Time Series of Urban Shrinkage Elements in Coal-exhausted Cities: A Case Study of Two Typical Cities in Northeast China

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Abstract: Based on the existing research, this paper first classifies the influencing factors of urban shrinkage into three categories: internal factors, external characteristics and potential factors, and further divides them into four categories: population structure change, economic and industrial change, spatial quality change and public facilities change. Secondly, taking Shuangyashan and Jixi city, two typical coal-based industrial cities in Heilongjiang Province of China as the research objects, from the point of view of time, using the method of big data classification and comparative analysis, the time series of key elements in each city is studied, the priority and lag relationship of elements are obtained, and the time law of mutual restriction of elements in each city is analyzed in depth, and the time series of key elements in each city is established. The time series model of the shrinkage of such coal-exhausted cities is put forward in order to put forward a common strategy to deal with the shrinkage of such cities from a time point of view.

Keywords: Urban shrinkage; Resource exhaustion; Time series; Northeast China

Introduction

Northeast China once owned more than 90% of China's heavy industry bases. Since the 1990s, under the background of traditional industrial transformation and changes in China's overall economic environment, with the depletion of mineral resources and forestry resources, the leading industries of many Northeast cities have gradually declined. Most cities developed by relying on traditional industries are facing a downturn in industrial development and urban development (Yu Tingting *et al*,2017).

In order to alleviate the problem of population shrinkage in the northeastern China and prevent the serious decline of the Northeast area, Chinese scholars began to study the causes and Countermeasures of such urban shrinkage, so that we can re-recognize the phenomenon of backward development and shrinkage in the Northeast area and try to improve the current situation of urban

shrinkage in the northeast area from a scientific point of view, and guide the healthy development of the cities in the Northeast area.

However, the current research mostly on urban shrinkage includes multi-concept definition, identification, dynamic mechanism, impact and coping strategies (GAO Shuqi,2015). Most of the studies are on the shrinking city in a region or the specific research of a single shrinking city, lacking of comparative research on the same type of shrinking city, and lacking of research on the evolution process of urban shrinkage. According to the experience of urban shrinkage in western developed countries, most resource-exhausted cities will experience a comprehensive decline in population, economy, society and environment (Yang Dongfeng *et al*.2013). There are also many studies on urban shrinkage in China based on the hypothesis of population shrinkage - economic decline - space dilapidation (LONG Ying *et al*.2015). If we make a comparative study on the factors of the same type of cities in the process of population shrinkage from the perspective of time, we will find the similarities and differences in the process of population shrinkage in each city.

Therefore, this paper chooses coal-exhausted cities as the research object to explore the shrinkage process of such cities. In view of the shrinkage situation of Shuangyashan and Jixi city in northeast China, based on the time factor, the shrinkage process is analyzed by time series, including the internal factors, external characteristics and potential factors. And the shrinkage of coal-based cities in population structure, economic and industrial changes, spatial quality changes, people's livelihood quality changes are explored. The relationship between priority and lag of specific factors is studied, and the common law of shrinkage factors and the reasons of difference are compared in depth.

Study area

This paper chooses Shuangyashan City and Jixi City in Heilongjiang Province in Northeast China as the research objects (Figure 1). Both of them are typical coal resource exhausted cities in Northeast China. The two cities are facing a reduction in urban population at the same time, but to varying shrinkage degrees. The comparative study of two cities with different population shrinkage and the same industrial type will have a good reference.

Figure. 1 Location of Shuangyashan City and Jixi City in Northeast China

Data and methods

Selection of Time Series Elements of Urban Shrinkage

In the process of urban shrinkage, many factors are changing, some of which have an impact on the process of urban shrinkage, and some of which are the phenomena manifested in the process of urban shrinkage. According to the existing research on the influencing factors of urban shrinkage (Table 1), the main influencing factors of urban shrinkage include industrial transformation (WU Kang *et al* .2015, Yang Lin *et al.* 2018), economic environment change (LIU Fengbao *et al* .2018, Zhang Wei *et al* .2019), population structure change (WU Kang *et al.*2015, Yu Tingting *et al* .2015, Yang Lin *et al* .2018), natural ecological environment change (Yu Tingting *et al* .2015, Zhang Wei *et al* .2019), urban facilities (Yang Lin *et al* .2018), urban space factor (Zhang Wei *et al* .2019). Based on the characteristics of coal-exhausted cities in Northeast China, the change of natural ecological environment has less impact on urban shrinkage. Therefore, population structure, industrial transformation, economic development, urban spatial elements and urban facilities are selected as time series elements of urban shrinkage.

Table. 1 Summary of factors affecting urban shrinkage

Author	Causes and Driving Forces of Urban Shrinkage
WU Kang et al,2015	Regional Economic Development, Urbanization Level, Administrative Level, Deindustrialization or Industrial Transition, Population Structure Change
Yu Tingting et al,2015	Natural environmental indicators, socio-economic indicators
LIU Fengbao et al,2018	Population Structure, Economic System, Geographical Environment, Government Policy, Zoning Adjustment
Lin Yang et al, 2018	External economy, location, climate, industrial structure, population structure, infrastructure, culture
Zhang Wei et al,2019	Natural Ecology Background, Urban Scale, Urban Economic Development, Urban Population Structure, Urban Municipal Construction, Urban Ecological

Factor Arrangement of Urban Shrinkage Time Series

Deepening the selected time series factors of urban shrinkage, combining the characteristics of urban shrinkage in Shuangyashan and Jixi, supplementing the above factors with micro-indicators, and establishing the time series research-factor system of urban shrinkage factors (Table 2). It includes the following aspects:

1. Population structure change;

The population structure of Shuangyashan and Jixi City has changed significantly. Firstly, the total population of the city and city district have decreased. It is expressed by the index of population change rate, which is also a big measure of the degree of urban shrinkage. Then, birth rate and natural growth rate of cities. Low fertility keeps the population growth rate in Northeast China at a fairly low level. What's more is the rate of population migration. In the 21st century, especially after 2010, with the deepening of China's economic system reform, the economic status of Northeast China has continued to decline. Northeast residents migrated from north to south in pursuit of better life, with a net outflow of 2.24 million in 2014. At the same time, the age and education level of the outflow population in Northeast China are low and high. Such a structural outflow of population will inevitably affect the shrinkage process in Northeast China (Zhou Daming, 2018).

2. Industrial Economic Change;

In the 1990s, driven by the recovery and rapid development of coal economy, the GDP of Shuangyashan and Jixi cities maintained a relatively rapid growth. The development of coal and related industries led to the growth of the overall economic level of the city, and the rapid development of urban infrastructure construction. The employment opportunities brought about by it attracted the influx of population. In recent years, under the influence of macroeconomic environment, the golden period of coal has ended, the supporting role of coal industry to the economy has weakened and declined year by year, and the salary cuts and job losses in coal and related enterprises, and the employment environment in cities have also begun to become severe. Therefore, firstly, the total GDP and the output value of secondary industry are selected as economic research indicators to explore the time relationship between urban economic environment and population shrinkage. Secondly, the number of employment at the end of the year, the unemployment rate, the number of employment in the secondary industry and the number of employment in the tertiary industry are taken as industrial research indicators to explore the time relationship between the development of different industries and population shrinkage.

3. Spatial Quality Change;

The change of urban spatial quality is the external representation of urban shrinkage. This paper chooses street greening, street pavement and street storefront activity as research indicators which are easy to extract large data, and reflects the change of urban spatial quality with the change of urban street spatial quality. Due to the decline of coal resources, the closure of some coal-related enterprises has made the spatial quality of some parts worse. If the population shrinks seriously, there will probably be a large area of building vacancies, which will affect the urban spatial quality. Therefore, the identification and research of spatial quality changes will be the focus of urban shrinkage in the future.

Table. 2 Time Series of Urban Shrinkage Elements - Element System

Classification	Large class	Subclass
Internal factors	Elements of Population Structure Change	Change rate of total urban population
		Urban Population Change Rate
		Natural Growth Rate of Urban Population
		birth rate
		Urban population emigration rate
	Elements of Economic Industry Change	GDP
		Second Industry Output Value
		Number of employee at the end of the year
		unemployment rate
		Employment in Secondary Industry
		Employment in tertiary industry
External representation	Elements of Urban Spatial Quality	Street greening
		Road Traffic and Pavement
		Street storefront activity
Potential elements	Elements of Quality of Life Change	Number of health institutions
		Number of health technicians
		Number of teachers per 10 students
		Urban public green space area
		Cultural performances
		Number of Fitness Events
		Number of full-time Sports Coaches

4. Changes in quality of life.

The elements of urban life quality change include health care, education, green space, culture and sports. These factors are the important demand factors for improving the living standards of all urban residents. The allocation of public facilities with different completeness will have an big impact on the attractiveness of different cities and different areas of cities. If the allocation of urban public facilities is inadequate, it will also affect people's pursuit of quality of life, and then choose a better quality of life in other cities. Therefore, the study of the time course of quality of life change will help us to understand the relationship between quality of life and other factors of population shrinkage better, and help us to make timely allocation Countermeasures of public facilities.

Data Processing Method of Urban Shrinkage Time Series Elements

- Data Sources

Data used in the study include: Shuangyashan Social and Economic Statistics Yearbook (2007-2016), Jixi National Economic Statistics Yearbook (2007-2016), Baidu Map Street View 2016 and Tencent Map Street View 2013. Among the small elements in Table 2, except street greening, road traffic and pavement, Street store activity data from Baidu Street View and Tencent Street View data, other data are directly derived from statistical yearbook or based on Yearbook for processing and calculation.

- Data Processing

The data in this study were normalized by Min-Max normalization, also known as 0-1 normalization, which is a linear transformation of the original data, so that the results fall in the 0-1 interval and the transformation function is as follows:

$$x' = \frac{x - x_{min}}{x_{max} - x_{min}}$$

In the formula, x_{min} is the maximum value in the sample data and x_{max} is the minimum value in the sample data. By transforming all data into 0-1 data, this data standardization process is conducive to comparing the data of different types of elements in different units, and more intuitively showing the changing trend of various elements.

Data Analysis

Analysis of Population Structure Elements

Combining with the Yearbook data, the data of population structure changes in Shuangyashan City (Table 3) and Jixi City are sorted out and processed. The trends of various data over time are analyzed as follows (Figure 2, Figure 3):

Table. 3 Statistics of Population Structure Elements in Shuangyashan City

End of the year	Urban Population change rate (%)	Urban District change rate (%)	Birth rate (‰)	Processed birth rate	Urban emigration rate (‰)	Processed Urban emigration rate	Natural Growth Rate of Urban Population (‰)
2006	-0.18	-0.25	6.68	0.82	18.2	0.63	0.99
2007	0.33	0.25	7.19	1	20.36	0.79	1.29
2008	0.01	0.27	6.77	0.86	18.63	0.66	1.13
2009	0.23	0.18	6.2	0.66	14.29	0.34	-0.64
2010	0.51	0.15	5.93	0.57	11.74	0.15	-0.65
2011	-0.22	-0.09	5.74	0.5	23.26	1	-0.16
2012	-0.55	-0.84	5.94	0.57	16.27	0.49	-1.37
2013	-0.41	-0.68	6.14	0.64	17.13	0.55	-2.24
2014	-0.53	1.30	6.43	0.74	15	0.39	-1.78
2015	-1.04	-1.29	4.29	0	9.68	0	-4.11

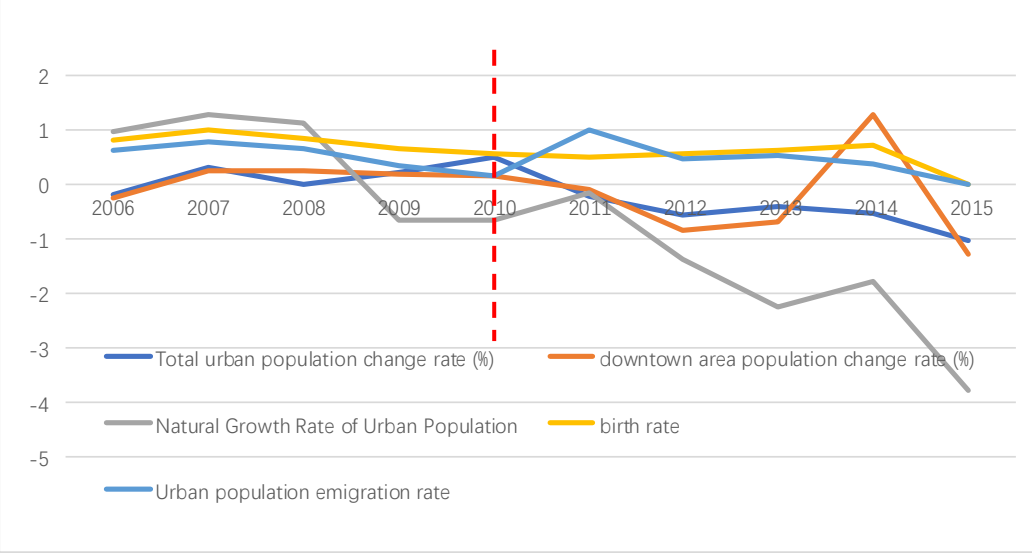

Figure. 2 Changes of Population Structure Elements in Shuangyashan City

Shuangyashan city's population was growing before 2000. The total population fluctuated in a small range from 2000 to 2010. The population declined obviously in 2011. Taking the end of 2010 as the demarcation line of population shrinkage, there was a phenomenon of declining birth rate and a sharp decline in natural population growth rate before 2010, which may be the most important potential impact factor before population shrinkage. From 2011 to 2012, with the increase of population emigration rate, the population shrinkage of Shuangyashan city is obvious. The urban population shrinkage rate in 2012 is 0.84% compared with 2011, and the urban population shrinkage rate in 2015 is 1.04%. Therefore, we conclude that the birth rate of Shuangyashan city declined before its population contracted, and the process of population shrinkage is accompanied by a large number of migration.

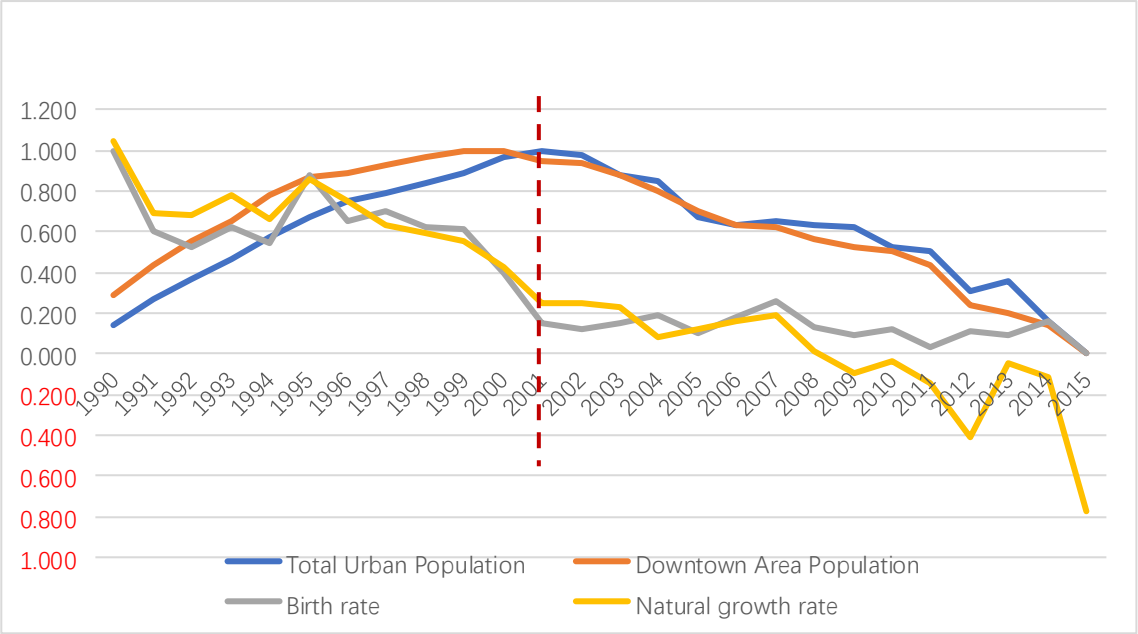

Figure. 3 Change of Population Structure Elements in Jixi City

The phenomenon of population shrinkage in Jixi City started earlier, nearly 10 years earlier than that in Shuangyashan City. According to the data, during the period of population growth from 1990 to 2001, the population increased by 127,000, with an average annual increase of 106,000, with an average annual increase of 0.56%. From 2002 to 2015, the population gradually decreased by 152,000, with an average annual decrease of 117,000. Taking the end of 2001 as the demarcation line, we can clearly see that the birthrate and natural growth rate of Jixi City have decreased significantly before 2001, which may be the main reason for the decrease of the total population of Jixi City. In 1990, the birthrate of urban population was 15.79 while in 2015, the birthrate of population was 5.13 which was 10.66 points lower than in 1990. Therefore, we conclude that the phenomenon of population shrinkage in Jixi City also occurred after the birth rate and natural growth rate dropped sharply. Judging from the situation of population outmigration in Jixi City, due to insufficient data, there is no trend of change in the Figure 3, However, the relevant data show that in recent years, the net population outmigration of Jixi City has maintained 10,000-20,000 people per year, so the process of population shrinkage has been accompanied by population outmigration.

Elements of Economic and Industrial Change

Based on the Yearbook data, this paper calculates the factors of economic and industrial change in Shuangyashan and Jixi (Table 4), and analyses the trend of various data over time as follows (Figure 4, Figure 5):

Table. 4 Statistics of Industrial Economic Change in Jixi City from 2006 to 2015

	GDP(10,000 yuan)	Second Industry Output Value (10,000 yuan)	Employment at the end of the year (10,000 people)	Unempl-oyment rate (%)	Employed population in secondary industry (10,000 people)	Employed population in tertiary industry (10,000 people)
2006	2362214	706349	14.65	0.43	10.52	3.98
2007	2752215	832696	15.08	0.46	10.81	4.21
2008	3158814	1024628	13.99	0.48	9.78	4.13
2009	3538182	1384019	13.79	0.56	9.52	4.21
2010	4194931	1774986	13.59	0.59	9.35	4.18
2011	5078321	2130289	13.65	0.59	9.13	4.45
2012	5823381	2382636	13.2	0.76	8.6	4.5
2013	5709117	2199844	13.6	0.79	8.7	4.8
2014	5160088	1535218	12.8	0.57	7.9	4.8
2015	5146868	1336132	14.9	0.56	7.6	5.8

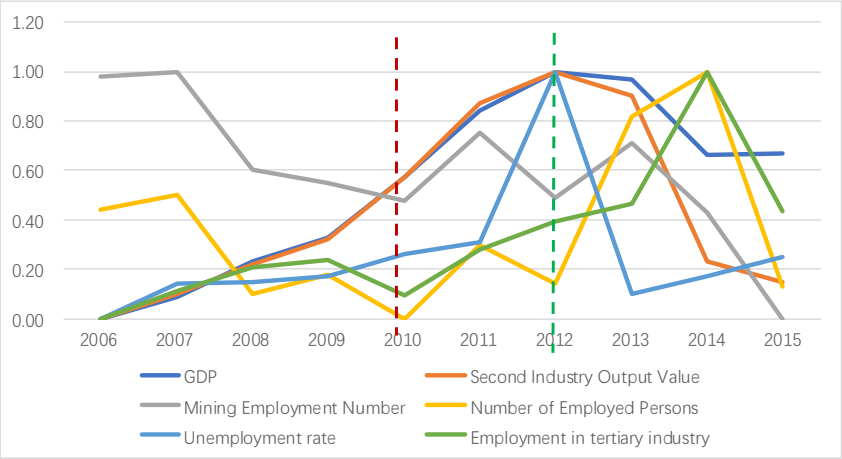

Figure. 4 Changes of economic and industrial Elements in Shuangyashan City

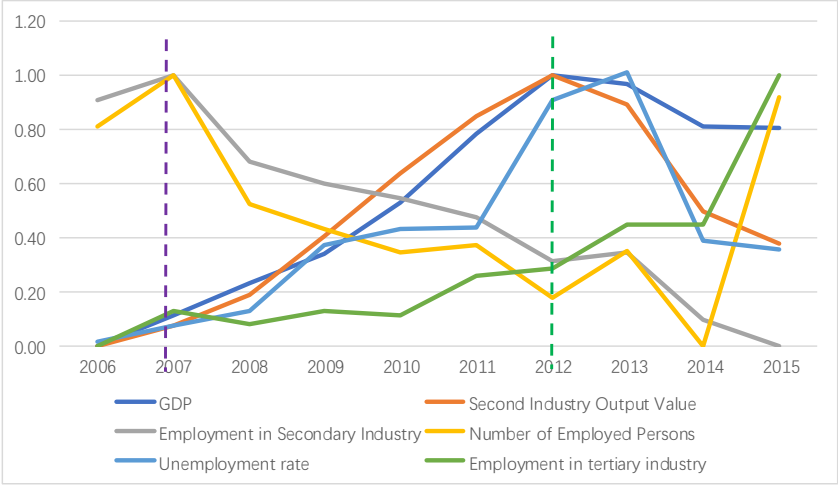

Figure. 5 Changes of Economic and Industrial Elements in Jixi City

Before 2012, the GDP of Shuangyashan City showed a growth state, and coincided with the growth trend of the output value of the secondary industry. However, since 2013, the GDP of the whole city has decreased slightly, while the output value of the secondary industry has decreased dramatically. It can be seen that after the urban population shrinkage began in Shuangyashan, the momentum of the development of the secondary industry has decreased along with the GDP reduction. Mining employment has fluctuated slightly since 2007, showing a declining trend as a whole, and decreased significantly in 2013, which may also indirectly reflect the decline of mining industry. At the same time, the unemployment rate is at the node of 2012. Before the GDP of the whole city decreased, the urban unemployment rate continued to rise, reaching its peak at the end of 2012. The total employment of Shuangyashan City has increased since 2013, and the unemployment rate has decreased, which shows that urban employment has eased down. The development of tertiary industry provides a suitable environment for urban employment. Generally speaking, Shuangyashan firstly has the problems of decreasing employment in mining industry and increasing urban unemployment rate. Secondly, it has the phenomena of declining GDP, declining output value of secondary industry and employment number of secondary industry, and rising output value of tertiary industry and employment number of tertiary industry.

Jixi's GDP also showed a growth state before 2012, and coincided with the change trend of Jixi's secondary industry output value. Similarly, starting from 2013, the GDP of the whole city has decreased and the output value of the secondary industry has decreased. At the same time, urban unemployment continued to rise before the city's GDP fell, and the most serious problem of unemployment occurred at the end of 2013. Since 2008, the number of employment in the secondary industry in Jixi City, mainly in coal mines, has declined in a straight line, and the total number of employment in Jixi City has also declined in the same trend, indicating the reduction of urban employment. Until 2015, the number of urban employment increased significantly, indicating that the development of tertiary industry has eased employment in resource-exhausted cities. Generally speaking, the economic and industrial factors in Jixi and Shuangyashan have the same trend in time dimension. First, the number of employment in the secondary industry decreases, the total number of employment in cities decreases, and the urban unemployment rate rises. Secondly, the overall GDP and the output value of the secondary industry decrease, and the output value of the tertiary industry and the number of employment increase.

Characteristics of Spatial Quality Changes

Through the evaluation of the changes of street scenery in the main urban areas in 2013 and 2016, the evaluation indicators include street greening, pavement and the street store vitality. The spatial quality was evaluated by scoring method , for example,Greening coverage increased by 1 point, unchanged by 0 points, reduced to -1 points; street pavement also scored 1 point, 0 points, or -1 points; street storefront vitality as a result of the city's obvious shrinkage characterization, so scored 2 points, 0 points and -2 points (table 5). Finally, when the total score is greater than or equal to 0, it is determined that the street level rises. Through the recognition and calculation of street scenery, it is concluded that the majority of the street space quality in Shuangyashan and Jixi has not declined. And the declining areas of urban spatial quality are distributed in the urban fringe, and the quality of urban central space is still steadily improved. Therefore, in terms of time, the decline of spatial quality is later than the decline of urban GDP.

Table. 5 Evaluating Indications of Urban Street View Change

Street View in 2013	Street View in 2016	Location	Spatial Quality Evaluation Elements	Evaluation score
			Street greening	1
			Street pavement	0
			Changes in Street Store Vitality	2
			Street greening	1
			Street pavement	1
			Changes in Street Store Vitality	0
			Street greening	1
			Street pavement	1
			Changes in Street Store Vitality	0

Change characteristics of people's livelihood quality

Based on the Yearbook data, data processing and calculation were carried out on the quality change factors of life in Shuangyashan City and Jixi City. The trend of various data over time was analyzed as follows (Figure 6, Figure 7).

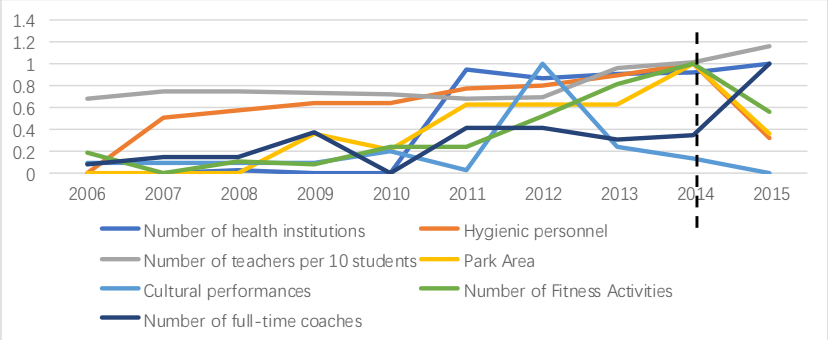

Figure. 6 Changes of quality of life factors in Shuangyashan

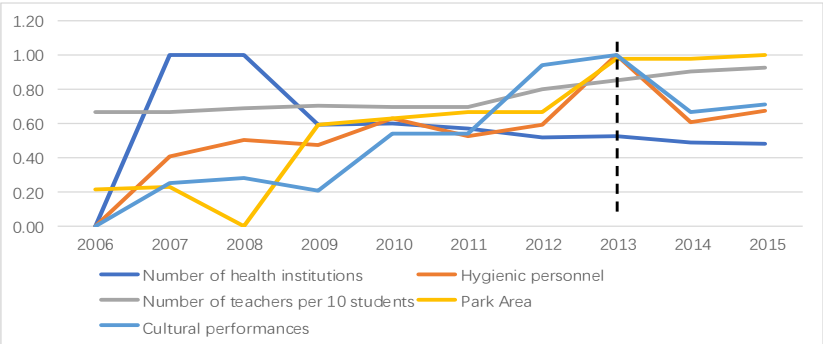

Figure. 7 Changes of quality of life factors in Jixi

From the data of the changes in the allocation of public service facilities, such as medical, education, parks, culture and sports, which are related to the quality of life of Shuangyashan citizens, it can be seen that the allocation of other facilities, such as health institutions, teachers and sports coaches, has increased. However, the area of parks, health technicians and the number of fitness activities held have a tendency to get worse since 2015. So far, there has been no obvious decline of public service facilities. On the contrary, with the population decreasing, the per capita ownership of public service facilities in urban areas has increased.

According to the changes of the related factors of Jixi citizens'quality of life, most public service facilities have shown an overall upward trend except the number of health institutions in the whole city has been slowly decreasing since 2009 and the number of cultural performances and the number of health technicians began to fluctuate in 2014. The future fluctuations are unknown, but if there is a decline, it occurs after the decline in urban GDP. The future development of urban public service facilities also depends on the government's adjustment policies and investment in the face of urban population shrinkage.

Results

By studying the time series of shrinkage factors in Shuangyashan and Jixi city, the two coal-exhausted cities in Northeast China, we find that although the shrinkage degree is different, there are many similarities in the time series of shrinkage factors, which may reflect some common problems in the shrinkage process of coal-exhausted cities. First of all, from a broad perspective, before the process of urban population shrinkage, the elements of urban population structure and the elements of urban economic industry are closely related to each other. However, the quality of urban space and the quality of urban public service facilities are obviously lagging behind and the population structure and economic industry change. From the point of view of sub-categories, comparing the four kinds of factors in time, *we can infer that Shuangyashan and Jixi have the similar time series of shrinkage factors in the process of urban shrinkage:*

Birth rate decline -- Natural growth rate decline -- Population shrinkage accompanied by population migration -- Employment reduction in mining (employment reduction in secondary industry) -- Employment reduction -- Unemployment rate rise -- The decline of output value of urban secondary industry -- The decline of urban GDP (The increase of output value of urban tertiary industry) -- The decline of public facilities such as urban culture and health - The overall change of urban spatial quality and people's livelihood quality.

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