Research Paper

Research on the efficiency of urban development towards urban shrinkage

a case study of Baishan City

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Abstract

The city of Baishan has become a unique new industrial city in Northeast China based on its mineral resources, and with the development of minerals has led to the development of related industries. This paper takes Baishan City as the study area, and constructs a comprehensive evaluation system for urban development in the context of urban shrinkage in four dimensions: population, economy, society and resources, with the help of data envelopment analysis and grey prediction models, to measure and evaluate the urban development efficiency of Baishan City from 2011 to 2020 and predict the future development trend. The impact of related factors on urban development is explored in depth. The results of the study show that although Baishan's urban development has been in contraction since 2011, most of the urban development efficiency values are greater than or equal to 0.95 during the study period, and the development momentum is good. During the study period, the level of economic development, the level of secondary industry structure, the level of openness to the outside world and the ability to deal with pollution have positively contributed to the urban development of Baishan; in the future, appropriate policies should be formulated to cultivate new urban businesses, upgrade and transform the industrial structure, vigorously develop the tertiary industry to renew the city's vitality, and focus on the protection and improvement of the ecological environment.

Keywords

Urban development efficiency, shrinking cities, DEA, GM(1,1), Tobit regression analysis

1. Introduction

1.1. Increasing urban shrinkage

With the development of urbanisation in China, the traditional industrial cities are experiencing a contraction phenomenon characterised mainly by a decrease in population, with a certain number of towns changing from the traditional growth scenario to a contraction trend. Although the specific manifestations and causes of this transformation are complex and varied, the internal causes can be attributed to deindustrialization, suburbanization, and social transformation. A study published in 2020 by Chengxin Wang, a professor in the School of Geography and Environment at Shandong Normal University in China, and his team found that between 2011 and 2017, 10 of 288 cities at the prefecture level and above experienced a comprehensive contraction, 41 cities characterized by population contraction, 28 cities characterized by economic contraction, and 3 cities characterized by social contraction. Shuai Zhang and Chengxin Wang et al. found that the spatial variation of urban shrinkage is significant, and most of the comprehensive shrinking cities and cities with sub-dimensions of population, economic and social shrinkage are in the northeast of China, and the degree of urban shrinkage has been increasing over time[1]. None of the phenomena does not indicate the increasing trend of urban shrinkage in China.

1.2. Resource-based cities face transformation issues

Among China's shrinking cities, resource-based cities are particularly characterized by urban shrinkage as resources are consumed, and the solution to their transformation problems is imminent. According to the National Sustainable Development Plan for Resource-based Cities (2013-2020) released by the State Council in 2013, there are 262 resource-based cities in China, accounting for about one-third of the total number of cities in China[2-4]. However, due to the decay of resources and the lack of long-term integrated planning of cities, resource-based cities present problems such as imbalanced industrial structures, serious brain drain, scarcity of sustainable industries, and deterioration of ecological and environmental quality[5-7]. Baishan City is a clear example.

Located in Jilin Province, Northeast China, Baishan City is a unique resource-based city in the Northeast due to its rich mineral resources. However, with the continuous exploitation of minerals, depletion of resources, loss of population and social development, Baishan City is gradually showing signs of urban shrinkage: employment rate and local students' local education rate continue to decline, and ecological data show environmentally unfriendly characteristics, Baishan City is in the context of urban shrinkage, and the transformation of its resource-based cities is an urgent issue[8-9]. Based on this, a rational analysis of Baishan's urban development efficiency and improvement of the results are essential for future urban development.

1.3. Urban Development Efficiency Study

For solving the problem of urban shrinkage, it is clear that urban development efficiency has a greater role, and the configuration of its output is invested to determine the direction of urban development. At present, most of the domestic and foreign studies on urban efficiency start from model measurement, mainly using DEA, stochastic frontier analysis (SFA) and other analytical tools to analyze the efficiency and level of urban development, and using Tobit regression, threshold effect model to explore[10] , and then use the results obtained to solve the urban disease problems related to cities[11-13] .

Based on the existing studies, this paper will select the super-efficient SBM model for calculating and analyzing the trade-offs between outputs and inputs, and overcome the shortcomings of the existing studies, i.e., ignoring the DEA validity analysis given by the model and the projection analysis of the model. This paper evaluates the current situation of urban development efficiency in Baishan City at the macro level, and provides theoretical guidance and empirical reference for urban planning and sustainable development through measuring urban development efficiency.

2. Urban Development Efficiency Research Data and Research Methodology

2.1. Research Data and Indicator Selection

The essence of urban development is man's control and reshaping of the natural environment, as well as his awareness and adaptability to the natural ecological environment on which he relies[14]. Accordingly, the precise construction of urban development efficiency evaluation indicators requires an all-round grasp of the connotation characteristics of urban development efficiency, which encompasses both industrial and economic development and environmental quality improvement of cities, and also relates to a variety of factors involving urban development quality, such as population, economy, society and resources, so as to provide empirical guidance for the construction of new urbanisation[11]. Therefore, based on the four principles of scientific, systematic, objective and representative selection of indicators, and with reference to relevant research results[15-16] , this paper establishes the urban development evaluation index system (Tabel 1) by dividing the target level of urban development efficiency evaluation indexes into two levels: input and output, taking into account the local urban characteristics and economic development of Baishan City.

Tabel 1. Urban Development Evaluation Indicator System. Source: Author.

Target level	Inputs	Land input	Area of urban built-up area
		Financial input	Amount of fixed asset investment in the whole society
		Labour input	Number of employees per unit at the end of the year
		Energy input	Total energy consumption
	Outputs	Expected output	Ecological benefits (greening coverage of built-up areas)
			Social benefits (total retail sales of social consumer goods, average wages of urban workers)
			Economic benefits (GDP)
		Non-desired output	Sulphur dioxide emissions
			Industrial wastewater and domestic wastewater emissions
			Domestic waste

In order to fully explain the scientific and reasonable construction of the evaluation indicator system, the selection of indicators is further explained. In terms of inputs, land input, capital input, labour input and energy input are selected to determine the input indicators of the city. Land input is chosen as the indicator because the area of the built-up area is directly related to urban land, which is one of the important input factors for urban development; capital input is chosen as the indicator because the amount of social fixed asset investment is a strong support for urban development; labour input is chosen as the indicator because the number of people employed per unit at the end of the year The change in the number of employees at the end of the year represents a gradual shift from primary to secondary and tertiary industries in the city; the total energy consumption is chosen as a measure of energy input, thus responding to the city's new urbanisation measures. In terms of output, it is mainly divided into desired output and non-desired output. In the construction process of new urbanisation, the focus on ecological civilisation should be strengthened, so the greening coverage of built-up areas is chosen as one of the indicators of desired output as ecological benefit; social benefit is chosen as a measure of GDP, as it is an important indicator of the economic condition and development level of a region; social benefit is expressed in terms of total retail sales of social consumer goods and the average wage of urban workers. In terms of non-desired outputs, the paper selects sulphur dioxide emissions, the total amount of industrial and domestic waste water discharged and the amount of domestic waste removed as indicators of non-desired outputs, taking into account the corresponding production and domestic pollution outputs brought about by urban development.The relevant data were obtained from the 2011-2020 Jilin Provincial Statistical Yearbook, Jilin Provincial Annual Report on Environmental Statistics, and the Statistical Bulletin of National Economic and Social Development of Baishan City, as described in the Baishan City Urban Development Efficiency Input-Output Indicators(Tabel 2), supplemented by interpolation for missing data.

Tabel 2. Description of input-output indicators for urban development efficiency in Baishan. Source: Author.

Variable Name	Sample size	Maximum value	Min	Mean	Standard deviation	Median	Variance
Area of urban	10	60721.32	43603.23	52894.555	6111.713	53216.89	37353035.58

built-up area							
Total social fixed asset investment	10	764	422.9	624.07	107	657.1	11449.08
Number of employees per unit at the end of the year	10	18.12	12	15.25	2.242	15.66	5.028
Total energy consumption	10	9028.3	6881.4	7821.3	912.253	7652.5	832204.9
Area covered by greenery in built-up areas	10	3312240	2242860	2745514	359067.656	2727835	1.2893E+11
Total retail sales of social consumer goods	10	310.38	139.08	242.504	61.045	255.2	3726.515
Average wage of urban workers	10	5251.83	2498.92	3813.888	933.818	3826.085	872015.974
GDP	10	715.77	509.42	627.31	75.614	660.885	5717.472
Sulphur dioxide emissions	10	3.64	0.31	2.031	1.27	2.725	1.613
Industrial and domestic wastewater emissions	10	7737.01	5264.7	6540.103	869.876	6686.425	756684.185
Domestic waste removal volume	10	21	10	17.6	4.356	19.465	18.979

2.2. Research Methodology

1.Data Envelopment Approach (DEA)

The data envelopment method is often used to measure the productivity of some measured sectors because it can be applied in a scientific way so that the inputs or outputs of the decision unit are always constant, independent of external factors[11、13]. In contrast to traditional CCR models based on constant returns to scale, SBM models take full account of input-output slack and provide a viable way of accounting for the effects of undesired outputs. Moreover, the SBM model can re-operate on a decision unit with an effective value of 1 during the evolution process, thus overcoming the problem of excessive technical efficiency caused by neglecting the slack factor, and also taking into account the non-desired outputs in urban development, making the calculated results more accurate and improving the credibility of the calculated results. In this paper, the SBM model based on constant payoffs of scale is used to measure the efficiency of urban development, and the algorithm is consistent with that of Qianbin Di[11].

2.Grey prediction model (GM(1,1))

The grey forecasting model is a scientific method of describing and analysing future development trends and conditions based on existing laws of development, and making scientific assumptions and judgements[17-18]. This paper uses a grey prediction model to simulate and predict the future urban development efficiency of Baishan City for the next seven years, based on the obtained urban development efficiency values, in order to obtain the future development trend of urban development efficiency in Baishan City.

2.3. Analysis of results

1. Time series characteristics of urban development efficiency values in Baishan City

MaxDEA software was used to compute 130 data for Baishan City from 2011 to 2020, and to calculate the urban development efficiency values for each year, taking into account the non-desired outputs and the urban development efficiency values without taking into account the non-desired outputs(Tabel 3), and visualise the results(Figure 1). As can be seen from Table 3 and Figure 1, the urban development efficiency values calculated with the consideration of non-desired outputs are significantly lower than those calculated without the consideration of desired outputs, thus indicating that non-desired outputs have a negative effect on the development of cities and that the results with the consideration of urban non-desired outputs are more credible[16]. Therefore, this paper uses the value of urban development efficiency considering undesired output for the subsequent analysis.

Tabel 3. Urban Development Efficiency Values for Baishan City. Source: Author.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Consider non-desired outputs	0.68	0.94	0.97	0.97	0.95	0.98	0.97	0.93	0.95	0.99
No consideration of non-desired outputs	0.84	0.97	1.01	0.97	0.95	0.99	0.98	0.98	0.97	1.02
Average value	0.76	0.96	0.99	0.97	0.95	0.99	0.98	0.95	0.96	1.01

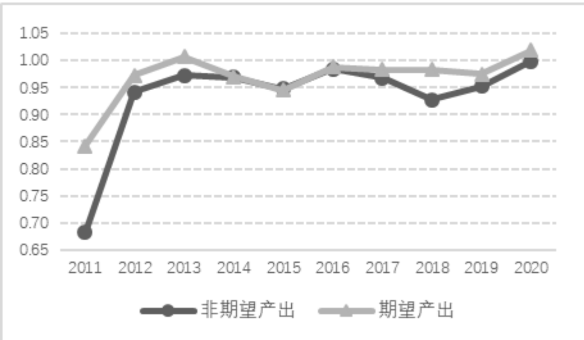

Figure 1. Urban Development Efficiency Values for Baishan City. Source: Author.

As can be seen from the 2011-2020 urban development efficiency values for Baishan (Figure 1), the city's urban development efficiency values are all below 1, and the allocation of inputs such as land, capital, labour and energy needs to be improved.In 2011, the urban development efficiency value was at its lowest, which, when combined with population and other data, indicates that Baishan has gradually entered a phase of urban contraction. In the face of urban contraction, the government advocated for urban transformation and upgrading while protecting the ecological environment, taking a series of measures that resulted in a steady increase in the average value of urban development efficiency in Baishan from 2011 to 2014, from 0.68 in 2011 to 0.97 in 2014. In 2015, the city of Baishan faced multiple challenges such as the complex situation at home and abroad, increasing downward pressure on the economy, the urgent need to transform and upgrade the city's industries, and the increasingly tightening resource and environmental constraints, which led to a slowdown in urban development. As a result of blind investment and low-level expansion in the form of rough upgrading, problems such as the lack of constraint mechanisms to conserve resources and environmental damage gradually emerged, thus causing another decline in the urban development efficiency value. after a small rebound in 2015-2016, the urban development efficiency value once again slowly declined to 0.93 from 2016-2018. however, from 2019 onwards, the urban From 2011 to 2020, the urban development efficiency value of Baishan City has risen to 0.99. Looking at the urban development efficiency value of Baishan City from 2011 to 2020, it can be seen that the rapid economic development was supported by the good ecological environment and rich resources in the early stage of development, but later the city looked for a transformation path, and the pollution emission exceeded the environmental carrying capacity, and the sustainable development was constrained by a rough economic development model. This has led to fluctuations in the efficiency of the city's development. As Baishan continues to explore the path of transformation, the urban development efficiency value continues to fluctuate and does not reach 1[19-21].

2.Future model projections of urban development efficiency values

Before building the grey forecasting model, the time series were subjected to a rank-ratio test. From the analysis inTabel 4, it can be obtained that all the rank-ratio values of the translation-transformed series lie within the interval (0.834, 1.199), indicating that the translation-transformed series are suitable for building the grey forecasting model. The posterior difference ratio was calculated for the data and the result showed a posterior difference ratio of 0.05, indicating high model accuracy.

Tabel 4. Grade ratio test results. Source: Author.

Index Terms	Original value	Level ratio value	Translated series value	Level ratio after translation
2011	0.683	-	1.683	-
2012	0.941	0.725	1.941	0.867
2013	0.972	0.968	1.972	0.984
2014	0.968	1.004	1.968	1.002
2015	0.948	1.022	1.948	1.011
2016	0.984	0.963	1.984	0.982
2017	0.968	1.017	1.968	1.008
2018	0.928	1.043	1.928	1.021
2019	0.952	0.975	1.952	0.988
2020	0.999	0.953	1.999	0.976

The urban development efficiency values were fitted and calculated, and the resulting model had an average relative error of 1.668%, which is less than 20%, implying a good model fit. The results are shown in Figure 2 which shows an overall increasing trend in the urban development efficiency values for Baishan City over the next seven time periods.

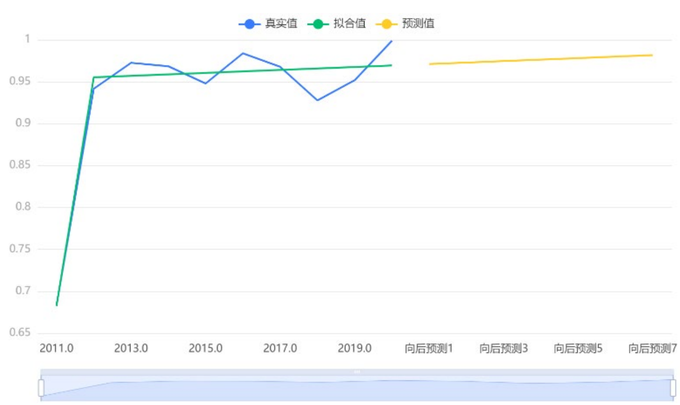

Figure 2. Simulated forecast of urban development efficiency in Baishan. Source: Author.

3. A study of factors influencing the efficiency of urban development

3.1. Research data and indicator selection

As can be seen from the above, there are significant time-series changes in the urban development efficiency of Baishan city, and the influencing factors are relatively complex. To further grasp the relationship between urban development efficiency and the influencing factors, this paper combines the results of existing research literature and, based on the availability of data, selects five types of indicators to measure the relationship between the level of regional economic development, the level of secondary industrial structure, the level of science and technology, the level of openness to the outside world and the pollution treatment capacity and urban development efficiency[19].

3.2. Analysis of results

1. Model construction

Using the value of urban non-desired urban development efficiency as the dependent variable, five indicators, namely gross regional product, share of secondary industry in gross regional product, scientific research, number of people in technical services, total import and export, comprehensive utilization rate of industrial solid waste and sewage and domestic waste treatment rate(which representing five categories of levels respectively), were selected for Tobit regression analysis.The Tobit regression model is as follows.

$$Y = \beta_0 + \beta_1 LNX1 + \beta_2 X2 + \beta_3 LNX3 + \beta_4 LNX4 + \beta_5 LNX5 + \beta_6 X6 + \mu$$

Where Y is the efficiency of urban development, X1 is the level of economic development, expressed as the natural logarithm of GDP, X2 is the level of secondary industry structure, expressed as the share of secondary industry in regional GDP, X3 is the level of infrastructure construction, expressed as the natural logarithm of the amount of investment in transport infrastructure construction, X4 is the level of science and technology, expressed as the natural logarithm of the number of personnel in the science research and technology service industry, X5 is the level of X5 is the level of openness to the outside world, expressed as the natural logarithm of the amount of foreign investment used, and X6 is the level of pollution treatment capacity, expressed as the rate of waste water and domestic waste treatment. Tabel 5 shows the results of the descriptive statistics for each variable.

Tabel 5. Variable Description Statistics. Source: Author.

Variable	Obs	Mean	Std.Dev.	Min	Max
Y	10	0.9342131	0.0908183	0.6826562	0.9987897
X1	10	627.31	75.61397	509.42	715.77
X2	10	0.4968471	0.1314024	0.2562326	0.6038537
X3	10	79594	42480.59	47849	192739
X4	10	0.189	0.0272641	0.13	0.23
X5	10	60856.9	66789.22	23370	206730
X6	10	1.30104	0.3369803	0.6544	1.7661

The mean value of urban development efficiency is 0.934, indicating that the efficiency of urban development is at a high level over the years; the mean value of economic development level is 627.31, with a standard deviation of 75.613, indicating that the level of economic development varies greatly over the years; the minimum value of secondary industry structure level is 25.62%, with a maximum value of 60.38%, indicating that the level of secondary industry structure varies greatly over the years The average value of infrastructure construction level is 79,594 and the standard deviation is 42,480.59, which means that the level of infrastructure construction has changed a lot over the years; the minimum value of the number of scientific research and technical service personnel is 0.13 million and the maximum value is 0.23 million, which means that the level of science and technology has changed a lot over the years; the minimum value of the level of opening up to the outside world is 23,370 and the maximum value is 206,730, which means that the level of opening up to the outside world has changed a lot over the years. This means that the level of openness to the outside world has changed a lot over the years; the average value of the level of pollution treatment capacity is 130.1%, which means that the pollution treatment capacity is at a high level.

2. Related tests

The factors were first tested for correlation with the efficiency of urban development and the results are shown in Tabel 6.

Tabel 6. Related tests. Source: Author.

	Y	LNX1	X2	LNX3	LNX4	LNX5	X6
Y	1.000						
LNX1	0.314	1.000					
X2	0.313	0.718	1.000				
LNX3	0.362	-0.534	-0.847	1.000			
LNX4	0.223	0.444	0.256	-0.593	1.000		
LNX5	0.358	-0.757	-0.913	0.737	-0.272	1.000	
X6	0.641	0.037	-0.583	0.621	0.074	0.339	1.000

From the correlation test results, it can be seen that the correlation coefficient between the level of economic development and urban development efficiency is 0.314, indicating that the level of economic development shows a positive correlation with urban development efficiency; the correlation coefficient between the level of secondary industrial structure and urban development efficiency is 0.313, indicating that the level of secondary industrial structure shows a positive correlation with urban development efficiency; the correlation coefficient between the level of infrastructure construction and urban development efficiency The correlation coefficient between the level of infrastructure construction and urban development efficiency is 0.362, indicating that the level of infrastructure construction and urban development efficiency show a positive correlation; the correlation coefficient between the level of science and technology and urban development efficiency is 0.223, indicating that the level of science and technology and urban development efficiency show a positive correlation; the correlation coefficient between the level of openness to the outside world and urban development efficiency is 0.3158, indicating that the level of openness to the outside world and urban development efficiency show a positive correlation The correlation coefficient between the level of pollution treatment capacity and the efficiency of urban development is 0.641, indicating that the level of pollution treatment capacity and the efficiency of urban development show a positive correlation.

3.3. Tobit regression analysis

The results of the model Tobit regression are shown in Tabel 7.

Tabel 7. tobit regression results. Source: Author.

Y	Coef.	Std. Err.	t	P>|t|	[95% Conf.Interval]	
LNX1	0.647412***	0.0910752	7.11	0.002	0.3945468	0.9002771
X2	0.6934558**	0.1875792	3.7	0.021	0.1726523	1.214259
LNX3	0.1061038*	0.0491938	2.16	0.097	-0.03048	0.2426875

LNX4	0.1405718	0.0721959	1.95	0.123	-0.0598762	0.3410198
LNX5	0.1795862***	0.0164105	10.94	0	0.1340233	0.225149
X6	0.0949123**	0.0330095	2.88	0.045	0.0032633	0.1865614
_cons	-6.565291***	0.5496928	-11.94	0	-8.091483	-5.039099
LR chi2(8)	38.70					
Prob	0.0000					
Log likelihood	29.674946					

Note: ***, ** and * denote 1%, 5% and 10% levels of significance respectively.

From Tabel 7, it can be seen that the LR chi2(8) statistic is 38.7 with a p-value of 0, which is less than 0.1, passing the significance test, i.e. the overall regression effect of the model guys. The model equation can be obtained, the equation is as follows.

$$Y = 0.647LNX1 + 0.693X2 + 0.106LNX3 + 0.140LNX4 + 0.179LNX5 + 0.094X6 - 6.565$$

The coefficient of regression between the level of economic development and urban development efficiency is 0.647412, the coefficient of regression between the level of secondary industrial structure and urban development efficiency is 0.6934558, the coefficient of regression between the level of infrastructure construction and urban development efficiency is 0.1061038, the coefficient of regression between the level of openness and urban development efficiency is 0.1795862, and the coefficient of regression between the level of pollution treatment capacity and urban development efficiency is 0.0949123. The regression coefficient between the level of economic development, the level of secondary industry structure, the level of infrastructure construction, the level of openness to the outside world and the level of pollution treatment capacity are all positively correlated with the urban development efficiency during the study period, and play a positive role in promoting urban development. The regression coefficient of the level of science and technology and urban development efficiency is 0.1405718, but it does not pass the significance test, indicating that the correlation between the level of science and technology and urban development efficiency is weak during the study period, i.e. the influence of the level of science and technology on urban development efficiency is not obvious.

4. Conclusion

In this paper, the SBM model based on non-expected output selects 130 city data of Baishan City from 2010 to 2020 for measuring urban development efficiency and compares it with urban development efficiency without considering non-expected output, the results show that:

The urban development efficiency value without considering non-desired output is significantly higher than the urban development efficiency value considering non-desired output, indicating that considering non-desired output value is more in line with the urban development in the actual situation; the average value of considering and not considering non-desired output value is greater than or equal to 0.95 except for 2011, indicating that the development is better but still has room for improvement.The temporal characteristics of urban development efficiency from 2010 to 2020 do not fluctuate much, but the stage characteristics are obvious. The overall trend is upward, and the city efficiency value is relatively stable and increasing. By constructing a Tobit panel data model to analyse the efficiency of urban development based on non-desired outputs, urban development has a positive correlation with the level of economic development, the level of secondary industrial structure, the level of openness to the outside world and the ability to deal with pollution, which has a catalytic effect on urban development during the study period, and is not significantly related to the level of science and technology.

Based on the measurement of non-expected output urban development efficiency, model prediction and regression analysis, the following recommendations are made: as a resource-based city in transition, Baishan City should invest human, financial and material resources reasonably, actively guide the optimisation and upgrading of industrial structure, promote the vitality of the tertiary industry, focus on the construction of the urban environment, increase the efforts to improve the ecological environment, and focus on energy conservation and emission reduction to guide the healthy development of the city. This paper analyses and evaluates the efficiency of urban development based on a non-expected output perspective, and combines the measurement results with predictive analysis for the future, which can more objectively reflect the actual level of urban development efficiency. However, as a small city, Baishan City has not been included in the analysis of urban development efficiency because some data are not available. The next step is to improve the collection and collation of data to fill in the indicators of urban development efficiency, so as to make a better analysis of urban development.

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