Spatial-Temporal Characteristics of Urbanization Efficiency in Coastal Cities of China

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Abstract. Taking the coastal cities in China as study case, this article used Super-SBM DEA and DEA Malmquist index models to analyse the urbanization efficiency, then use the Moran’s I to conclude the spatial cluster characteristics of the urbanization efficiency in coastal cities. The results show that: (1) The urbanization efficiency of coastal cities keeps increasing gradually, with the average value rising from 0.4920 in 2006 to 0.8262 in 2016. The cities with higher values locate mainly in the south of the Yangtze River, especially in Guangdong Province. (2) Technical level is the main reason that restricts the improvement of urbanization efficiency in coastal cities. On the contrary, scale efficiency and pure technology efficiency promote the improvement of urbanization efficiency. (3) There is an obvious positive agglomeration relationship in the urbanization efficiency of coastal cities, but this relationship becomes weaker in recent years. (4) The local Moran’s I of urbanization efficiency in coastal cities shows that: H-H cities are mainly located in the Pearl River Delta and Yangtze River Delta. L-L cities are mostly distributed in the north of the Yangtze River. L-H and H-L cities are scattered in each province and their spatial agglomeration is weaker.

1. Introduction

Since the reform and opening-up, China's urbanization level has been continuously improving. As the pioneer area of China's economic development, coastal cities have a higher urbanization rate, which has exceeded 60% in 2017. However, with the deepening of the resource exploitation, the resource and environment issues have become increasingly serious. To coordinate the development of resource, environment and urbanization, China has put forward the New-type Urbanization Plan, aiming at improving the urbanization efficiency.

China’s urbanization efficiency has attracted scholars’ attention since the 1980s, Charnes measured the urban economic efficiency of 28 cities in China in 1984, which verified the feasibility of DEA model in the measurement of urbanization efficiency [1]; Henderson calculated the process efficiency of urbanization, pointing out that inter-regional cooperation is a major factor to improve the efficiency of urbanization [2]. Chinese scholars started the empirical research on the urbanization efficiency since the 1990s, concentrating on the regional differences [3], dynamic evolution process [4] and influencing factors [5]. Existing studies found that: ① There are obvious regional differences in urbanization efficiency in China. The urbanization efficiency in the eastern region is much higher than...
that in the central, western and north-eastern regions [6]. Also, there is obvious spatial correlation between urbanization efficiency in Chinese cities [7]; ② There is significant dynamic change trend of urbanization efficiency in Chinese provinces and cities [8]. Recently, China has put up with relevant policies to balance the development of the eastern and western regions. As a result, the urbanization efficiency growth rate of the central and western regions has been higher than that of the eastern regions in recent years [9]; ③ The optimization of industrial structure, investment promotion, administrative promotion, infrastructure construction and land scale effect are reasons of fast urbanization development and the improvement of development efficiency in China [10]. Also, these factors are reasons to the differences of regional urbanization efficiency; ④ Most researchers used the mainstream efficiency measurement methods such as DEA, SFA and their improved models to evaluate the urbanization efficiency. As one strategic area for China's development, coastal urban cities have not yet been specially studied by scholars on the urbanization efficiency issue.

As a priority development area for urbanization construction, coastal cities have comparative advantages in resource adsorption, innovation, transportation and so on, thus making them leaders in China's overall economic and social development. Considering the problems such as greater pressure of resource, ecological problems, higher cost of factors and more intense market competition in coastal cities, it is quite urgent for these cities to improve the urbanization efficiency to optimize urban space use, energy resource utilization and improve the ecological environment. Based on this, we choose the 53 coastal cities (including Shanghai and Tianjin, two province-level municipalities; HK, Macao and Taipei are not included) as the research area, and used the cross-sectional data of 2006, 2011 and 2016 to summarize the spatial evolution and differentiation characteristics of urbanization efficiency, so as to provide a reference basis for local governments to carry out urbanization construction.

2. Indicators and Methods

2.1. Indicators

According to the definition of urbanization efficiency and existing researches, we choose the urban built-up area, urban fixed assets investment and non-agricultural population as the input indicators from the three aspects of land, capital and labour force. Since population urbanization, economic urbanization, social urbanization and ecological urbanization are four basic units of urbanization construction, we choose urbanization rate, non-agricultural output, total consumer goods, green coverage rate of urban built-up areas as output indicators. Data in this paper are collected from China Urban Statistical Yearbook (2007, 2012 and 2017). Partial missing data are interpolated according to the data of adjacent years.

2.2. Methods

2.2.1. Super-SBM DEA Model. To evaluate the efficiency of the k-th \((k = 1, 2, ..., K)\) DMU with \(M (i = 1, ..., M)\) input indicators and \(N (j = 1, ..., N)\) output indicators, we use the following function [11]:

\[
\min \delta = \frac{1}{M} \sum_{i=1}^{M} x_{i0} \left/ \sum_{j=1}^{N} y_{j0} \right.
\]

S.t.

\[
x \geq \sum_{k=1}^{K} x_{k} \cdot \lambda_{k}
\]

\[
y \leq \sum_{k=1}^{K} y_{k} \cdot \lambda_{k}
\]

\[
\overline{x} \geq x_{0} \text{ and } \overline{y} \leq y_{0}
\]
\[ \sum_{k=1}^{K} \lambda_k = 1 \]
\[
\bar{y} \geq 0, \lambda \geq 0
\]

The score of the efficiency will be:
\[
P\left(x_0, y_0\right) = \left\{ \left(\bar{x}, \bar{y}\right) \mid \bar{x} \geq \sum_{k=1}^{K} \lambda_k \cdot x_k, \bar{y} \leq \sum_{k=1}^{K} \lambda_k \cdot y_k, \bar{y} \geq 0, \lambda \geq 0 \right\}
\]

Based on the result we got to make the following improvement: \( P\left(x_0, y_0\right) = P\left(x_0, y_0\right) \cap \left\{ \bar{x} \geq x_0 \text{ and } \bar{y} \leq y_0 \right\} \)

where \( x_{ik}, y_{jk} \) are the amount of the \( i \)-th input and \( j \)-th output, \( \lambda_k \) is the weight of the \( k \)-th input indicator.

### 2.2.2. DEA-Malmquist Model

Compared with the traditional DEA model, DEA-Malmquist model is used to measure the dynamic characteristic of the efficiency among two neighboring periods. It was firstly created by Cave, who combined the Malmquist method and the DEA model. Based on the static results, we use the DEA-Malmquist to find the dynamic characteristic of the urbanization efficiency of coastal cities in China. So, the changing index of urbanization efficiency of coastal cities in China can be expressed as follow [12]:

\[
I(x', y', x'^{t+1}, y'^{t+1}) = \sqrt{D'_t(x', y') \cdot D'_t(x', y')^{VRS} \cdot D'_t(x'^{t+1}, y'^{t+1}) \cdot D'_t(x'^{t+1}, y'^{t+1})^{VRS}}
\]

where \( i \) implies the DMU, meaning the 53 coastal cities in this paper, \( t \) and \( t+1 \) implies two neighbouring periods, \( x \) and \( y \) implies the input and output indicators of the DMU. \( D'_t(x', y') \) implies the technical level of the \( t \)-th period, \( D'_t(x'^{t+1}, y'^{t+1}) \) implies the technical level of \( t+1 \)-th period under the technical condition of \( t \)-th period and the technical level of \( t \)-th period under the technical condition of \( t+1 \)-th period. \( VRS \) implies the variable return of scale. The changing index of the urbanization efficiency is the product of the changes of technical level, pure technical efficiency and scale efficiency, among which the product of pure technical efficiency change and scale efficiency change is technical effect. It means that the urbanization efficiency of coastal cities shows an increase trend when \( I > 1 \), and vice versa.

### 2.3. Spatial Autocorrelation

#### 2.3.1. Global Moran’s I

Global Moran’s I was created by Professor Luc to measure regional spatial correlation to evaluate whether the spatial distribution of geographical elements is clustering model, discrete model or random model according to the location and attributes of elements. The formula is as follow[13]:

\[
I(3) = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \sum_{i=1}^{n} (x_i - \bar{x})^2}
\]

Where \( I \) is a global autocorrelation index with a range of values [-1,1]. When \( I \) is positive, it represents positive spatial autocorrelation. Conversely, when \( I \) is negative, it represents negative spatial autocorrelation. The smaller the difference between absolute value of 1 and 0 is, the weaker
spatial correlation and the stronger spatial randomness are. \( x_i \) is the variable attribute value of spatial position \( i \), which is the urbanization efficiency in this paper; \( n \) is the number of observations, which is the number of coastal cities in this paper; \( W_{ij} \) is the spatial weight matrix, that is, the spatial weight of spatial location \( i \) and \( j \).

2.3.2. Local Moran’s I. Compared with Global Moran’s I, Local Moran’s I is used to evaluate the local heterogeneity of spatial autocorrelation. The formula of Local Moran's I is as follow:

\[
I_i = \frac{n \left( x_i - \bar{x} \right) \sum_{j=1}^{n} W_{ij} \left( x_j - \bar{x} \right)}{\sum_{j=1}^{n} (x_j - \bar{x})}
\]

Where \( I_i \) is the local autocorrelation index.

3. Result Analysis

3.1. Spatial-temporal Characteristics Analysis of Urbanization Efficiency in Coastal Cities
We used the Super-SBM DEA model to calculate the urbanization efficiency in coastal cities of China. The average values of all 53 cities in 2006, 2011 and 2016 are 0.4920, 0.5984 and 0.8262(Figure 1.), indicating that the average level of all coastal cities in these three years had not reached DEA-efficient. The scale and structure of input factors need to be improved in the process of urbanization in coastal cities of China in order to achieve a higher urbanization efficiency. From 2006 to 2016, DEA-efficient cities increased from 14 to 30, showing obvious growth trend during this period. Among the 53 cities, 45 cities showing an upward trend, accounting for 84.91\% of all observations. Beihai was the one with largest growth rate, increasing from 0.40 to 1.58. The urbanization efficiency of Shantou, Nantong, Zhoushan, Maoming, Sanya, Zhongshan, Dongguan and Yangjiang showed a downward trend, all of which decreased from the effective level of DEA in 2006 to the ineffective level.

Spatially, there are obvious differences of urbanization efficiency in coastal cities. Taking the Yangtze River as the demarcation line, the urbanization efficiency of the southern cites were obviously higher than those of the northern cities. In 2010, among the 14 DEA-efficient cities, Nantong was the only one located in the north of the Yangtze River. With the improvement of overall urbanization efficiency, more and more cities in the north of the Yangtze became DEA-efficient. There were 3 and 8 DEA-efficient cities in the northern part in 2011 and 2016, accounting for 18.75\% and 26.67\% of all DEA-efficient cities. Among these new DEA-efficient cities, most locate in Shandong Province, which benefits from the new urbanization plan implemented by Shandong Province Government in 2014. The urbanization construction objectives of “population urbanization, optimization of urbanization layout, promotion of urban comprehensive carrying capacity, and promotion of urban-rural integration” points out the direction for the new urbanization construction and promotes the urbanization efficiency. Among cities in the south of the Yangtze River, cities in Guangdong province always got the higher efficiency score. There were 5, 5 and 6 coastal cities in Guangdong Province were DEA-efficient in 2006,2011 and 2016. With the help of the Pearl River Delta urban agglomeration, Guangdong province has the comparative advantages in the construction of new urbanization. Besides, Guangdong had carried out series of measures to achieve the goal of building a society with ecological civilization, social harmony, cultural prosperity, habitable urban and rich life.
3.2. Dynamic Analysis of Urbanization Efficiency in Coastal Cities

We used the DEA-Malmquist model to analyze the dynamic trend of the urbanization efficiency of coastal cities, the results (Figure 2.) show that, among 2011 to 2016, the average value of total factor productivity index in coastal cities was 0.931, indicating that the urbanization efficiency decreased by 6.9%. Specifically, the average value of scale efficiency index was 1.056, increased by 5.6%; the technical level index was only 0.84, decreased by 16%, showing that the decrease of technical level is the main reason for the decrease of urbanization efficiency. There was obvious difference on the dynamic change trend of total factor productivity in coastal cities since the standard deviation was 0.3894. There were 24 cities with an upward trend of total factor productivity, accounting for 45.28% of the total cities. Fangchenggang was the one with the highest increase trend, with an increase index of 163.1%. Specifically, there were 28 cities with technical efficiency index more than 1, 8 cities with technical efficiency index equal to 1, and 17 cities with technical efficiency index less than 1. Among them, Fangchenggang had the highest increase in technical efficiency and Ningbo had the highest decline. As technical efficiency is obtained by multiplying pure technical efficiency and scale efficiency, we took a further analysis of the pure technical efficiency and scale efficiency. The results showed that there were 22 cities whose pure technical efficiency index exceed 1, 15 cities whose technical efficiency index equal to 1 and 16 cities whose technical efficiency index was less than 1, showing similar changing trend to the technical efficiency. The change of the scale efficiency was weaker than the overall technical efficiency, since there were 27 cities whose scale efficiency index was greater than 1, 11 cities whose scale efficiency index was equal to 1, and 15 cities whose scale efficiency was less than 1. Based on upon, we can tell that the change of technical efficiency was more caused by the change of pure technical efficiency level. Since technical level is another important factor in the changing of urbanization efficiency, we took the technical level analysis as well. The results showed that only 9 cities whose technical level index was greater than 1. Fangchenggang was the city with the highest improvement by 27.3%, on the contrary, Hangzhou was the city with the highest technological level reduction by 40.1%.
To find the spatial agglomeration characteristic of the urbanization efficiency in the coastal cities, we use the GeoDa software to calculate the global and local Moran’s I. The results (Table 1.) showed that the global Moran’s I values in all three years were positive, indicating that urbanization efficiency presents a certain trend of agglomeration. In 2006, Moran’s I equalled 0.200, and P value was significantly less than 0.1, indicating that urbanization efficiency of coastal cities was significantly positively spatial correlated. Dynamically, Moran’s I shows a downward trend, indicating that the agglomeration degree of urbanization efficiency has been weakened. In 2016, not only the Moran’s I index declined almost to 0, but also the P-value was significantly higher than 0.1, so it can be seen that the urbanization efficiency of coastal cities tended to be random in 2016.
Table 1. The Univariate Global Moran of Total Factor Efficiency for Urbanization of Coastal Cities in China

| Year | Global Moran’s I | Expected Index | Variance | P-value |
|------|------------------|----------------|----------|---------|
| 2006 | 0.200            | -0.019         | 0.013    | 0.029   |
| 2011 | 0.090            | -0.019         | 0.013    | 0.089   |
| 2016 | 0.001            | -0.019         | 0.013    | 0.407   |

In order to further analyze the spatial agglomeration characteristics of urbanization efficiency in coastal cities of China, we used the GeoDa software to calculate the Local Moran’s I in 2006, 2011 and 2016, and the LISA chart (Figure 3.) was generated to reveal the types of local spatial correlation of urbanization efficiency in coastal cities. In 2006, the amounts of H-H, L-H, L-L and H-L type cities were 10, 15, 21 and 7. Among them, H-H type cities were mainly located in the Pearl River Delta, L-H type cities were scattered in the southern coastal provinces of the Yangtze River, while the northern coastal cities of the Yangtze River were basically L-L type cities, and H-L type cities were scattered in the most coastal provinces. In 2011, the amounts of H-H, L-H, L-L and H-L type cities were 12, 14, 19 and 8. Compared with 2006, the regional distribution characteristics of different types of cities changed little. Only L-H type cities were more concentrated, locating mainly around the Yangtze River Delta and the Pearl River Delta. In 2016, the amount of H-H, L-H, L-L and H-L type cities were 15, 17, 8 and 13. Compared with 2006 and 2011, all types of cities were spatially dispersed. The H-H type cities were still mainly located in the south coastal regions of the Yangtze River. The L-H type cities were scattered in most coastal provinces. The L-L type cities were still mainly northern coastal cities, but the number of L-L type cities obviously reduced. In summary, L-L type coastal cities are concentrated in the north of the Yangtze River. The geographical concentration of H-L type coastal cities is the lowest among all four types cities. The geographical distribution of H-H and L-H types cities varies greatly.

Figure 3. The Univariate Local Moran Scatter of Total Factor Efficiency for Urbanization of Coastal Cities in China

4. Conclusions
This paper analyses the spatial-temporal characteristics of urbanization efficiency of coastal cities in China in 2006, 2011 and 2016. The main conclusions are as follow:

①With more and more cities reaching DEA efficiency, the urbanization efficiency of China's coastal cities has an obvious growth trend, however, it still needs to be further improved. There is significant spatial differences of the urbanization efficiency among coastal cities, since the cities in the south of the Yangtze River are more urbanized than that of northern cities. Among the north region, cities in Shandong Province have a higher urbanization efficiency, and correspondingly, cities in Guangdong Province have a higher urbanization efficiency among all southern coastal cities.
The DEA-Malmquist index shows that the average of total factor productivity index of urbanization in coastal cities in China is less than 1, implying that the average of total factor productivity has decreased. Decomposition efficiency shows that the decline of technical level is the reason behind the decrease of total factor productivity efficiency. On the contrary, the pure technical efficiency and scale efficiency index are greater than 1, showing an increasing trend, indicating that pure technical efficiency and scale efficiency both improved the total factor productivity efficiency. To conclude, technical level has become the main reason that restricts the improvement of urbanization efficiency.

The global Moran’s I shows that the urbanization efficiency of China's coastal cities are positively agglomerated, but this relationship tends to be quite weaker in 2016; the local Moran’s I shows that the spatial characteristics of four types of cities are as follow: L-L-type cities are mostly located in the north of the Yangtze River, H-H type cities are mainly located in the Pearl River Delta and the Yangtze River Delta. The distribution of L-H and H-L cities are widely distributed in coastal cities without obvious agglomeration characteristics.

In this paper, we measured the urbanization efficiency of coastal cities and found that although the urbanization rate of coastal cities has reached a quite high level, optimizing the structure of resource allocation and upgrading the technical level are still important works to improve the urbanization efficiency. Since coastal cities are the pioneers of China's economic and urbanization development, it can be seen that technical innovation and adjustment of input structure are essential works to improve the urbanization efficiency in China. By Summarizing the temporal and spatial characteristics of urbanization efficiency of coastal cities, we found that there are obvious differences in urbanization efficiency between the north and the south. As coastal cities with similarities in factor endowments, we can see that the difference of regional development policies may be the potential cause of urbanization efficiency. Therefore, how to draw lessons from high-efficiency urbanization cities to achieve overall high efficiency urbanization is worth to be further studied.

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