An Analysis on Urban Land Use Efficiency Based on Super-efficiency DEA

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Abstract. The purpose of this research is to, by taking Wuhan city as an example, build the super-efficiency DEA to calculate and analysis the urban land use efficiency so as to provide reference for improving urban land use efficiency. Methods employed include super-efficiency DEA. The results show that: 1) the overall land use efficiency of Wuhan city in 2010-2016 is relatively high, most of the regional land use efficiency is relatively effective, but the difference of land use efficiency is relatively large, 2) super-efficiency DEA model can effectively measure and distinguish the urban land use efficiency from the quantitative point of view.

1. Introduction

There are some general problems, such as rapid expansion of city scale, quick decrease of arable land, unreasonable structure of land use and low use efficiency and so on. The research and analysis on the influencing factors of urban land use has important practical significance on realizing frugal and intensive utilization of land and improving the efficiency of urban land use to promote the sustainable development of economic and social[1]. Land use efficiency refers to the ability to achieve the maximum economic output under a given amount of land input, or the ability to minimize the amount of land input under a given level of economic output. The urban land use efficiency studied in this chapter is defined as the urban production efficiency from the perspective of the input and output efficiency of urban land. It refers to the material output achieved and effective results achieved by the input and consumption of unit land[2].

At present, scholars actively engaged in the research of urban land use efficiency. They use different methods to study and innovate the index system of land use efficiency. David and Eligius[3] put forward using linear regression method to measure the land use efficiency. Mattthews and Buchan[4] put forward using computer to calculate urban land use comprehensive efficiency. In China, the evaluation method of urban land use efficiency has been developed continually and the research method has increasingly diversified, mainly including the principal component analysis (PCA)[5], fuzzy comprehensive evaluation method[6], analytic hierarchy process (AHP)[7], regression analysis[8] and data envelopment analysis (DEA)[9]. The previous evaluation method faces the limitation of weight setting and decision of functional relation between input and output[10]. However, DEA method does not need to determine the specific functional relation between input and output, and its unique advantage makes the DEA method widely applied in the evaluation of land use efficiency[11].

According to the literature, it can be seen that using DEA method to measure the urban land use...
efficiency is more scientific and reasonable. However, these studies have the deficiencies that existing research using the DEA method cannot distinguish and compare the efficiency difference further between the effective decision making units (efficiency value is 1).

In view of the shortage of the existing literature, Super-efficiency DEA model is put forward to measure and distinguish urban land use efficiency, the paper empirically analyzes land use efficiency of 13 districts in Wuhan, China during the period of 2010-2016.

2. Methods and index system

2.1. Super-efficiency DEA model

The Data Envelopment Analysis (DEA) was proposed in 1978 by the operational research experts of Charnes and Cooper. DEA is an evaluation method for efficiency which is developed on the basis of the concept of relative efficiency[12]. The DEA model only divides the decision making units into efficient and inefficient, so it can’t distinguish the efficiency difference among decision making units completely. Therefore, the Super-efficiency DEA is proposed[13]. The model is expressed as follows:

\[
\begin{align*}
\min & \quad \theta \\
\text{s.t} & \quad \sum_{k=1}^{n} X_k \lambda_k + s^- = \theta X_i \\
& \quad \sum_{k=1}^{n} Y_k \lambda_k - s^+ = Y_i \\
& \quad \lambda_k \geq 0, k = 1, 2, \cdots, n \\
& \quad s^- \geq 0, s^+ \geq 0
\end{align*}
\]

In the expression, \( \theta \) is the efficiency value of decision making unit. If \( \theta \geq 1 \), the decision making unit will be considered to be effective; otherwise, the decision making unit will be invalid.

2.2. The Index System

For the selection of indicators of inputs and outputs in DEA model, on the basis of existing literatures, considering the quantization of indicators, the characteristics of DEA model as a method of evaluating relative efficiency[9], the availability of data, and Cobb-Douglas function[14], the selected input indicators include the city’s land area, fixed asset funding that reflect the investment in urban construction, economic development and urban population density reflecting labor resources. About output indicators, most scholars choose local fiscal revenue, the added value of secondary industry, tertiary industry’s added value and gross domestic product (GDP) to reflect the land outputs. However, from the perspective of scientific analysis, the evaluation of urban land use efficiency should not only attach importance to economic benefits, but also should consider social and environmental benefits. Therefore, on the basis of continuing to use the above output indicators, urban per capital disposable income that reflects the social benefit is added to the output index system in this thesis.

3. Empirical analysis

3.1. Study area and data sources

Wuhan is located in the middle of Hubei province, China. It is the urban agglomeration which takes Wuhan as the center, which is composed of 13 districts of Jiangan, Jianghan, Qiaokou, Hanyang, Wuchang, Qingshan, Hongshan, Dongxihu, Hanan, Caidian, Jiangxia, Huangpi, and Xinzhou, with a total area of about 85.69×10²km²(Figure 1). By the end of 2017, the resident population of Wuhan was 10.89 million, and the annual GDP reached 1340 billion Yuan, accounting for 36.71% of the province’s total GDP. It is also an important economic development center in Hubei Province, and an important strategic fulcrum of “rise of central China”. Therefore, it is beneficial to select Wuhan to
analyze land use efficiency and the influencing factors and their influencing degree of urban land use efficiency. It can provide a reference for the government to make reasonable land use policy.

The land use efficiency of 13 districts in Wuhan from 2010 to 2016 is analyzed by using super-efficiency DEA. The quantitative data that is used in the paper comes from statistical yearbook in Wuhan, Hubei province from 2011 to 2017, web site statistical information of statistical bureau of Hubei province and districts.

3.2. The measure and analysis of land use efficiency in Wuhan

Taking the system composed of 13 districts in Wuhan as research objects, super-efficiency DEA model and EMS (Efficiency Measurement System, Version 1.3.0) software are used to calculate the land use super-efficiency value (SE) of every district in Wuhan from 2010 to 2016, for distinguishing the efficiency variance among different decision making units completely. The calculation is shown in Table 1.

| District | 2010 Value | Sorting | 2011 Value | Sorting | 2012 Value | Sorting | 2013 Value | Sorting | 2014 Value | Sorting | 2015 Value | Sorting | 2016 Value | Sorting |
|----------|------------|---------|------------|---------|------------|---------|------------|---------|------------|---------|------------|---------|------------|---------|
| Jiangan  | 1.075      | 9       | 1.056      | 10      | 1.067      | 10      | 1.419      | 8       | 1.411      | 7       | 1.431      | 9       |            |         |
| Jianghan | 2.466      | 5       | 2.419      | 4       | 2.418      | 2       | 2.564      | 3       | 2.559      | 4       | 2.607      | 4       |            |         |
| Qiaokou  | 0.935      | 11      | 0.872      | 12      | 0.885      | 13      | 0.882      | 12      | 0.827      | 13      | 0.992      | 12      |            |         |
| Hanyang  | 1.179      | 11      | 1.220      | 4       | 1.589      | 2       | 2.045      | 3       | 2.401      | 3       | 2.325      | 5       |            |         |
| Wuchang  | 0.918      | 12      | 1.088      | 3       | 1.101      | 9       | 1.291      | 6       | 1.285      | 7       | 2.167      | 6       |            |         |
| Qingshan | 2.645      | 3       | 2.442      | 4       | 1.982      | 9       | 1.800      | 5       | 1.752      | 4       | 2.239      | 4       | 2.317      |         |
| Hongshan | 2.793      | 3       | 2.227      | 5       | 2.285      | 5       | 2.307      | 5       | 2.345      | 4       | 2.492      | 6       | 2.667      | 4       |
| Dongxihu | 4.563      | 3       | 3.777      | 5       | 4.041      | 5       | 2.868      | 3       | 2.750      | 6       | 2.627      | 2       | 2.687      |         |
| Hannan   | 2.811      | 2       | 2.722      | 3       | 2.226      | 4       | 2.102      | 3       | 2.821      | 3       | 3.323      | 3       | 3.487      |         |
| Caidian  | 1.081      | 2       | 0.853      | 4       | 0.892      | 4       | 0.881      | 4       | 0.882      | 4       | 0.935      | 4       | 0.853      |         |
| Jiangxia | 2.390      | 8       | 1.743      | 12      | 1.645      | 12      | 1.519      | 12      | 1.511      | 12      | 1.331      | 12      | 1.450      |         |
| Huangpi  | 1.029      | 10      | 1.178      | 8       | 1.247      | 8       | 1.321      | 8       | 1.311      | 8       | 1.310      | 8       | 1.355      |         |
| Xinzhou  | 0.888      | 13      | 1.028      | 11      | 1.026      | 11      | 1.029      | 11      | 1.027      | 11      | 1.040      | 11      | 1.036      |         |
| AVG      | 1.906      |         | 1.740      |         | 1.722      |         | 1.632      |         | 1.734      |         | 1.828      |         | 1.952      |         |

The value and sorting of land use efficiency of 13 districts in Wuhan from 2010 to 2016 are shown in Table 1. By analyzing the super efficiency value of 13 districts in Wuhan, it is found that the effective districts are at least 10 every year, accounting for 76.9% of the sample, but the efficiency variance of effective districts is huge, with the gap reaching its previous peak, 3.534, in 2010. All these shows that the land use overall efficiency in Wuhan are high in the past seven years, but the efficiency between different districts is unbalanced.
The land use efficiency rankings of Dongxiu, Hongshan, Jiangan, and Hannan district are top among the 13 districts. This shows that the land use efficiency of the four districts is relatively high compared with other regions. Jiangan has maintained effective. Its efficiency ranking does not fluctuate from 2010 to 2013, and its land use efficiency has been at the edge of effective value, but its efficiency ranking rise since 2014. The land use efficiency ranking of Hannan in 2010-2014 has obvious fluctuations, the super efficiency value ranks second in 2010 and 2011, fourth in 2012, first in 2014-2016. The land use efficiency ranking of Qingshan shows the trend of falling down from 2010 to 2016. The land use efficiency ranking of Hanyang has shown increasing trend as a whole from 2010 to 2016.

Far City, such as Huangpi and Jiangxia, their land use efficiency ranking show the trend of falling down from 2010 to 2016. The ranking of Xinzhou does not change, and its land use efficiency keeps effective from 2011. Bottom of the ranking are Qiaokou and Caidian, their land use efficiency are invalid from 2011 to 2016.

From Table 1, it can be found that central urban area, such as Jiangan, Wuchang and Qiaokou, rank lowly in urban land use efficiency. However, the new development areas, such as Dongxiu, Hannan and Hongshan, have high efficiency. This may be due to the fact that the government has increased investment in the less developed areas, local economies develop rapidly and the land use efficiency is improved greatly in these areas. The ranking of far city area, such as Huangpi, Xinzhou and Caidian, are either very near or at the bottom, this is mainly due to the fact that these districts are far away from the central urban area, with no geographical advantage, less population mobility and less impetus for economic development.

4. Conclusions and Suggestions

The super-efficiency DEA model is proposed to calculate and distinguish land use efficiency. Using panel data of 13 districts in Wuhan from 2010 to 2016, an empirical analysis is conducted to analyze the land use efficiency of Wuhan. The following conclusions and discussions are obtained.

(1) The overall land use efficiency of Wuhan city in 2010-2016 is relatively high, most of the regional land use efficiency is relatively effective, but the difference of land use efficiency is relatively large. There is a positive correlation between urban land use efficiency and government development behavior, the urban land use efficiency of new development areas is obviously higher than old city districts. The government should recognize that government development behavior has a significant impact on urban land use efficiency, rationally allocates input factors and resources to improve urban land use efficiency according to the situation of each district.

(2) The super efficiency DEA model can measure and distinguish the efficiency value among different decision making units effectively. But, considering the influence of the comprehensiveness of selected evaluation index and completeness of data on the evaluation result, the research of this paper has some limitations that it cannot measure dynamic change trend of land use efficiency, and these will wait for further study in the future.

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References

[1] Lu, Z. (2017) Review on the research of urban land intensive use assessment. Scientific and Technological Management of Land and Resources, 26: 44-53.
[2] Li, L., Shen, C., Yu, Z.H. (2013) Evaluation of regional land use structure and efficiency based on spatial lorentz curve and dea -- a case study of heilongjiang province. Scientific and Technological Management of Land and Resources, 19: 68-73.
[3] David, M., Eligius, M.T. (2006) A framework to study nearly optimal solutions of linear
programming models developed for agricultural land use exploration. Ecological Modeling, 131: 65-77.

[4] Matthews, K.B., Buchan, K. (2006) Combining deliberative and computer-based methods for multi-objective land use planning. Agricultural Systems, 87: 18-37.

[5] Zhan, H.B. (2017) Evaluation on urban land intensive utilization of xiangyang city based on the principal component analysis. Journal of Anhui Agricultural Sciences, 33: 201-203.

[6] Han, S.C., Li, D., Xiong, J.H., Yi, S.P. (2016) Evaluation of urban land intensive use based on entropy weight-fuzzy comprehensive evaluation model: a case study of huizhou city, guangdong province. Scientific and Technological Management of Land and Resources, 33:86-92.

[7] Dong, Y.H., Zhong, D.S., Lu, X.L. (2016) Comparative study of the application of pca and ahp to the analysis and evaluation of the regional sustainable development. Journal of Safety and Environment, 16:359-365.

[8] Li, L., Li, X., Zhang, J.M. (2017) Impacts of traffic and land use on the environment in tianjin based on regression analysis. Journal of Hebei University of Technology(Social Sciences Edition, 31: 53-57.

[9] Xie, M.M., Li, X.X. (2015) Research on spatiotemporal evolution regulation of eco-efficiency of land utilization in jilin province based on data envelopment analysis. Bulletin of Soil and Water Conservation, 35: 225-230.

[10] Wu, D.W., Mao, H.Y. (2011) Assessment of urban land use efficiency in china. Economic Geography, 66: 1111-1121.

[11] Mehdì, T., Ali, E., Placido, M. (2017) A linear relational dea model to evaluate two-stage processes with shared inputs. Computational and Applied Mathematics, 36: 45-61.

[12] Cooper, W.W., Charnes, A.A. (1978) Measuring the efficiency of DMU. European Journal of Operational Research, 2: 429-444.

[13] Andersen, P., Petersen, N.C. (1993) A Procedure for ranking efficient units in data envelopment analysis. Management Science, 39: 1261-1264.

[14] Liang, J.Y., An, L. (2016) Research on Influencing factors of university innovation ability in guangdong based on cobb-douglas function. Science and Technology Management Research, 16: 85-89.