Fenjie Long · Sheng Zheng · Yuzhe Wu ·
Gangying Yang · Yan Yang *Editors*

Proceedings of the 23rd International Symposium on Advancement of Construction Management and Real Estate

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Contents

How Efficient is the Urbanization Process in China?

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Abstract. China has been witnessing an unprecedented urbanization process since the implementation of reform and opening policy in 1980s. And the blueprint of Chinese urbanization program will continue for the coming future. Nevertheless, the rapid urbanization progress in China has been consuming vast amount of resources, and the conflicts between limited resources and rapid urbanization development has become much more intensified. It is therefore essential to pursue and improve efficiency during the urbanization construction in order to save resources and achieve urbanization sustainability. This study investigates the efficiency of Chinese urbanization construction by employing "I-O" (input-output) indicators with considering not only desirable output also the undesirable outputs of urbanization construction. The Super-efficiency SBM (Slack-based Measure) model is adopted for conducting the analysis, and the research data are collected from 30 Chinese provinces during 2008–2015. The analysis results tell that the average performance of urbanization efficiency at national level in China is relatively low, though an improvement has been achieved during this surveyed period (2008–2015). There is significant variation between top performers and bottom players, and the results suggest that those socially and economically advanced provinces are found to be more efficient in the process of urbanization construction. It is also discovered that East China is much more advanced on the efficiency performance during the urbanization process, however Southwest region presents the lowest urbanization efficiency performance during the time period of 2008–2015.

Keywords: Urbanization efficiency · "I-O" (Input-output) dimensional indicators · Desirable and undesirable output · Super efficiency-SBM model · China

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1 Introduction

Urbanization epitomizes the development of human society and is an important social process in developing countries. And this is particularly the case in China [1, 2]. Since early 1980s, China has witnessed a dramatic and unprecedented urbanization process, the national urbanization level increased from 17% to 58% during the year 1978–2017, with an average increase rate of more than 1% annually [2]. Comparatively, the average annual increase rate of urbanization development worldwide is only less than 0.5% [3].

Whilst the urbanization progress in China has been consuming huge amount of resources, for example, water, timber, coal, other natural resources and labor forces [4]. For example, it is reported that more than 400 Chines cities are facing the problem of water shortage, and among these cities, more than 200 are under severe shortage or water resources, which jeopardizes the urbanization development in these cities [4, 5]. However, resources particularly those non-renewable resources are of limitation, especially for the country such as China which carries on large scale of population.

The conflicts between limited resources and urbanization development in developing countries have been widely appreciated [4], this is particularly the case in large developing countries like China. With the aim of saving resources and achieving the sustainability of urbanization process, it is important to pursue and improve efficiency during the urbanization construction. Furthermore, a proper and adequate understanding about whether the resources are utilized efficiently is considered as a helpful approach not only for evaluating the quality of urbanization development but also for assessing the level of resource waste during urbanization construction process.

Urbanization can be appreciated as a complex "input-output" systematic development process, and the efficiency of urbanization process can be assessed by examining and comparing the benefits or outputs to the resources consumed (inputs) [6]. An urbanization process with high efficiency is defined that the process generates more benefits whilst consumes less resources. Different types of economic development mode and different industrial structures will lead to different urbanization efficiency performance [7]. By evaluating scientifically the urbanization efficiency of individual provinces and regions, the experience from top performers and the lessons from bottom players can be mined and shared, which can further enable the efficiency improvement across the whole country of China. And the urbanization efficiency improvement can also provide valuable references for the efficiency upgrading in other developing countries worldwide.

Based on the above information, this study aims to examine holistically and properly the efficiency of current urbanization construction in China, and analyze the experiences and lesson in terms of efficiency performance from different provinces and regions during its urbanization practice. Measures for improving urbanization efficiency will also be investigated to promote the sustainable urbanization development.

2 Research Method

Super-efficiency SBM (Slack-based Measure) model is employed in this study to investigate the efficiency performance of urbanization construction process in China. Based on the studies of Tone and Li et al. [8–11]. The applying procedures of Super-efficiency SBM model (with incorporating not only desirable outputs also undesirable outputs) are presented as follows.

Assume that an urbanization development system owns n independent and homogeneous decision-making units (DMUs). And each DMU includes three elements, namely, consuming m types of inputs, generating s_1 types of desirable outputs, and producing s_2 types of undesirable outputs (such as pollutant discharge).

The above explanation of parameters is accordingly denoted in details by three independent vectors, namely, vector of input elements, $x \in R^m$; vector of desirable output, $y^d \in R^{s_1}$; and undesirable output vector, $y^{ud} \in R^{s_2}$.

As assumed above, there are n independent and homogeneous DMUs in an system of urbanization construction, then three matrices: X, Y^d and Y^{ud} can be obtained:

$$X = [x_1, x_2, \ldots, x_n] \in R^{m \times n},$$

$$Y^d = \left[y_1^d, y_2^d, \ldots, y_n^d\right] \in R^{s_1 \times n},$$

$$Y^{ud} = \left[y_1^{ud}, y_2^{ud}, \ldots, y_n^{ud}\right] \in R^{s_2 \times n},$$

In line with the establish of above three vectors, a production possibility set (P) is then described by the Eq. (1) below:

$$\mathrm{P} = \left\{\left(x, y^d, y^{ud}\right) | x \geq \mathrm{X}\lambda, y^d \leq \mathrm{Y}^d \lambda, y^{ud} \geq Y^{ud}\lambda\right\} \tag{1}$$

In Eq. (1), λ is the non-negative intensity vector, indicating that above Eq. (1) is under the condition of constant returns to scale (CRS). And the inequality "$x \geq \mathrm{X}\lambda$" indicates that the actual level of input elements in the urbanization practice is greater than the input level of production frontier. $y^d \leq \mathrm{Y}^d \lambda$ indicates that actual level of desirable output elements is below the desirable output level of production frontier. And $y^{ud} \geq Y^{ud}\lambda$ indicates that the actual level of undesirable output elements is greater than the undesirable output level of production frontier.

A DMU to be measured is denoted as $\left(x_0, y_0^d, y_0^{ud}\right)$, its efficiency to be measured by the Slack-based Measure (SBM) model is described by using the Eq. (2):

$$\rho = \min \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_i^-}{x_{i0}}}{1 + \frac{1}{s_1 + s_2}\left(\sum_{r=1}^{s_1} \frac{s_r^d}{y_{r0}^d} + \sum_{r=1}^{s_2} \frac{s_r^{ud}}{y_{r0}^{ud}}\right)}$$

$$\text{Subject to}\begin{cases} x_0 = X\lambda + S^- \\ y_0^d = Y^d\lambda - S^d \\ y_0^{ud} = Y^{ud}\lambda + S^{ud} \\ S^- \geq 0, S^d \geq 0, S^{ud} \geq 0, \lambda \geq 0 \end{cases} \tag{2}$$

Where S^- means the redundancy of inputs, S^d refers to the desirable outputs shortage, S^{ud} refers to the undesirable outputs shortage, $\mathrm{S} = (S^-, S^d, S^{ud})$ is called slacks. The efficiency ρ assumes the values in the range $[0, 1]$. Only if $\rho = 1$, and $S^- = 0, S^d = 0, S^{ud} = 0$, then the urbanization construction process of DMU (x_0, y_0^d, y_0^{ud}) is appreciated as SBM-efficient. However, if the efficiency value $\rho < 1$, then the urbanization construction of DMU (x_0, y_0^d, y_0^{ud}) is considered not efficient [8, 10].

In most conditions of the efficiency analysis, when the amount of DMU become large, it happens that the ρ value of some DMUs becomes 1 at the same time, then it will be difficult to further distinguish DMUs by its SBM-efficiency value ρ, which is obtained by model (2). Thus, in order to further discriminate and rank the DMUs according to their efficiency values, the Super-efficiency SBM model is used as follows.

Then, we assume that the DMU (x_0, y_0^d, y_0^{ud}) is efficient according to Slack-based Measurement (SBM) model, i.e. $\rho = 1$ by employing the Eq. (2). Under this circumstance, to further discriminate the DMU (x_0, y_0^d, y_0^{ud}) with other SBM-efficient DMUs and rank the DMU (x_0, y_0^d, y_0^{ud}) by a specific efficiency value, which may be larger than 1, a production possibility set $\mathrm{P} \backslash (x_0, y_0^d, y_0^{ud})$ is defined, spanned by $(\mathrm{X}, Y^d, Y^{ud})$ excluding (x_0, y_0^d, y_0^{ud}), and this production possibility set is described in the following Eq. (3).

$$\mathrm{P} \backslash (x_0, y_0^d, y_0^{ud}) = \{(\bar{x}, \bar{y}^d, \bar{y}^{ud}) | \bar{x} \geq \sum\nolimits_{j=1,\neq 0}^{n} \lambda_j x_j, \bar{y}^d \leq \sum\nolimits_{j=1,\neq 0}^{n} \lambda_j y_j^d, \bar{y}^{ud} \geq \sum\nolimits_{j=1,\neq 0}^{n} \lambda_j y_j^{ud}, \bar{y}^d \geq 0, \lambda \geq 0\} \tag{3}$$

Then the efficiency performance value of the concerned DMU (x_0, y_0^d, y_0^{ud}), measured by Super-SBM model, which can be larger than 1, denoted as ρ^*, is measured by the following Eq. (4):

$$\rho^* = min \frac{\frac{1}{m}\sum_{i=1}^{m} \frac{\bar{x}_i}{x_{i0}}}{\frac{1}{s_1 + s_2}\left(\sum_{r=1}^{s_1} \frac{\bar{y}_r^d}{y_{r0}^d} + \sum_{r=1}^{s_2} \frac{\bar{y}_r^{ud}}{y_{ro}^{ud}}\right)}$$

$$\text{Subject to}\begin{cases} \bar{x} \geq \sum_{j=1,\neq 0}^{n} \lambda_j x_j \\ \bar{y}^d \leq \sum_{j=1,\neq 0}^{n} \lambda_j y_j^d \\ \bar{y}^{ud} \geq \sum_{j=1,\neq 0}^{n} \lambda_j y_j^{ud} \\ \bar{x} \geq x_0, \bar{y}^d \leq y_0^d, \bar{y}^{ud} \geq y_0^{ud}, \bar{y}^d \geq 0, \lambda \geq 0 \end{cases} \tag{4}$$

3 Research Data

This paper investigates the urbanization efficiency of 30 provinces in Mainland China during the time period of 2008–2015, Tibet is excluded from the surveyed provinces because of the data unavailability.

3.1 Establish of Input-Output Dimensional Indicators

In order to employ the method established in Sect. 2 of this study, and measure properly the urbanization efficiency performance of 30 Chinese provinces during the time period of 2008–2015, the inputs and outputs of urbanization construction process should be comprehended and identified. By incorporating previous studies, this study establishes the input-output elements of urbanization construction system, as presented in Fig. 1. The inputs of urbanization construction system include capital, land, labor, water resource and energy. The outputs of urbanization construction system include both desirable outputs and undesirable outputs, for which desirable outputs include population aggregation, economic growth, urbanization habitation, urban living quality, urban landscaping and urban-rural integration, and undesirable outputs include greenhouse gas emission and water pollution.

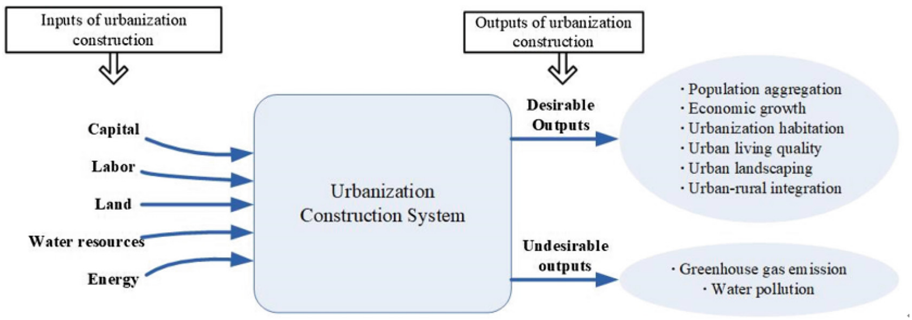

Fig. 1. The input-output elements of urbanization construction system

In line with the established “input-output” elements of urbanization construction in Fig. 1, and in referring to existing literatures, the specific indicators for measuring urbanization inputs and outputs elements are determined.

Table 1 shows the input indicators of urbanization construction process: Urban total investment in fixed assets (I_1) for measuring the capital level [12–15]; number of urban employed persons (I_2) for the labor level [15–18]; urban construction land area (I_3) for measuring the consumption of land [17, 19]; total water consumption (I_4) for measuring the water resources consumed [20–24]; and total energy consumption (I_5) for measuring the energy invested in the urbanization construction process [21, 25, 26].

Table 1. Indicators for measuring the input elements of urbanization construction system

Input indicator	
Elements	Measuring indicator
Capital	Urban total investment in fixed assets *(I_1)*
Labor	Urban employed persons *(I_2)*
Land	Urban construction land area *(I_3)*
Water	Total water consumption *(I_4)*
energy	Total energy consymption *(I_5)*

Table 2 further presents the output indicators of urbanization construction system:

Table 2. Indicators for measuring the output dimensions in urbanization process

Output indicator		
Type of outputs	Dimension	Indicator
Desirabel outputs	• Population aggregation	Urbanization rate *(O_1)*
	• Economic increment	Non-agricultural GDP *(O_2)*
	• Urbanization habitation	Urban built-up area *(O_3)*
	• Urban living quality	Total retail sales of social consumer goods *(O_4)*
	• Urban landscaping	Green coverage in built-up area *(O_5)*
	• Urban-rural integration	Income ratio of rural to urban residents *(O_6)*
Undesirable outputs	• Greenhouse gas emission	CO_2 emission *(O_7)*
	• Water pollution	Discharge of wastewater *(O_8)*

The desirable output of population aggregation is assessed by the indicator O_1 (urbanization rate) [27, 28], economic increment is assessed by the indicator O_2 (non-agricultural) [12, 27, 29], urbanization habitation is measured by the indicator O_3 (urban built-up area) [30, 31], urban living quality is measured by the indicator O_4 (total urban retails sales of social consumer goods) [32–34], urban landscaping is measured by the indicator O_5 (green coverage in urban built-up area) [35, 36], and urban-rural integration is measured by the indicator O_6 (income ratio of rural- urban residents [30, 31].

In terms of those undesirable outputs of the urbanization construction process defined in Fig. 1, greenhouse gases emission and water pollution are two most significant undesirable output brought in the urbanization construction process. Accordingly, indicator O_7 (CO_2 emission) is used to assess the emission level of greenhouse gases, indicator O_8 (discharge of wastewater) is used to assess the level of water pollution [37, 38].

3.2 Data Processing

In referring to the established input-output indicators listed in above Table 1 and Table 2, the indicator data of 30 surveyed Chinese provinces during the time period of 2008–2015 are collected respectively from various official statistical publications, including China Statistical Yearbook (2009–2016) and China Energy Statistical Yearbook (2009–2016). Furthermore, in order to ensure the accuracy of analysis result, the monetary variables are converted into the constant prices in the year 2007. Specifically, variable I_1 is deflated with the price index of investment in fixed assets, variable O_2 is deflated with GDP deflators, and variable O_4 is deflated with consumer price index (CPI).

In terms of the indicator O_7 (CO_2 emissions), there is no official statistical publication about the carbon emission at provincial level in China. With this background, in referring to previous study, this research uses the calculation guideline of CO_2 emission published by the IPCC (Intergovernmental Panel on Climate Change) [39]. Thus, carbon emission can be calculated by using the Eq. (5) as follows.

$$EC_t = 44/12 \times \sum\nolimits_{i=1}^{n} E_t^i \times LCV_i \times CF_i \times O_i \tag{5}$$

Where EC_t refers the total carbon emissions for an individual province from the consumption of n types of fossil fuel in year t. In this study, 8 types of fossil fuel are concerned, namely, natural gas, raw coal, kerosene, fuel oil, gasoline, rude oil, liquefied petroleum gases and diesel oil. And number (44/12) in Eq. (5) indicates the ratio of molecular weight of CO_2 (44) to the molecular weight of carbon (12). And E_t^i denotes the total consumption amount of fossil fuel i in the year t, LCV_i refers the lower calorific value of the concerned fuel i, CF_i indicates the carbon emission factor of the concerned fossil fuel i, and O_i refers to the oxidation rate of the carbonaceous fuel i.

And the above coefficient values of eight types of fossil fuels in China can be obtained from official guideline [40]. Thus the indicator data of O_7 of 30 surveyed Chinese provinces during the year 2008–2015 can be calculated accordingly.

4 Data Analysis

In line with the research method established in Sect. 2, by employing the empirical research data processed in Sect. 3, the performance value of urbanization efficiency in 30 surveyed Chinese provinces during the year 2008–2015 can be obtained, as shown below in the Table 3.

Table 3. The analysis results of urbanization efficiency (ρ^*)

Surveyed Provinces	2008	2009	2010	2011	2012	2013	2014	2015	Average	Rank of average value
Beijing	1.1641	1.1774	1.1791	1.1901	1.1993	1.2006	1.2043	1.1922	1.1884	4
Tianjin	1.2803	1.2686	1.2950	1.2809	1.2436	1.2648	1.2707	1.2818	1.2732	2
Hebei	1.0032	1.0034	1.0031	0.6669	0.5962	1.0082	1.0106	1.0087	0.9125	17
Shanxi	1.0021	0.5259	0.5819	1.0013	0.6017	0.5693	0.5361	0.5422	0.6701	21
Inner Mongolia	1.0202	1.0202	1.0148	1.0345	1.0482	1.0474	1.0375	1.0377	1.0326	9
Liaoning	1.0015	1.0029	1.0104	1.0122	1.0134	1.0095	1.0053	1.0082	1.0079	16
Jilin	1.0208	1.0215	1.0243	1.0407	1.0429	1.0357	1.0345	1.0406	1.0326	8
Heilongjiang	1.0332	1.0347	1.0325	1.0208	1.0192	1.0315	1.0348	1.0322	1.0299	10
Shanghai	1.0228	1.0225	1.0235	1.0193	1.0142	1.0172	1.0152	1.0160	1.0188	13
Jiangsu	1.0264	1.0408	1.0364	1.0485	1.0576	1.0089	1.0157	1.0482	1.0353	7
Zhejiang	1.0159	1.0185	1.0186	1.0172	1.0142	1.0091	1.0105	1.0197	1.0155	14
Anhui	0.6236	0.5781	0.5949	0.6055	0.5601	0.5060	0.5018	0.5234	0.5617	24
Fujian	1.0508	1.0452	1.0266	1.0197	1.0110	1.0130	1.0212	1.0042	1.0240	11
Jiangxi	0.6442	0.6805	0.6548	0.6354	0.5839	0.5205	0.4883	0.6295	0.6046	22
Shandong	1.0128	1.0106	1.0087	1.0241	1.0244	1.0284	1.0296	1.0290	1.0209	12
Henan	0.6408	1.0007	0.4381	0.4019	0.3778	0.4022	0.4867	0.5105	0.5323	25
Hubei	0.5673	1.0008	0.5323	0.5240	0.5947	1.0033	1.0014	1.0001	0.7780	19
Hunan	0.5250	0.4319	0.4658	0.4655	0.4759	0.5947	0.6786	1.0003	0.5797	23
Guangdong	1.1299	1.1320	1.1355	1.1388	1.1317	1.1213	1.1154	1.1117	1.1270	5
Guangxi	0.4480	0.5319	0.5820	0.5482	0.4367	0.4913	0.4847	0.5773	0.5125	27
Hainan	1.3835	1.3674	1.3490	1.3442	1.3481	1.3694	1.3646	1.3628	1.3611	1
Chongqing	0.6607	0.5715	0.6578	1.0011	1.0104	1.0065	1.0100	1.0128	0.8664	18
Sichuan	0.4851	0.5561	0.5002	0.4684	0.4672	0.3663	0.3678	0.4311	0.4553	29
Guizhou	0.4954	0.4528	0.4980	0.4994	0.4673	0.5881	0.4715	0.6030	0.5094	28
Yunnan	0.4269	0.3990	0.4381	0.3989	0.3987	0.5395	0.4008	0.5544	0.4445	30
Shannxi	0.5137	1.0002	1.0064	1.0173	1.0018	0.5345	0.5102	0.5277	0.7640	20
Gansu	1.0116	1.0108	1.0098	1.0056	1.0067	1.0072	1.0044	1.0093	1.0082	15
Qinghai	1.3099	1.1441	1.2162	1.2186	1.2223	1.1798	1.1574	1.2254	1.2092	3
Ningxia	1.0902	1.1024	1.1066	1.1164	1.1019	1.0913	1.0814	1.0803	1.0963	6
Xinjiang	0.5562	0.5707	0.5620	0.7198	0.4998	0.4620	0.4401	0.4248	0.5294	26
Annual average	0.8722	0.8908	0.8667	0.8828	0.8524	0.8676	0.8597	0.8948	0.8734	

5 Discussion

5.1 The Performance of Urbanization Efficiency at National Level in China

It can be seen from the analysis result in Table 3 that the urbanization efficiency performance is relatively low during the surveyed period (2008–2015) across the whole country in China, with the evidence that: For each surveyed year, the average urbanization efficiency performance of 30 provinces in China is less than 1, and this average value is only 0.8734 for the whole surveyed time period.

Furthermore, the information in Table 3 tells that in 2008, 18 surveyed provinces presented the performance of urbanization efficiency larger than 1, and this figure becomes 20 by the year 2015. This growth indicates that the efficiency performance in China has improved significantly during the surveyed time period.

In fact, this improvement of Chines national urbanization efficiency is attributed to multiple aspects, for example, the innovation of technology, which enables less carbon emission and wastewater pollution in line with the improvement of productivity. According to the empirical research data processed in Sect. 3 of this study, the annual increase rate of carbon emission at national level decreased significantly from 5.71% during 2008–2009 to only 0.97% during 2014–2015. And the annual increase of wastewater emission has also decreased from 3.05% (2008–2009) to 2.67% (2014–2015).

The analysis result information in Table 3 can also be presented by a graphical approach, as shown in the following Fig. 2. The figure indicates that the performance values of urbanization efficiency present significant variations between both provinces and the surveyed years. And those provinces in the East China region perform better efficiency during the urbanization construction process in the surveyed time period.

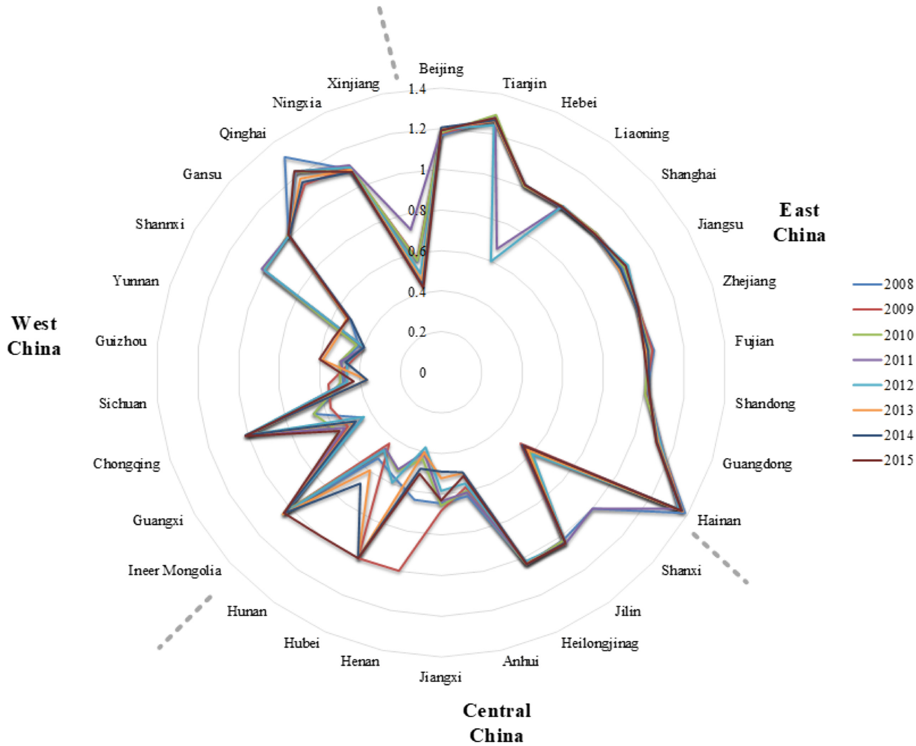

Fig. 2. Urbanization efficiency (ρ^*) between individual provinces in China during 2008–2015

And China can also be divided into eight economic zones in terms of economic performance perspective, including Northeast, North Coast, South Coast, East Coast, Middle Yangtze River, Middle Yellow River, Northwest and Southwest, which can be illustrated in Fig. 3.

Fig. 3. Geographic division of the eight economic regions in China

The analysis result in Table 3 can be further processed to show the average performance value of urbanization efficiency of above eight economic regions in China during surveyed time period. The regional urbanization efficiency performance is described in Fig. 4. The figure further indicates that South Coast region has performed best in terms of urbanization efficiency during surveyed time period (2008–2015). In fact, it is widely appreciated that this region has been devoting great efforts in many aspects to enhance the overall quality of the urbanization development. For example, it was widely reported that the provinces of Guangdong and Fujian, two typical provinces belong to the South Coast region, have been promoting the development of energy saving innovation during the Chinese Eleventh and Twelfth 5-year plans.

Figure 4 further tells that the development of urbanization in the regions of North Coast, East Coast and Northeast present relatively good efficiency during the surveyed period, evidenced by the average efficiency performance values of 1.10, 1.02 and 1.02. Nevertheless, the average urbanization efficiency performance in Southwest China is very poor during the surveyed period. Actually the lagged behind condition of urbanization development in Southwest China has also been echoed in previous studies [1, 7, 36], locating at interior China and being at a disadvantage by China's long term unbalanced development strategies which focus more on the development of East part of the country. Actually, in referring to the research data processed in Sect. 3, the energy consumption and the carbon emission per unit GDP in the Southwest China is much higher than the average level.

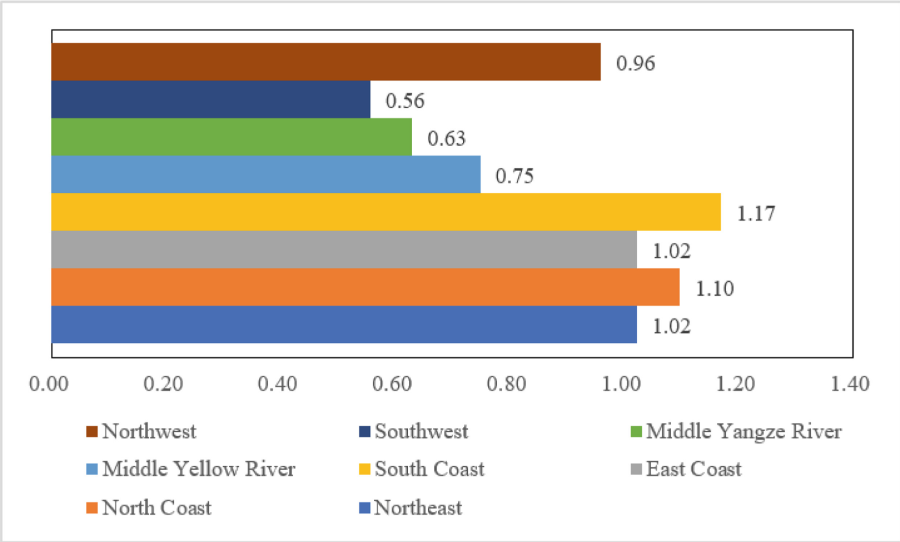

Fig. 4. Average urbanization efficiency performance of eight economic zones in China

5.2 Comparisons Between Provinces on Urbanization Efficiency Performance

Top Performers of Urbanization Efficiency in China. It can be seen from Table 3 that the top 5 urbanization efficiency performers include Hainan, Tianjin, Qinghai, Beijing and Guangdong. This section will take Guangdong as an example to investigate why it can achieve relatively high performance in terms of urbanization efficiency during surveyed period (2008–2015).

Guangdong ranked 5th in terms of the performance of urbanization efficiency during surveyed period (2008–2015). In fact, Guangdong has devoted great efforts in promoting energy conservation and improvement of resource utilization during its urbanization construction practice. For example, the implementation of “Green Building Action Implementation Plan”, and a series of policy instruments to conduct green building standards in the aspects of government investment, public rental housing, etc. Driven by the above policy forces, Guangdong has increased green building of more than 8100 10^4 square meters, and conducted the energy-saving renovation work towards more than 2050 10^4 square meters in the existing buildings. These measures have helped effectively reduce the undesirable outputs such as carbon mission and wastewater pollution during the urbanization construction process. According to the empirical data described in the Sect. 2 of this study, the annual increase of carbon emission in Guangdong has decreased significantly from 8.7% (2007–2008) to 3.5% (2014–2015).