Analysis on the Dynamic Evolution of Ecological Efficiency in the Yangtze River Economic Belt

Xueqiao Yao[1, a], Bo Liu[2, b]

[1]School of Economics and Management, Shanghai Maritime University, Shanghai 201306, China;

[2] Merchant Marine College, Shanghai Maritime University, Shanghai 201306, China.

[a]yaoxueqiao1995@126.com, [b]boliu68@foxmail.com

Abstract

Based on the panel data of the provinces and cities in the Yangtze River Economic Belt from 2006 to 2017, this paper selects the super-efficient SBM-DEA model as the evaluation method of ecological efficiency, and analyzes the regional differences and dynamic evolution characteristics in detail. The results show that: the eco-efficiency of the Yangtze River Economic Belt is at a medium level; as the year increases, the inter-provincial differences in the eco-efficiency of the Yangtze River Economic Belt show an increasing trend; the internal eco-efficiency of the Yangtze River Economic Belt increases with the year, the spatial imbalance has gradually expanded. Therefore, we should adhere to the path of factor resource conservation and sustainable development, thereby promoting the harmonious and sustainable development of the Yangtze River Economic Belt.

Keywords

Yangtze River Economic Belt, Ecological efficiency, Super SBM-DEA.

1. Introduction

The economic aggregate of the Yangtze River Economic Belt continues to rise, with key industries including home appliances, automobiles, electronic information, textiles and clothing, and the regional economic strength is growing stronger. However, along with the rapid economic development of the Yangtze River Economic Belt, the extensive development model of "first pollution after treatment" in the Yangtze River Economic Zone has caused serious problems such as serious air pollution in the Yangtze River Basin, limited environmental carrying capacity, and irrational watershed ecology [1].

Therefore, how to maintain the safety of ecological functions in the Yangtze River Basin, achieve high-speed economic growth and long-term sustainable development, and enhance the competitiveness of the Yangtze River Economic Belt is an urgent problem to be solved in the further development of the Yangtze River Economic Belt. Under the background of maintaining the coordinated development of economic benefits and environmental benefits, the research on ecological efficiency has practical significance.

The main problems to be solved in this paper are: (1) What is the current status of sustainable development of the Yangtze River Economic Belt, and whether the degree of economic and environmental development is compatible; (2) From the dynamic perspective, what are the laws governing the ecological efficiency of the Yangtze River Economic Belt, and what is the guiding significance of this development experience for future policy development?

Ecological efficiency was first proposed in 1990 by German scholars Schaltegger and Sturn [2]. Based on the concept of sustainable development, the environmental impact and economic benefits are combined for the first time. It is defined as the ratio of the added value of economic output to environmental impact based on quantitative analysis. In 1992, the World Business Council for Sustainable Development (WBCSD) defined eco-efficiency from a commercial perspective as " on the basis of meeting the needs of human life , keeping the intensity of environmental impact within the Earth's loadable range by increasing the price advantage of goods and services" [3]. In 1998, the Organization for Economic Co-operation and Development (OECD) extended the scope of eco-efficiency to the entire economic field, such as enterprises and economic entities, and defined it as "the efficiency of ecological resources to meet human needs" [4]. In 2001, based on the reduction of resource input, the European Environmental Agency (EEA) defined it as "creating more benefits with minimal input" [5].

It is concluded that different organizations and research scholars have different perspectives on ecological efficiency, but their cores are all around human needs, ecological load and green development. Therefore, based on the socio-economic-environment composite system, eco-efficiency can be seen as the maximization of regional economic benefits and resource utilization efficiency and the minimization of environmental load by effectively utilizing and rationally allocating various resources within the region. In short, eco-efficiency can be seen as an effective measure of regional sustainable and coordinated development.

2. Research Methods

2.1 Super Efficient SBM-DEA Model.

The Data Envelopment Analysis Method (DEA) is a nonparametric analysis method based on linear programming theory that evaluates the efficiency of similar decision-making units based on multiple input and output indicators. In recent years, this method has been widely used in the field of ecological efficiency evaluation. The super-efficiency DEA-SBM model introduces the super-efficiency theory, on the one hand, measures the undesired output phenomenon in production, and subtracts the non-efficiency part caused by the relaxation. On the other hand, further sorting between effective decision-making units improves the evaluation accuracy of the model. The specific expression is as follows:

$$p=\min \frac{1+\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ik}}}{1-\frac{1}{q_1+q_2}\left(\sum_{r=1}^{q_1}\frac{s_r^g}{y_{rk}^g}+\sum_{r=1}^{q_2}\frac{s_r^b}{y_{rk}^b}\right)} \tag{1}$$

$$s.t.\ \sum_{j=1,j\neq k}^{n} x_{ij}\lambda_j - s_j^- \le x_{ik} \tag{2}$$

$$\sum_{j=1,j\neq k}^{n} y_{rj}\lambda_j + s_r^g \ge y_{rk}^g \tag{3}$$

$$1-\frac{1}{q_1+q_2}\left(\sum_{r=1}^{q_1}\frac{s_r^g}{y_{rk}^g}+\sum_{r=1}^{q_1}\frac{s_r^b}{y_{rk}^b}\right)>0 \tag{4}$$

$$\lambda, s^-, s^g, s^b \ge 0 \tag{5}$$

$$i=1,2,\cdots,m; r=1,2,\cdots,q; j=1,2,\cdots,n\left(j\neq k\right) \tag{6}$$

In addition to the research results of the existing literature, this paper believes that the establishment of the ecological efficiency evaluation system of the Yangtze River Economic Belt should follow the connotation goal of the "N-E-S" composite ecosystem and ecological civilization construction. In the process of selecting indicators, it should be based on the principles of science, relevance, and comparability, and combine the reality and uniqueness of the regional development of the Yangtze River Economic Belt[6]. Based on the above principles, this paper builds an indicator system from both input and output, as shown in Table 1.

Table 1 Yangtze River Economic Belt Ecological Efficiency Evaluation Index System

index	category	Description
Input indicator	Resource consumption	Total energy consumption Construction land area Total water use Number of employees Total fixed assets investment in the whole society
	Expected output	Area GDP Total Discharge of Industrial Waste water
Output indicator		Total Emission of Industrial Smoke (Powder) Dust
	Unexpected output	Total Emissions of Industrial Sulfur Dioxide

2.2 Coefficient of Variation and the Tyre Index.

Based on the ecological efficiency of the Yangtze River Economic Belt, this paper uses the two statistical indicators of the coefficient of variation and the Theil index to analyze the regional differences in the eco-efficiency of the Yangtze River Economic Belt [7][8]. Firstly, the coefficient of variation is used to analyze the regional differences in the overall ecological efficiency. In order to further measure the degree of internal differences in the upper, middle and lower reaches of the Yangtze River Economic Belt, it is decomposed by the Theil Index. The coefficient of variation method mainly represents the discrete trend of the data by the ratio of the standard deviation σ and the mean $\overline{U}$, the calculation formula is as follows:

$$CV=\frac{\sigma}{\overline{U}}=\sqrt{\sum_{m=1}^{M}\frac{\left(U_m-\overline{U}\right)^2}{M}} \tag{7}$$

Among them, U_m is the regional ecological efficiency value, and M is the total number of regions.

The Theil index is mainly used to measure the inequality between regions. Theil (1967) uses the entropy concept in information theory to quantify through mathematical expressions. The expression is:

$$T=\frac{1}{n}\sum_{i=1}^{n}\frac{y_i}{\overline{y}}\ln\left(\frac{y_i}{\overline{y}}\right) \tag{8}$$

According to the expression of the Tyre index, the above formula can be used to measure the degree of difference in each region, and further measure the intra-group gaps and inter-group gaps in the Yangtze River Economic Belt and the contribution to the total gap [9].

$$T=T_b+T_w=\sum_{K=1}^{K}y_k\ln\left(\frac{y_k}{n_k/n}\right)+\sum_{K=1}^{K}y_k\left(\sum_{i\in g_k}\frac{y_i}{y_k}\ln\frac{y_i/y_k}{1/n_k}\right) \tag{9}$$

2.3 Nuclear density analysis.

The nuclear density analysis method is a non-parametric statistical method. The distribution of data points is directly smoothed by a kernel function to fit the probability distribution curve. The nuclear density analysis method sets a kernel function at each data point, and uses the kernel function to fit the probability density through the distance and the range of the kernel function itself, and the fitting order follows the near and small. The fitted data is then linearly superimposed and then normalized to form a kernel density probability function. Let any point X, the contribution rate of the known point X_i in the neighborhood to it depends on the distance from X to X_i and the range of values of the kernel function itself. The expression is as follows:

$$f_h = \frac{1}{n}\sum_{i=1}^{n} K_h(x - x_i) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right) \tag{10}$$

Among them, f(x) is the fitted kernel density estimation function, w is the bandwidth, and K(•) is the kernel function. This paper chooses to use the Epanechikov kernel function for correlation estimation[10].

3. Empirical Analysis

3.1 Comprehensive Efficiency Analysis.

Based on the variable returns of scale, using Maxdeaultra7.0 software, using the super-efficient SBM-DEA model, the input and output data of the 11 provinces and cities of the Yangtze River Economic Belt from 2006 to 2017 are calculated year by year, and the eco-efficiency values of each region are obtained, as shown in Table 2.

Table 2 Ecological efficiency values of various provinces and cities in the Yangtze River Economic Belt (2006-2017)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
GUIZHOU	0.396	1.013	1.013	1.024	1.032	0.349	0.316	0.330	0.308	0.299	0.236	0.215	0.544
SICHUAN	0.477	0.469	0.469	0.498	0.607	1.005	0.789	1.006	0.774	0.650	0.332	0.299	0.615
YUNAN	1.029	0.394	0.377	0.627	0.468	0.347	0.369	0.427	0.388	0.369	0.264	0.272	0.444
CHONGQING	0.475	0.467	0.474	0.497	0.549	1.011	1.037	1.029	1.022	1.023	0.474	0.459	0.710
JIANGXI	0.454	0.420	0.413	0.428	0.419	0.420	0.424	0.427	0.426	0.393	0.297	0.292	0.401
HUBEI	0.447	0.437	0.386	0.437	0.389	0.382	0.383	0.436	0.380	0.451	0.343	0.307	0.398
HUNAN	1.008	0.459	0.468	0.453	0.482	0.483	0.509	0.569	1.008	1.015	1.027	1.019	0.708
JIANGSU	1.017	1.002	1.006	1.018	1.021	1.018	1.019	1.026	1.027	1.025	0.644	1.000	0.985
ZHEJIANG	1.084	1.079	1.071	1.086	1.080	1.081	1.072	1.068	1.064	1.069	1.030	1.023	1.067
SHANGHAI	1.250	1.254	1.245	1.247	1.230	1.201	1.174	1.195	1.178	1.204	1.187	1.286	1.221
ANHUI	0.404	0.370	0.333	0.356	0.355	0.369	0.362	0.363	0.354	0.340	0.281	0.270	0.346
Average	0.731	0.669	0.660	0.697	0.694	0.697	0.678	0.716	0.721	0.713	0.556	0.586	-

As shown in Table 2, the average ecological efficiency of the Yangtze River Economic Belt fluctuated around the 0.6 level. After 2012, it showed a trend of rising first and then decreasing. The average value was 0.556 and the maximum was 0.731. Specifically, the overall eco-efficiency during the sample period showed a downward trend in the fluctuations. In 2012, the ecological efficiency of the provinces and cities in the Yangtze River Economic Belt has increased in different degrees. In conjunction with relevant policies, the 18th National Congress of the year has incorporated ecological civilization into the strategic layout of the socialist cause, and has made key plans for reforming the ecological civilization construction mechanism. All regions have actively responded to central policies and actively promoted ecological civilization. Construction. In 2016, the eco-efficiency of the Yangtze River Economic Belt showed a downward trend. The reason is that economic development has entered the "new normal" period and the "three-phase superposition" stage. The Yangtze River economic belt is in a period of weak economic growth, conversion growth momentum, and industrial structure optimization, resulting in a decline in the ecological efficiency of various provinces and cities. Overall, the eco-efficiency of the Yangtze River Economic Belt is at a low level and there is a downward trend in volatility. The degree of coordinated development of regional economic development and ecological environmental protection needs to be improved.

3.2 Regional Difference Analysis.

According to formula (7) and (8), the Thail index and coefficient of variation of the Yangtze River Economic Belt from 2006 to 2017 are calculated respectively. The results are shown in Figure 1.

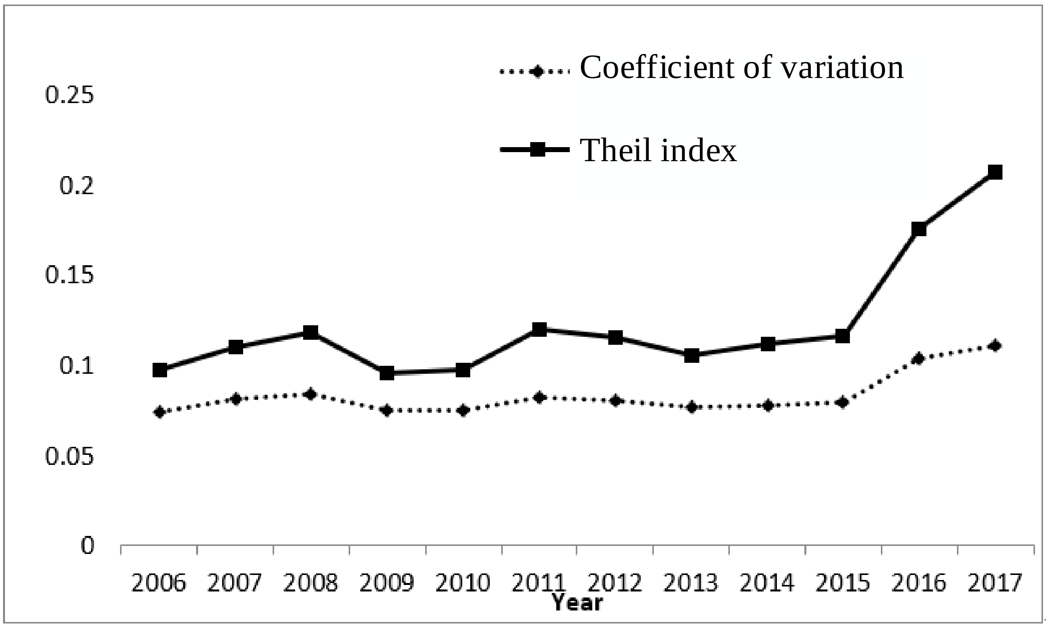

Fig. 1 Time trend graph of coefficient of variation and Theil index

As can be seen from Figure 1, the coefficient of variation for 2006-2015 is maintained at around 0.07.

It shows that the overall degree of ecological efficiency of the Yangtze River Economic Belt has remained stable during the period; The coefficient of variation for 2016-2017 has risen significantly, exceeding 0.1. It shows that the overall differentiation degree of ecological efficiency of these two Yangtze River economic belts shows an expanding trend.

In order to further reveal the composition of the relative differences in ecological efficiency in the Yangtze River Economic Belt, according to the decomposition formula of the Tyre Index (9), the Taier index and the decomposition index value of the eco-efficiency in 2006-2017 are calculated, as shown in Table 3.

Table 3 Regional Theil index and its decomposition results

years	Thai index	Upstream area		Midstream area		Downstream area		Three zones	
		Index	Contribution rate	Index	Contribution rate	Index	Contribution rate	Group gap	Contribution rate
2006	0.0973	0.0813	24.69%	0.0824	24.36%	0.0038	1.63%	0.0480	49.32%
2007	0.1096	0.0806	23.40%	0.0031	0.64%	0.0045	1.84%	0.0813	74.12%
2008	0.1178	0.0832	22.71%	0.0074	1.39%	0.0041	1.59%	0.0875	74.31%
2009	0.0957	0.0493	17.76%	0.0041	0.93%	0.0036	1.66%	0.0762	79.64%

2010	0.0974	0.0499	17.84%	0.0064	1.41%	0.0031	1.39%	0.0773	79.37%
2011	0.1200	0.1236	36.45%	0.0056	1.00%	0.0024	0.85%	0.0740	61.70%
2012	0.1152	0.1148	33.56%	0.0088	1.73%	0.0017	0.66%	0.0738	64.05%
2013	0.1058	0.1111	37.24%	0.0136	2.94%	0.0021	0.84%	0.0624	58.99%
2014	0.1116	0.1096	30.87%	0.1093	26.79%	0.0017	0.63%	0.0465	41.71%
2015	0.1165	0.1146	29.38%	0.1081	26.03%	0.0024	0.86%	0.0509	43.72%
2016	0.1752	0.0378	4.61%	0.1768	32.15%	0.0302	8.06%	0.0967	55.18%
2017	0.2072	0.0403	3.76%	0.1913	27.07%	0.0163	1.68%	0.1398	67.49%

In terms of differences between groups and groups, the differences between groups are the main factors for the regional differences in the Yangtze River Economic Belt. From the regional perspective, the degree of ecological efficiency in the downstream, midstream and upstream areas increases in turn, indicating that the ecological efficiency of the Yangtze River Economic Belt is caused. The core factor of regional disparity is the excessive difference in efficiency between upstream and downstream. From the inside of the region, in 2006-2017, the Tyre index of the provincial and municipal differences in the upstream region is the largest among the three regions. Therefore, the improvement of ecological efficiency should pay attention to the "polarization" problem of the provinces and cities within the upstream region. The relative differences between the provinces in the middle reaches are relatively small. The Tyre index has been at a low level since 2006-2012. After 2012, the difference has increased significantly, reaching a maximum of 0.1913 in 2017.

3.3 Dynamic Evolution Analysis.

Based on Eviews 8.0 software, the Epanechikov kernel function was used to estimate and map the nuclear density distributions for 2008, 2011, 2014 and 2017. As shown in Figure 2, the horizontal axis represents eco-efficiency and the vertical axis represents density.

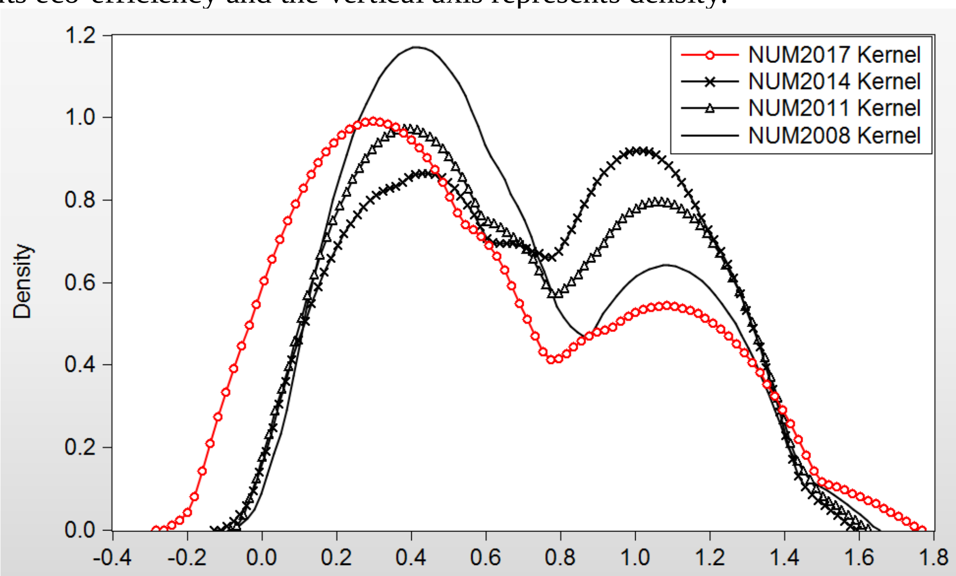

Fig. 2 Nuclear density estimation distribution graph

Firstly, in terms of the change of the position of the nuclear density distribution curve, the overall distribution of the nuclear density distribution curve in 2008-2017 is a trend of shifting slightly to the left after shifting to the right, which explains to some extent how the ecological efficiency of the Yangtze River Economic Belt changes with time. It is the first to degenerate and then degenerate.

Secondly, as far as the kurtosis of the curve is concerned, the trend of the distribution of the curve from 2008 to 2017 is mainly from the peak to the broad peak, indicating that the ecological efficiency of the Yangtze River Economic Belt increases with the degree of the year, and the spatial imbalance is gradually increased.

Thirdly, from the perspective of the shape of the curve, the ecological efficiency of the Yangtze River Economic Belt in the study interval maintains a bimodal trend. Some provinces and cities have concentrated on low-efficiency eco-efficiency, while other provinces have concentrated on high-efficiency values. It shows that there is significant spatial non-equilibrium in the distribution of ecological efficiency. Over time, the peaks of the clusters at low levels are significantly reduced, and the peaks of high-level aggregates increase year by year. By 2014, the height difference between the two peaks is significantly reduced. The distribution of ecological efficiency during the whole sample period generally maintained the characteristics of “low and low agglomeration, high agglomeration”, which approximated the phenomenon of “club convergence” [11].

4. Conclusions and Recommendations

Based on the above studies, the following conclusions can be drawn: (1) Overall, the average eco-efficiency of the 2006-2017 Yangtze River Economic Belt is 0.6765, which is at a medium level. The eco-efficiency showed a downward trend around the 0.6 level during the sample period, with an average of 0.556 and a maximum of 0.731. (2) From the perspective of regional differences, the inter-provincial differences between the eco-efficiencies of the Yangtze River Economic Belt show an increasing trend with the increase of years, and the differences between the groups in the upper, middle and lower reaches are greater than the differences within the group. The internal difference is upstream > midstream > downstream; (3) From the perspective of dynamic evolution, between 2006 and 2017, the internal ecological efficiency of the Yangtze River Economic Belt increases with the degree of year differentiation, and the spatial imbalance is gradually expanded. Moreover, some provinces and cities have a low level of ecological efficiency, while another part of the provinces and cities have a higher level of ecological efficiency, which tends to converge toward two different states.

Through the above empirical analysis and research, the following policy recommendations are proposed: (1) In terms of environmental policy, environmental policies should not be limited to administrative areas. Inter-regional and inter-departmental environmental pollution prevention and control linkage mechanisms should be established as soon as possible to build an integrated platform for ecological data sharing and real-time monitoring, thereby promoting the coordinated development of the Yangtze River; (2) In terms of industrial structure, the provinces and cities of the Yangtze River Economic Belt should gradually adjust and upgrade the industrial structure by combining their own location and resources; (3) In terms of technical level, a long-term mechanism based on financial research subsidies and innovation guarantees should be established. Secondly, we should formulate corresponding talent strategy policies, increase the cultivation of technical talents, and give full play to the backbone of talents in technological innovation.

References

[1] Li Qiang, Gao Nan. Research on the spatial and temporal evolution of ecological efficiency in the Yangtze River Economic Belt and its influencing factors[J]. Journal of Chongqing University: Social Sciences Edition, 2018, 24(3): 29-37.
[2] Schaltegger S, Sturm A. kologische Rationalitat [M].Die Unternehmung Nr4, 1990: 273-290.
[3] Stigson B. Eco-efficiency: Creating more value with less impact[R]. WBCSD, 200:5-36.
[4] Organization for Economic Cooperation and Development. Eco-efficiency[R].OECD,1998.
[5] European Environment Agency. Making Sustainability Accountable: Eco-efficiency, Resource Productivity and Innovation [M]. Copenhagen: EEA, 1999.
[6] Huang Heping, Wu Shi'an, Zhi Yingwei, et al. Dynamic Assessment of Resource and Environment Performance Based on Ecological Efficiency: A Case Study of Jiangxi Province[J]. Journal of Resource Science, 2010, 32(5): 924-931.
[7] Wang Lina. Analysis of Spatial and Temporal Differences and Influencing Factors of Ecological Efficiency in Liaoning Province[J]. Journal of Liaoning Normal University(Natural Science Edition).
[8] Liu Jun, Ma Yong, et al. Measurement of regional eco-efficiency in China from 2000 to 2014 and its spatial and temporal differences[J]. Journal of Eco-Environment, 2018, 27(3): 498-508.

[9] Liu Yue, Wang Keliang, Shi Lijuan, et al. Temporal and Spatial Differences, Factor Decomposition and Energy Saving and Emission Reduction Potential of China's Provincial Ecological Efficiency[J]. Journal of Anhui University of Science and Technology: Social Science Edition, 2018(2):29-37 .
[10] Liu Mingqi. Research on the dynamic evolution and influencing factors of environmental efficiency in the Pearl River Delta urban agglomeration [D]. South China University of Technology, 2018.
[11] Cheng Jinhua, Sun Qiong, Guo Mingjing, et al. Regional Differences and Dynamic Evolution of Ecological Efficiency in China[J]. China Population: Resources and Environment, 2014, 24(1): 47-54.