ISSN: 2710-0170

Empirical Analysis of Urban Construction Land Use Efficiency based on the Three-Stage DEA Model

-- Taking Hunan Province as an Example

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Abstract

Currently, with the acceleration of urbanization in China and the shortage of urban construction land, it is particularly important to objectively and scientifically evaluate the efficiency of urban construction land use. This paper takes Hunan Province as the research object, uses the three-stage DEA model to analyze, obtains the efficiency value except for environmental factors and random factors, and compares and analyzes the change of urban construction land use efficiency of 13 Prefecture-level city in Hunan Province in 2018. The research results indicate that the utilization efficiency of urban construction land in Hunan Province is good, and the resource allocation is relatively reasonable. However, some cities have redundant inputs or insufficient outputs, unreasonable resource allocation, and low urban scale efficiency. Based on the above conclusions, this article proposes suggestions to improve the efficiency of urban construction land use in Hunan Province from three aspects.

Keywords

Urban Construction Land; Utilization Efficiency; Three-Stage DEA Model.

1. Introduction

As a fundamental resource for human life and urban development, land has play a fundamental role in the process of urban development, while urban construction land, as the carrier of various urban functions, also provides a venue for various human activities. The comprehensive development and scale expansion of cities are constrained by the continuous supply of urban land. At the same time, urban construction land often uses the occupation of arable land around the city as a means of expansion. With the continuous deepening of urbanization, the demand for land in urban development will become greater, which will lead to a series of difficulties, such as the intensification of land supply and demand contradictions, disorderly expansion of land, and low efficiency of land use, all of which will ultimately lead to low efficiency of urban land use. The emergence of the above-mentioned practical difficulties requires that in the process of modern urban development, more attention should be paid to the rational layout of land, efficient allocation and utilization of land resources.

Therefore, saving land resources and achieving efficient and intensive land use are important measures to promote the economic revitalization of Hunan Province. Therefore, this study conducted data analysis on the efficiency of urban construction land in 2018 through the three-stage DEA model, and compared with the change trend of urban construction land efficiency in 13 Prefecture-level city in Hunan, gave targeted policy recommendations, hoping to provide reference for the municipal governments of all regions in Hunan to scientifically and rationally plan urban construction land resources and improve urban construction land efficiency.

ISSN: 2710-0170

2. Research Methods and Data Sources

2.1. Research Methods

There are two evaluation methods for land use efficiency: single indicator evaluation method and multi indicator evaluation method. The single indicator method is relatively simple. It often uses indicators such as Floor area ratio and land output ratio of urban built-up areas to directly compare and analyze the efficiency of urban construction land use. However, the land use system is a complex system that requires consideration of multiple inputs and outputs. A single indicator method does not meet the characteristics of multiple inputs and outputs. The multi indicator evaluation method often combines quantitative analysis to evaluate the comprehensive efficiency of multiple factors such as economy, society, and ecological environment in land use. Currently, it has become the mainstream method for evaluating land use efficiency. There are two main types of multi indicator evaluation methods, one is the analysis using Analytic Hierarchy Process, Principal Component Analysis, etc., and the other is the Data Envelopment Analysis (DEA) using non parametric analysis.

The three-stage DEA method was proposed by Fried et al. (2002), which uses the three-stage DEA method to evaluate the efficiency of decision-making units. It can filter out the influence of environmental and random factors on the evaluation object in traditional DEA models and obtain more accurate results. At present, academia has conducted a lot of research on efficiency, focusing on the efficiency of a certain region or industry, but there is less evaluation on the efficiency of urban construction land use in Hunan Province. Therefore, this paper uses the existing research results to study the current situation and spatial differences of urban construction land use efficiency of 13 Prefecture-level city in Hunan Province in 2018. In addition, this paper adopts a three-stage DEA model that takes into account the impact of external environmental factors on DMU evaluation, so that the efficiency value of the results can be more accurate, Confounding can be eliminated, and more substantive suggestions can be put forward.

2.2. Indicator Selection and Data Sources

2.2.1. Indicator Selection

The most basic input factors for production are land, labor, and capital. Based on the actual situation of Hunan Province and the existing research results on input-output factors, in the investment indicators of DEA, urban construction land area and urban employees are selected as land and labor input factors, and financial expenditure is used as capital input. In terms of DEA output indicators, Gross regional product, fiscal revenue and disposable income of urban residents are selected as the output indicators of urban construction land use efficiency. The environmental variable refers to the external factors that affect the efficiency of urban construction land use. The environmental variable in this paper adopts two variables: (1) government dominance: government dominance directly affects the direction of policy implementation and the strength of macro-control, reflects the degree of local government support for local development, and is expressed by the proportion of local fiscal expenditure in Gross regional product. The greater the influence, the stronger the guidance for economic investment, the more reasonable the allocation of land and other resources, and the higher the environmental efficiency; (2) Urban density: urban population density is an important indicator of regional natural attributes, which is expressed by the ratio of urban population to urban area, and has a significant impact on the efficiency of urban construction land use. The high density of Urban density usually means that the level of urbanization is high, infrastructure is perfect, people's living conditions and regional economic development are high, the utilization of construction land may be relatively high, and residents' quality and awareness of environmental protection are strong, which is conducive to the improvement of environmental

ISSN: 2710-0170

efficiency; At the same time, the high density of Urban density also means that urban land is under greater ecological pressure, which will burden regional ecology and environment, which is not conducive to the improvement of environmental efficiency.

Table 1. Variables and variable descriptive statistics

Variable	Index	Mean value	Standard deviation	Minimum value	Maximum value
Input variables	Urban construction land area	113.769	121.284	33	505
	Financial expenditure	4922780.462	2677823.772	1755791	13007895
	Urban employees	39.695	25.924	8.45	119.45
Output variables	Revenue	1759020.692	2161254.674	346563	8797072
	Disposable income of urban residents	32648.315	7268.017	24825.3	50791.9
	GDP	2847.592	2581.027	578.92	11003.41
Environment variable	Urban population density	3.134	0.947	1.277	4.545
	Government dominance	0.205	0.063	0.118	0.307

2.2.2. Data Sources

In the input indicators, the data of urban construction land area, urban employees, fiscal expenditure, Gross regional product, fiscal revenue, urban residents' disposable income in the output indicators, and urban population in the environmental variables are all from the 2018 Statistical Yearbook of Hunan Province.

3. Analysis on the Efficiency of Urban Construction Land Use in Hunan Province

3.1. First Stage DEA Evaluation Results

Table 2. The first stage DEA evaluation results

Numble	City name	Comprehensive technical efficiency	Pure Technical Efficiency	Scale efficiency	Return to scale
1	Changsha	1	1	1	-
2	Zhuzhou	0.944	1	0.944	drs
3	Xiangtan	1	1	1	-
4	Henyang	0.842	0.843	0.998	irs
5	Shaoyang	0.718	0.745	0.964	irs
6	Yueyang	1	1	1	-
7	Changde	1	1	1	-
8	Zhangjiajie	1	1	1	-
9	Yiyang	0.901	0.921	0.977	drs
10	Chenzhou	1	1	1	-
11	Yongzhou	0.953	0.973	0.98	irs
12	Huaihua	0.953	0.992	0.961	irs
13	Loudi	1	1	1	-
Mean		0.947	0.96	0.986	

Note: drs means that Returns to scale decreases, and irs means that Returns to scale increases.

ISSN: 2710-0170

In the first stage, Deap2.1 software was directly used to analyze the utilization efficiency of urban construction land in various cities of Hunan Province in 2018, calculate the comprehensive technical efficiency, pure technical efficiency and scale efficiency of urban construction land utilization in various cities of Hunan Province, and obtain the following evaluation results (Table 2).

The BCC model of DEA method is used to evaluate the efficiency of urban construction land use in cities at all levels in Hunan Province. The average comprehensive efficiency of urban construction land use in cities at all levels in Yunnan Province in 2018 is 0.947, the average value of pure technical benefits is 0.96, and the average value of scale benefits is 0.986. The overall efficiency value of Changsha, Xiangtan, Yueyang, Changde, Zhangjiajie, Chenzhou and Loudi is 1.000, which is in the effective state of DEA; Zhuzhou and Yiyang are in a state of diminishing returns to scale; Except for the efficiency value of Shaoyang City, which is 0.718, the other Prefecture-level city are all above 0.800, which is relatively efficient.

3.2. Second Stage Stochastic Frontier Analysis (SFA) Model

Perform SFA model regression analysis using Frontier 4.1 software (Table 3). A positive coefficient indicates that an increase in this environmental variable is not conducive to improving the efficiency of urban construction land use, resulting in waste of input factors. A negative coefficient indicates the opposite, which is beneficial for improving the efficiency of urban construction land use. The LR values are 10.59, 0.42, and 10.69 respectively, which are significant at the 10% levels. Therefore, using the SFA model is reasonable. The regression coefficient of government dominance and Urban density in the area of urban construction land, financial expenditure, and investment relaxation of urban employees is positive, and tends to zero, which proves that the government dominance has a small impact on land, labor, and capital investment. The government's fiscal intervention expenditure has no significant impact on the use and development of urban construction land, and the population density has a small impact on land, labor, and capital investment. Since these two environmental variables have different impacts on the 13 Prefecture-level city, it is necessary to eliminate them and put the 13 Prefecture-level city under the same external environment for analysis to obtain a true and effective efficiency level.

Table 3. SFA model regression analysis results

Variable	Slack variable					
	Urban construction land area		Fiscal expenditure		Urban employees	
	Coefficient	t-values	Coefficient	t-values	Coefficient	t-values
Constant term	-3.73	-4.22	-1.94	-1.94(*)	-4.87	-3.28(*)
Government dominance	0.31	12.703(*)	0.88	4.88(*)	0.06	1.08(*)
Urban population density	0.09	-5.21(*)	0.82	2.82(*)	0.15	1.90(*)
Sigma-squared	1.17	1.33*)	4.24	4.24(*)	1.69	1.70(*)
Gamma	1.00	1.36(*)	8.70	6.80(*)	1.00	8.85(*)
Unilateral likelihood ratio	-3.81		-1.87		-2.56	
LR unilateral error	10.589(*)		0.423(*)		10.693(*)	

3.3. Analysis of DEA Efficiency after Adjusting Variables in the Third Stage

Import the adjusted input data into the deap2.1 software and use the BCC-DEA model for recalculation to obtain the efficiency value of urban construction land use in Hunan Province, excluding environmental and random factors. The comparison between before and after adjustment is shown in Table 4.

ISSN: 2710-0170

Table 4. DEA efficiency analysis after adjusting variables in the third stage

DUM	Before adjustment				After adjustment			
	Comprehensive technical efficiency	Pure Technical Efficiency	Scale efficiency	Return to scale	Comprehensive technical efficiency	Pure Technical Efficiency	Scale efficiency	Return to scale
Changsha	1	1	1	-	1	1	1	-
Zhuzhou	0.944	1	0.944	drs	1	1	1	-
Xiangtan	1	1	1	-	1	1	1	-
Henyang	0.842	0.843	0.998	irs	0.877	0.895	0.98	irs
Shaoyang	0.718	0.745	0.964	irs	0.761	0.807	0.943	irs
Yueyang	1	1	1	-	1	1	1	-
Changde	1	1	1	-	1	1	1	-
Zhangjiajie	1	1	1	-	1	1	1	-
Yiyang	0.901	0.921	0.977	drs	0.935	0.935	1	-
Chenzhou	1	1	1	-	1	1	1	-
Yongzhou	0.953	0.973	0.98	irs	0.972	0.991	0.98	irs
Huaihua	0.953	0.992	0.961	irs	0.979	1	0.979	irs
Loudi	1	1	1	-	1	1	1	-
Average value	0.947	0.96	0.986		0.963	0.971	0.991	

The adjusted comprehensive efficiency values of some Prefecture-level city have increased to varying degrees, which indicates that the overall level of urban land use efficiency in Hunan Province is underestimated, and the adjusted pure technical efficiency has increased to varying degrees, indicating that the pure technical efficiency is greatly affected by environmental factors, while the high pure technical efficiency indicates that the decision-making and management level of Hunan Province in controlling the use of urban construction land has become mature. The average comprehensive technical efficiency of urban construction land in 13 cities and prefectures in Hunan Province in 2018 was adjusted to 0.963, indicating that the actual production capacity accounts for 96.3% of the ideal production capacity and the utilization efficiency is relatively high. After the adjustment, the pure technical efficiency of Hengyang City and Shaoyang City has been improved, but their scale efficiency has been reduced. The low scale efficiency indicates that Hunan Province needs to further optimize the allocation of production factors, adjust the land structure, and realize the scale economy of urban construction land use. The adjusted pure technical efficiency of Huaihua City is 1, indicating that its pure technical efficiency has reached the optimal level and has reached the maximum utilization of resources. The scale efficiency of Changsha, Xiangtan, Yueyang, Changde, Zhangjiajie, Chenzhou and Loudi is equal to 1, which is an effective state, and the scale of urban construction land utilization is optimal. Before the adjustment, Zhuzhou City and Yiyang were in a state of diminishing Returns to scale. We should reduce the scale of investment, save and use resources intensively to achieve optimal scale efficiency.

3.4. Evaluation and Analysis of Technology and Scale Efficiency

3.4.1. Analysis of Pure Technical Efficiency

From the perspective of technology and economy, pure technical efficiency is to study whether the decision-making unit can reach the maximum output level under the assumption of Returns to scale change and input reduction, and under a certain level of scientific and technological input, which is equivalent to whether the resource allocation of the decision-making unit's urban construction land use is in an effective state during the economic development process. According to the calculation results in Table 4, the average value of pure technical efficiency is 0.96, indicating that the overall level of input-output system for construction land use in various prefecture level cities in Hunan Province is relatively high. The technical efficiency value is high.

ISSN: 2710-0170

Except for the pure technical efficiency of Shaoyang City, which is 0.745, the pure technical efficiency of the other 12 decision-making units is higher than 0.843. When the value of pure technical efficiency is higher, it represents a higher utilization rate of input resources. The reason why decision-making units cannot achieve DEA effectiveness is due to insufficient resource allocation or insufficient output.

The level of technological efficiency reflects the level of technological level and the speed of technological updates in the process of urban construction. Therefore, the value of technological efficiency depends to a certain extent on the level of regional economic development. The economic development level of Shaoyang is at a high level in Hunan Province, and its technical efficiency is basically in an effective state. The disposable income of urban residents in Changsha City is only one half of that of Changsha City, and its average technical efficiency is only 0.745, which also shows a positive correlation between technical efficiency and regional economic development.

3.4.2. Analysis of Scale Efficiency

When the scale efficiency is equal to 1, it indicates that the scale is effective, i.e. the production scale has reached the optimal scale, indicating that the input scale is the most appropriate. According to Table 4, the average value of scale efficiency is 0.986, and it is found that regions with effective comprehensive efficiency are also regions with effective scale efficiency. There are decision making units with pure technical efficiency but inefficient scale efficiency, which leads to invalid comprehensive efficiency of these decision making units. For example, in Zhuzhou City, the technical efficiency value is 1, but the scale efficiency value is less than 1, indicating that this decision making unit is in a state of increasing or decreasing returns to scale. To improve the efficiency of urban construction land utilization, the technical level has reached the optimal level, and it is necessary to reduce redundant investment in order to achieve comprehensive efficiency and effectiveness. The effective decision-making units of DEA are all in a state of constant returns to scale, as their production scale has reached the optimal scale and maximized returns to scale, indicating that input and output will increase year-on-year. Hengyang, Shaoyang City, Yongzhou City and Huaihua four decision-making units are in the state of increasing returns to scale (irs). From the perspective of scale efficiency, to achieve the optimization of scale efficiency, the investment scale needs to be expanded; Zhuzhou City and Yiyang are in a state of diminishing scale (drs), which means that even if these decision-making units expand the input scale, they cannot bring about the same proportion of increase in output. At this time, in order to achieve scale efficiency optimization, we should control the input scale, improve the intensity of urban construction land use, change the status of extensive land use, and increase input.

The difference in scale efficiency across the province is not significant, with an average of 0.986 in 2018. The scale efficiency of urban construction land use in Hunan Province is mostly in a state of increasing scale efficiency, which indicates that to achieve optimization of scale efficiency, it is necessary to expand the investment scale. Among the 13 Prefecture-level city in Hunan Province, Huaihua City has the lowest scale efficiency, which is consistent with its relatively low comprehensive efficiency across the province. This indicates that Huaihua City should pay attention to the resource allocation in the urban construction land planning, improve the economical and intensive level of urban construction land, so as to effectively and reasonably improve the utilization efficiency of urban construction land in Huaihua City.

4. Conclusion

The utilization of land, especially urban construction land, is closely related to economic factors. The utilization efficiency of urban construction land in all cities of Hunan Province is generally high, but compared with the Economic efficiency of urban construction land utilization in other

ISSN: 2710-0170

provinces, there are still shortcomings and certain gaps, and the utilization efficiency of urban construction land in 13 cities is different, with significant spatial differences. As of 2018, the comprehensive efficiency of Changsha, Xiangtan, Yueyang, Changde, Zhangjiajie, Chenzhou and Loudi is far greater than that of other Prefecture-level city. Among the six cities in Hunan Province that are not DEA efficient, Zhuzhou's pure technical efficiency has been the best, but the scale efficiency has not reached the best. It is necessary to improve the scale efficiency and increase the scale of factor input to achieve DEA efficient. The comprehensive technical efficiency, pure technical efficiency and scale efficiency of Hengyang City, Shaoyang City, Yiyang City, Yongzhou City and Huaihua are not equal to 1, which should be considered from the perspective of input and output. If there is redundancy in input, resources should be saved and intensively used to prevent extensive abuse; If the output is insufficient, the input of resources and technology can be appropriately increased, the scale of input can be controlled, and the Returns to scale can be reduced. The DEA method calculates the relative efficiency, and the calculation results obtained in this study are the relative comparison results of each city in all aspects, which cannot accurately understand the actual land use efficiency of each city. Future research can specifically target individual cities and construct economic, ecological, and social indicator systems to comprehensively analyze the land use efficiency of individual cities. For decision units with DEA calculation results less than 1, the improvement direction can be determined through the analysis of invalid unit improvement results, but for decision units with DEA equal to 1, in-depth analysis cannot be conducted. For the limitations of the DEA method, future research can consider combining it with other methods or improving the model to draw more accurate and comprehensive conclusions.

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