness	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	
Unit/Growth Rate	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	
2009-2010	0. 62%	0. 74%	-0. 27%	-0. 50%	-0. 43%	-0. 13%	-0. 03%	1.25%	1.64%	3. 22%	0. 66%	-0. 25%	-3. 84%	0. 77%	-0. 17%	
2010-2011	0. 70%	-2. 40%	3. 45%	4. 48%	-0. 21%	-0. 04%	0. 33%	0. 76%	-1.04%	-0. 33%	6. 30%	-0. 04%	5. 12%	-0. 33%	-0. 33%	
2011-2012	0. 58%	0. 69%	-0. 14%	-0. 51%	-0. 77%	-0. 23%	0. 13%	0. 38%	-0. 27%	14. 95%	-1. 94%	-1. 07%	-0. 03%	-0. 64%	-0. 33%	
2012-2013	0. 47%	0. 69%	-0. 30%	-0. 61%	-0. 63%	-0. 22%	3. 98%	0. 36%	-0. 46%	-0. 27%	0. 31%	-0. 55%	-0. 05%	-0. 13%	-0. 25%	
2013-2014	0. 73%	1.00%	-0. 13%	-0. 42%	-0. 35%	-0. 01%	-4. 25%	0.87%	-0. 36%	-0. 22%	0. 33%	-0. 14%	0. 33%	0.64%	-0. 20%	
2014-2015	0.27%	0.21%	-0. 70%	-0. 99%	-0. 80%	-0. 55%	3. 60%	0. 22%	-1. 05%	-0. 47%	0. 33%	-0. 64%	-0. 08%	-5. 16%	-1. 17%	
2015-2016	9. 66%	23. 44%	-0. 22%	-0. 55%	-0. 99%	-0. 05%	0. 11%	0. 47%	-0. 39%	-0. 25%	37. 16%	-0. 18%	0. 46%	4. 40%	-0. 23%	
2016-2017	0. 78%	0. 32%	-0. 51%	-1. 95%	-1. 54%	0. 38%	-1. 75%	0.01%	-1.30%	-1. 10%	-0. 30%	-1. 26%	-0. 33%	-1. 55%	-0. 91%	
2017-2018	1. 71%	0.21%	-0. 97%	-0. 95%	-1.29%	-0. 32%	-0. 20%	0. 46%	-0. 97%	-0. 75%	0.21%	-0. 70%	0. 26%	-0. 07%	-1.41%	
2018-2019	1.83%	1.06%	-0. 76%	-1.00%	-1. 37%	-0. 97%	-0. 01%	0. 36%	-1.00%	-0. 74%	0. 05%	-0. 95%	0. 18%	0. 13%	-0. 77%	
2019-2020	1.22%	1.36%	-1. 02%	-2. 13%	-1. 65%	-0. 63%	-0. 47%	-0. 15%	-1. 17%	-1. 15%	-0. 52%	-1.39%	-0. 57%	-1. 62%	-1. 16%	
2009-2018 Number of Wasters	89. 16	98. 38	0. 34	-2. 58	-6. 45	-0.91	2. 06	4. 39	-3. 17	12. 68	41.93	-2. 10	1. 55	-2.23	-3. 39	
2009-2018 The rate of population loss	17.41%	32.53%	0. 23%	-1. 86%	-6. 75%	-1. 15%	2.21%	4. 92%	-4. 09%	17. 44%	69. 17%	-4. 70%	2. 59%	-2.30%	-4. 35%	
2009-2018 Average Annual Population Loss Rate	1. 74%	3. 26%	0. 02%	-0. 19%	-0. 68%	-0. 12%	0. 22%	0. 49%	-0. 41%	1. 74%	6. 92%	-0. 47%	0. 26%	-0. 23%	-0. 48%	
2019-2020 Number of Wasters	7. 56	5. 56	-1.43	-2. 32	-1.43	-0. 48	-0. 45	-0. 14	-0. 35	-0. 96	-0. 53	-0. 53	-0. 35	-1. 55	-0. 76	
2019-2020 The rate of population loss	1.23%	1.37%	-1. 01%	-2. 09%	-1.63%	-0. 62%	-0. 47%	-0. 15%	-1. 15%	-1. 13%	-0. 52%	-1. 37%	-0. 57%	-1.60%	-1. 15%	
2019-2020 Average Annual Population Loss Rate	0. 62%	0. 69%	-0. 51%	-1.04%	-0. 31%	-0. 31%	-0. 24%	-0. 07%	-0. 58%	-0. 57%	-0. 26%	-0. 69%	-0. 28%	-0. 80%	-0. 57%	
2009-2020 Lost population	107. 94	108. 23	-2. 25	-6. 75	-9. 03	-2. 14	1.6	4. 59	-4. 76	11. 09	41.45	-3. 03	1. 31	-3. 70	-4. 66	
2009-2020 The rate of population loss	21. 07%	35. 34%	-1. 53%	-4. 85%	-9. 50%	-2.71%	1. 71%	5. 14%	-6. 13%	15.25%	63. 38%	-6. 89%	2. 19%	-3. 73%	-6. 66%	
2009-2020 Average Annual Population Loss Rate	1. 76%	2. 99%	-0. 13%	-0. 40%	-0. 79%	-0. 23%	0. 14%	0. 43%	-0. 51%	1.27%	5. 70%	-0. 57%	0. 13%	-0. 31%	-0. 55%	
area	AFANGDIA	ZHUANGHE	HAICHENG	DONGGANG	FENGCHENG	LINGHAI	BEIZHEN	GAIZHOU	DASHIQIAO	DENGTA	AOBINGSHA	KAIYUAN	BEIPIAO	LINGYUAN	XINGHCENG	
frequentness	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR	
Unit/Growth Rate	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	MILLION	
2009-2010	-0. 13%	-0. 29%	0. 23%	-0. 67%	-0. 87%	-0. 73%	-0. 80%	-0. 47%	-0. 42%	-0. 90%	-0. 06%	-0. 86%	-1. 74%	0. 11%	-0. 87%	
2010-2011	-2. 22%	0. 09%	-4. 79%	0. 07%	-0. 32%	-0. 16%	-0. 15%	-0. 77%	-0. 28%	-1. 12%	-0. 15%	-0. 09%	-0. 53%	-0. 75%	-0. 03%	
2011-2012	-0. 08%	-0. 15%	-0. 52%	-0. 23%	-0. 34%	-0. 33%	-0. 19%	-0. 60%	-0. 40%	-13. 48%	-1. 02%	-0. 34%	-0. 24%	0. 13%	-0. 51%	
2012-2013	-0. 14%	-0. 32%	0. 22%	-0. 05%	-0. 87%	-0. 61%	-0. 42%	-2. 17%	-1. 96%	0. 06%	-0. 37%	-0. 08%	-0. 92%	-0. 12%	-1.09%	
2013-2014	0. 06%	0. 14%	-0. 97%	0. 15%	-0. 29%	-0. 42%	-0. 29%	0. 05%	-0. 09%	0. 16%	-0. 27%	0. 15%	0. 03%	0. 03%	0. 20%	
2014-2015	-0. 32%	-0. 28%	-0. 37%	-0. 35%	-0. 69%	-8. 93%	-0. 98%	-0. 72%	-0. 53%	-0. 39%	-0. 35%	-0. 62%	-0. 64%	0. 52%	-0. 14%	
2015-2016	0. 00%	0. 31%	0. 03%	-0. 22%	-0. 15%	-0. 23%	-0. 15%	-0. 14%	-0. 19%	-0. 04%	-0. 46%	-0. 19%	-0. 39%	0. 32%	-0. 28%	
2016-2017	-0. 61%	-1. 56%	-0. 59%	-2. 07%	-1. 65%	-1. 71%	-1. 75%	-1.00%	-0.49%	-1.42%	-2. 08%	-2. 55%	-2. 19%	-1. 87%	-1.40%	
2017-2018	-0. 33%	-0. 18%	-0. 24%	-0. 45%	-0. 63%	-0. 55%	-0. 34%	-0. 55%	-0. 62%	-0. 45%	-1. 31%	-0. 65%	-0. 43%	-0. 28%	-0. 20%	
2018-2019	-0. 45%	-0. 35%	-0. 33%	0. 43%	-0. 76%	-0. 67%	-0. 75%	-0. 65%	-0. 72%	-0. 44%	-1. 66%	-0. 75%	-0. 66%	-0. 31%	-0. 76%	
2019-2020	-1.25%	-1. 50%	-0. 97%	-0. 73%	-1.30%	-1. 38%	-1.61%	-1. 38%	-0. 88%	-1. 13%	-2. 28%	-1.27%	-2.12%	-0. 96%	-1. 05%	
09-2018 Number of Wast	-3. 77	-1.99	-7. 57	-2. 28	-3. 32	-7. 13	-2. 60	-4. 50	-3. 50	-7. 94	-1. 53	-2. 98	-4. 00	-1. 18	-2. 34	
2009-2018 The rate of population loss	-3. 67%	-2. 19%	-6. 60%	-3. 72%	-5. 66%	-12. 43%	-4. 93%	-6. 14%	-4. 83%	-15. 40%	-6. 32%	-5. 05%	-6. 72%	-1. 81%	-4. 21%	
2009-2018 Average Annual Population Loss Rate	-0. 37%	-0. 22%	-0. 66%	-0. 37%	-0. 57%	-1. 24%	-0. 49%	-0. 61%	-0. 48%	-1. 54%	-0. 63%	-0. 50%	-0. 67%	-0. 18%	-0. 42%	
19-2020 Number of Wast	-1.22	-1. 31	-1.02	-0. 46	-0. 70	-0. 63	-0. 79	-0. 93	-0. 60	-0. 51	-0. 50	-0. 70	-1. 15	-0.61	-0. 55	
2019-2020 The rate of population loss	-1. 24%	-1.48%	-0. 96%	-0. 77%	-1.28%	-1. 36%	-1.59%	-1. 36%	-0. 88%	-1. 17%	-2. 23%	-1.25%	-2. 07%	-0. 95%	-1.04%	
2019-2020 Average Annual Population Loss Rate	-0. 62%	-0. 74%	-0. 43%	-0. 39%	-0. 64%	-0. 68%	-0. 79%	-0. 68%	-0. 44%	-0. 53%	-1. 12%	-0. 63%	-1. 04%	-0. 48%	-0. 52%	
009-2020 Lost populatio	-5. 42	-3.61	-9. 00	-2. 48	-4. 45	-3. 14	-3. 76	-5.87	-4. 60	-3.64	-2. 39	-4. 10	-5. 51	-1.98	-3. 29	
2009-2020 The rate of population loss	-5. 29%	-3. 97%	-7. 34%	-4. 05%	-7. 58%	-14. 19%	-7. 13%	-8. 02%	-6. 34%	-16. 75%	-9. 90%	-6. 94%	-9. 25%	-3. 06%	-5. 92%	
2009-2020 Average Annual Population Loss Rate	-0. 44%	-0. 33%	-0. 65%	-0. 34%	-0. 63%	-1. 18%	-0. 59%	-0. 67%	-0. 53%	-1.40%	-0. 33%	-0. 53%	-0. 77%	-0. 25%	-0. 49%	

Figure 1: Results of urban shrinkage with population dimension change

3.3 Combined comprehensive factors contraction city identification and identification results

3.3.1 Combined comprehensive factors shrink city identification factors

Through the classification and judgment of a single factor on urban shrinkage, we further study and classify shrinking cities by combining comprehensive factors. Because there are too many factors affecting GDP, it is impossible to make a judgment by direct prediction. Therefore, the shrinking cities of Liaoning Province are also divided into two stages according to the time series: 2009-2018 and 2019-2020. The development status of the research unit was evaluated by using the changes of urban GDP and population size. The formula is as follows:

$$E_i = \frac{E_{i,t}}{E_{i,0}}; \qquad P_i = \frac{P_{i,t}}{P_{i,0}} \tag{10}$$

Where, E_i and P_i represent the respective change values of GDP and population size for city i; $E_{i,t}$ and $E_{i,0}$ denote the total GDP of city i in year t and base year, respectively. Similarly, $P_{i,t}$ and $P_{i,0}$ refer to the urban population size of city i in year t and base year, respectively [4,5]. In cases where both population and GDP increase $E_i > 1, P_i > 1$), the shrinking city is referred to as experiencing absolute growth. If the urban population increases while GDP decreases ($E_i < 1, P_i > 1$), it is termed as a case of population agglomeration. Conversely, if the urban population decreases while GDP increases ($E_i > 1, P_i < 1$), it is classified as smart shrinking type. Finally, when both city's population and GDP decrease ($E_i < 1, P_i < 1$), it falls under the category of absolute shrinking type.

3.3.2 Analysis of identification results of shrinking cities by combining comprehensive factors

As for shrinking cities caused by joint factors, it is necessary to conduct multidimensional comprehensive analysis from GDP and population. According to the formula and method 5.3.1, the attached urban population statistics table of Liaoning Province is used to divide the 30 cities in Liaoning Province into two stages from 2009 to 2018 and from 2019 to 2020 according to the time series. The cities are classified, and the specific identification results are shown in Figure 2.

	2009～2018					2019～2020				
	Change in GDP	E	population size	P	Contraction type	Change	E	population	P	Contraction
SHENYANG	1.53	> 1	1.17	> 1	Absolute growth pattern	1.01	> 1	1.01	> 1	Absolute growth pattern
DALIAN	1.97	> 1	1.33	> 1	Absolute growth pattern	0.99	< 1	1.01	> 1	Population agglomeration
ANSHAN	0.88	< 1	1.01	> 1	Population agglomeration type	0.99	< 1	0.99	< 1	Absolute contraction type
FUSHUN	1.75	> 1	0.98	< 1	Smart contraction type	0.97	< 1	0.98	< 1	Absolute contraction type
BENXI	1.15	> 1	0.93	< 1	Smart contraction type	1.04	> 1	0.98	< 1	Smart contraction type
DANDONG	1.11	> 1	0.99	< 1	Smart contraction type	1.01	> 1	0.99	< 1	Smart contraction type
JINZHOU	1.94	> 1	1.02	> 1	Absolute growth pattern	0.98	< 1	0.99	< 1	Absolute contraction type
YINGKOU	1.89	> 1	1.05	> 1	Absolute growth pattern	1.01	> 1	0.99	< 1	Smart contraction type
FUXIN	1.37	> 1	0.96	< 1	Smart contraction type	1.03	> 1	0.99	< 1	Smart contraction type
LIAOYANG	1.81	> 1	1.17	> 1	Absolute growth pattern	0.99	< 1	0.99	< 1	Absolute contraction type
PANJIN	1.82	> 1	1.69	> 1	Absolute growth pattern	1.01	> 1	0.99	< 1	Smart contraction type
TIELING	1.06	> 1	3.59	> 1	Absolute growth pattern	1.01	> 1	0.99	< 1	Smart contraction type
CHAOYANG	1.57	> 1	1.03	> 1	Absolute growth pattern	1.03	> 1	0.99	< 1	Smart contraction type
HULUDAO	1.49	> 1	0.98	< 1	Smart contraction type	0.88	< 1	0.98	< 1	Absolute contraction type
XINMIN	1.26	> 1	0.95	< 1	Smart contraction type	1.08	> 1	0.99	< 1	Smart contraction type
WAFANGDIAN	1.95	> 1	0.96	< 1	Smart contraction type	1.05	> 1	0.99	< 1	Smart contraction type
ZHUANGHE	1.67	> 1	0.98	< 1	Smart contraction type	1.01	> 1	0.99	< 1	Smart contraction type
HAICHENG	1.08	> 1	0.93	< 1	Smart contraction type	0.99	< 1	0.99	< 1	Absolute contraction type
DONGGANG	0.75	< 1	0.96	< 1	Absolute contraction type	1.03	> 1	0.99	< 1	Smart contraction type
FENGCHENG	0.95	< 1	0.94	< 1	Absolute contraction type	1.01	> 1	0.99	< 1	Smart contraction type
LINGHAI	1.03	> 1	0.88	< 1	Smart contraction type	1.01	> 1	0.99	< 1	Smart contraction type
BEIZHEN	1.46	> 1	0.95	< 1	Smart contraction type	1.03	> 1	0.98	< 1	Smart contraction type
GAIZHOU	1.51	> 1	0.94	< 1	Smart contraction type	1.01	> 1	0.99	< 1	Smart contraction type
DASHIQIAO	0.94	< 1	0.95	< 1	Absolute contraction type	0.98	< 1	0.99	< 1	Absolute contraction type
DENGTA	1.12	> 1	0.85	< 1	Smart contraction type	1.03	> 1	0.99	< 1	Smart contraction type
DIAOBINGSHAN	1.02	> 1	0.94	< 1	Smart contraction type	1.02	> 1	0.98	< 1	Smart contraction type
KAIYUAN	0.47	< 1	0.95	< 1	Absolute contraction	1.05	> 1	0.99	< 1	Smart contraction type
BEIPIAO	1.05	> 1	0.93	< 1	Smart contraction type	1.05	> 1	0.98	< 1	Smart contraction type
LINGYUAN	1.46	> 1	0.98	< 1	Smart contraction type	1.48	> 1	0.99	< 1	Smart contraction type
XINGCHENG	2.61	> 1	0.96	< 1	Smart contraction type	1.02	> 1	0.99	< 1	Smart contraction type

Figure 2: Results of multi-dimensional joint indication of urban shrinkage

According to Figure 2, we further classify the 30 cities into four types and two stages. From the data in Table, it can be seen that among the 30 cities in the time series from 2009 to 2018, 8 are

absolute growth types, namely Shenyang, Dalian, Jinzhou, Yingkou, Liaoyang, Panjin, Tieling and Chaoyang; 1 population agglomeration type: Anshan. 17 smart contraction types: Fushun, Benxi, Dandong, Fuxin, Huludao, Xinmin, Wafangdian, Zhuanghe, Haicheng, Linghai, Beizhen, Gaizhou, Lighthouse, Tiaobingshan, Beipiao, Lingyuan and Xingcheng; 4 are absolutely convergent: Donggang, Fengcheng, Dashiqiao and Kaiyuan; In the 2019-2020 time series, only 1 of the 30 cities is absolute growth type: Shenyang; 1 population agglomeration: Dalian; 21 smart contraction types: Benxi, Dandong, Yingkou, Fuxin, Panjin, Tieling, Chaoyang, Xinmin, Wafangdian, Zhuanghe, Donggang, Fengcheng, Linghai, Beizhen, Gaizhou, Lighthouse, Tiaobingshan, Kaiyuan, Beipiao, Lingyuan and Xingcheng; And 7 absolute shrinkage types: Anshan, Fushun, Jinzhou, Liaoyang, Huludao, Haicheng and Dashiqiao. The comprehensive analysis of the two time series from 2009 to 2020 shows 7 absolute growth types, namely: Shenyang, Dalian, Jinzhou, Yingkou, Liaoyang, Panjin and Chaoyang; There are 17 smart contraction types, respectively: Fushun, Benxi, Dandong, Fuxin, Tieling, Huludao, Xinmin, Wafangdian, Zhuanghe, Haicheng, Linghai, Beizhen, Gaizhou, Lighthouse, Beipiao, Lingyuan, Xingcheng; The population agglomeration type is 0; The absolute contraction type is 6: Anshan, Donggang, Fengcheng, Dashiqiao, Tiaobingshan, Kaiyuan.

4. Conclusions

The phenomenon of urban contraction in Liaoning Province during the study period is serious, which brings challenges to economic and social development. In view of the shrinking cities, it is suggested to formulate corresponding development strategies to promote the sustainable development of cities in Liaoning Province. At the same time, we need to pay attention to the relationship between urban population mobility and economic growth to provide a scientific basis for policy-making.

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