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Research on Regional Ecological Efficiency Based on AQI Index

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Abstract:
In this paper, we use DEA model to study the regional ecological efficiency of China in 2015. And measure the redundant input of provinces and cities without DEA effective. The results show that there are significant differences in eco efficiency among provinces.

Keywords: *Ecological efficiency, index of AQI, DEA*

1. Introduction

China's contemporary economic development has made tremendous achievements. The total GDP increased from 364.52 billion yuan in 1978 to 6855.58 billion yuan in 2015. However, China's economic growth is at the cost of the environment. For example, China's SO2 emissions increased from 2254,900 tons in 2004 to 1859,194.09 tons in 2015, an increase of 824. 4%; the total discharge of wastewater in China increased from 4824.94 million tons in 2004 to 7353226.83 tons in 2015, an increase of 152.4%; the output of industrial solid waste in China increased from 816.08 million tons in 2000 to 3229.54 million tons in 2014, an increase of 403.4%. Therefore, the development of ecological economy has become one of the major strategies of China's economic and social development, and how to evaluate the level of ecological economic development scientifically and quantitatively, and then analyze the way to achieve better development, has become a difficult problem in China's current ecological economic research.

There are three types of studies on the evaluation of ecological economy. One is the construction and comprehensive evaluation of the index system for evaluating the level of eco-economic development, such as Zhang Dongmei, Zhao Leilei (2011) and others pointed out in the study that the improved entropy method was used to determine the weight of the eco-economic comprehensive evaluation; Lu Yuling (2010) in her article analyzed the shortcomings and defects of the existing evaluation index system. Second, factor analysis is used to analyze the level of eco-economic development. For example, Yang Qing and Zhang Caicai (2015) set up corresponding index system from three dimensions of resource consumption, environmental pollution and economic development, and selected 12 years statistical data samples. The ecological and economic benefits of Shaanxi province were evaluated by factor analysis and input output method. Third, based on ecological efficiency, the DEA model is used to measure the level of ecological and economic development, such as Zhang Bing's (2008) evaluation of the ecological efficiency of Hangzhou Bay Fine Chemical Industrial Park enterprises; Yang Bin's (2009) research on regional ecological efficiency in China from a macro perspective; Deng Bo's (2011) use the three-stage DEA model to evaluate the regional ecological efficiency in China. Rate study. However, the existing literature on the study of ecological efficiency fails to take into account the air quality index. In 2015 and 2016, fog and haze seriously affect people's daily life, primary schools were forced to suspend classes, and Beijing had a three-day vacation in the worst fog and haze areas. This situation urgently requires scholars to add the fog and haze index to the eco-economic indicators. In the middle. Therefore, based on the relevant data of China in 2015, and on the basis of the index system of ecological efficiency evaluation proposed in the literature, this paper adds AQI index to the index system, and with the help of the basic DEA model, expects to describe the ecological efficiency of various provinces and cities in China more accurately; at the same time, it finds out the main factors affecting the ecological efficiency of China, and makes a textual research. Considering the relationship between AQI index and ecological efficiency, it can provide reliable basis for government decision-making.

2. Research Methods

2.1. Basic DEA Model

Data Envelopment Analysis (DEA) is a multi-input and multi-output analysis method, i.e. a systematic analysis method for evaluating the relative efficiency between factor inputs and outputs. The advantage of DEA is that it abandons the traditional subjective weighting method.

Suppose there is a decision-making unit to be evaluated, using m kinds of input factors (x_{ij} , $i = 1,...,n$； $j = 1,...,m$), production p kinds of output (y_{ir} , $i = 1,...,n$； $r = 1,..., p$),$y_{ir}(i = 1, \dots, n; r = 1, \dots, p)$And, $x_{ij} \ge 0$ $x_{ij} \geq 0$, $y_{ir} \ge 0$ $y_{ir} \geq 0$, There is a $h_i$corresponding relative efficiency evaluation index for all DMU_i:

$$h_i(u,v) = \frac{\sum_{r=1}^{p} u_r y_{ri}}{\sum_{j=1}^{m} v_j x_{ji}}$$

Among them, u_r represents the weight coefficient of the output of r , v_j represents the weight coefficient of the input of j.

CCR model is constructed with the efficiency index of the o decision unit as the objective and the efficiency index of all decision units as the constraint.

$$\max_{u,v} h_o(u,v) = \frac{\sum_{r=1}^{p} u_r y_{ro}}{\sum_{j=1}^{m} v_j x_{jo}}$$

$$s.t. \begin{cases} \dfrac{\sum_{r=1}^{p} u_r y_{ro}}{\sum_{j=1}^{m} v_j x_{jo}} \le 1 \\ u_r, v_j \ge 0; j = 1,...,m; r = 1,..., p; i = 1,...,n \end{cases} \qquad (1)$$

Transform the formula (1) into its dual form, as shown in formula (2):

$$\min_{\theta,\lambda} \theta$$

$$s.t. \begin{cases} \sum_{i=1}^{n} \lambda_i y_{ri} \ge y_{ro} \\ \theta_{xjo} - \sum_{i}^{n} \lambda_i x_{ji} \ge 0 \\ \lambda_i \ge 0; j = 1,...,m; r = 1,..., p; i = 1,...,n \end{cases} \qquad (2)$$

Formula (2) is the CCR model under the condition of "constant returns to scale". Among them, the value is the relative efficiency of the evaluated decision-making unit, whose value is between 0 and 1, which means that the decision-making unit DEA is valid when equal to 1, and that the decision-making unit is non-DEA valid when less than 1. By introducing restrictive conditions in the CCR model, the BCC model with variable scale returns can be constructed.

2.2. Super Efficiency DEA Model

When the basic DEA model calculates the efficiency value, there may be multiple effective decision-making units (that is, the efficiency value is 1), so it is difficult to make a further comparative analysis of the effective decision-making units. The super-efficiency model proposed by Andersen P&Petersen N C (1993) mainly considers the efficiency of DMUs relative to other DMUs. Compared with the basic DEA model, the reference set constructed by the super-efficiency model does not include the evaluated DMUs themselves, and the evaluation result (super-efficiency value) may be greater than 1, which can be effectively solved. The problem of comparison between decision units is discussed. The mathematical models of the super efficiency DEA model are as follows:

$$\min[\theta - \varepsilon(\sum_{j=1}^{m} s_j^- + \sum_{r=1}^{p} s_r^+)]$$

$$s.t. \begin{cases} \sum_{i=1, i\neq k}^{n} \lambda_i x_{ij} + s_j^- = \theta x_{jk} \\ \sum_{i=1, i\neq k}^{n} \lambda_i y_{ir} - s_r^+ = y_{rk} \\ s_j^- \geq 0; s_r^+ \geq 0; \lambda_i \geq 0 \\ j = 1,\ldots,m; r = 1,\ldots,p; i = 1,\ldots,n \end{cases} \quad (3)$$

In the formula (3), θ represents the relative efficiency under constant returns to scale, and ε represents Archimedes infinitesimal.

3. Evaluation Index System and Data Sources

3.1. Index Selection

Yang Qing selected environmental, resource and economic indicators to evaluate the ecological and economic benefits. According to the principles of scientific, relative completeness, relative independence, operability and dynamics, Liu Huabo selected indicators of economic development level, resource and energy utilization level, pollutant emission level, environmental management and other indicators to evaluate the development level of circular economy. Zhang Dongmei selected per capita GDP, sulphur dioxide emissions per unit GDP, population density and other indicators to evaluate the eco-economic comprehensive evaluation index system in Guizhou. Li Chongyong thinks that the evaluation index system of regional eco-economic system includes ecological environment subsystem, social economic evaluation subsystem and comprehensive evaluation index. Guo Li established a regional ecological efficiency evaluation index system, including the level of economic development, total energy consumption, water consumption, industrial waste gas emissions, industrial waste water emissions and other indicators.

According to the research findings and the availability of data, the input and output indicators are as follows. The output of ecological efficiency mainly reflects the economic value brought by resource input and environmental consumption. Therefore, when studying the output efficiency of macro-level regional economic entities, GDP is selected as the output index of efficiency evaluation. Input indicators include environmental pollution, resource consumption, capital investment and human resources input. Environmental pollution is an unexpected output in the calculation of ecological efficiency. In view of the fact that DEA model generally regards cost-based indicators as input indicators, and input indicators are generally regarded as the smaller the better, this paper treats environmental pollution as input indicators. In this paper, the current serious haze problem, so the air quality index (AQI) as an indicator of environmental pollution. Resource consumption is measured by the total inter-provincial energy consumption (10,000 tons of standard coal); capital input is measured by construction land (square kilometers) and total water consumption (100 million cubic meters); and human resource input is measured by the total number of employees (10,000 people) in each region.

The input and output items must conform to the "homotropy" hypothesis, that is, when the input increases, the output cannot be reduced, the commonly used method is to use Pearson correlation test method to detect it. The above inputs and outputs are tested by SPSS software, and the results are as follows. From table 1, we can see that the correlation coefficient between input variables and output variables is positive, which shows that the input-output index conforms to the "homotropy" principle required by the model and is reasonable.

Input Output	AQI	Energy Consumption	Land Input	Water Input	Human Input
GDP of province	0.175	0.949^{**}	0.953^{**}	0.54^{**}	0.96^{**}

Table 1: Pearson Correlation Coefficient of Input and Output Variables in 30 Provinces and Cities of China in 2015

3.2. Data Sources

The data in this paper come from China Science and Technology Statistics Yearbook, China Energy Statistics Yearbook, China Environmental Statistics Yearbook and China Environmental Monitoring Website. In view of the timeliness and completeness of the data, this study selected the data set of China Environmental Statistics and Statistical Yearbook 2015. The DMU selected by DEA method has the following characteristics: (1) All decision-making units must perform the same tasks and have similar goals. (2) operate under the same conditions. The input and output of all decision-making units must be the same, but the intensity or extent of the input and output items may be different.

4. Empirical Analysis

4.1. Efficiency Analysis of Regional Eco Efficiency Based on DEA Model

The DEA model was used to calculate the ecological efficiency of each province, and the DEAP 2.1 software was used to calculate the comprehensive ecological technology efficiency and its decomposition.

Province	Comprehensive Technical Efficiency	Pure Technical Efficiency	Scale Efficiency	Scale Reward
Beijing	1.000	1.000	1.000	-
Tianjin	1.000	1.000	1.000	-
Hebei	0.921	0.942	0.977	drs
Shanxi	0.631	0.638	0.989	irs
Neimeng	1.000	1.000	1.000	-
Liaoning	0.876	0.883	0.992	irs
Jilin	0.751	0.752	0.998	irs
Heilongjiang	0.640	0.680	0.940	irs
Shanghai	0.757	0.797	0.950	irs
Jiangsu	1.000	1.000	1.000	-
Zhejiang	1.000	1.000	1.000	-
Anhui	0.787	0.796	0.988	irs
Fujian	1.000	1.000	1.000	-
Jiangxi	0.708	0.740	0.957	irs
Shandong	1.000	1.000	1.000	-
Henan	0.861	0.911	0.945	drs
Hubei	0.828	0.838	0.988	drs
Hunan	1.000	1.000	1.000	-
Guangdong	1.000	1.000	1.000	-
Guangxi	0.792	0.848	0.935	irs
Hainan	0.629	1.000	0.629	irs
Chongqing	0.780	0.806	0.968	irs
Sichuan	0.807	0.811	0.996	irs
Guizhou	0.777	0.905	0.859	irs
Yunnan	0.741	0.813	0.912	irs
Shannxi	0.404	0.404	1.000	-
Gansu	0.470	0.501	0.938	irs
Qinghai	0.727	1.000	0.727	irs
Ningxia	0.666	0.940	0.709	irs
Xinjiang	0.499	0.504	0.990	irs

Table 2: Ecological Efficiency of Different Regions in 2015

The ecological efficiency level and scale reward status of 30 provinces and cities in China were analyzed by DEAP2.1 software. The results are shown in Table 2. From table 2, it can be seen that the average ecological comprehensive technical efficiency of each province and city in China in 2015 is 0.802, the average pure technical efficiency is 0.850, and the average scale efficiency is 0.946. Other provinces and municipalities have varying degrees of room for improvement in terms of pure technical efficiency and scale efficiency. This result shows that China's ecological efficiency is optimistic and needs further measures. According to previous studies, the value of ecological efficiency in China was 0.801 in 2002, 0.723 in 2005, 0.604 in 2008, and 0.802 in 2015. With the development and destruction of the environment, ecological efficiency has declined. In recent years, the government has taken a lot of measures to protect the environment and maintain the coordination of ecological civilization and economic development. Obviously, the results have been achieved and the ecological efficiency has been reversed. Years of research show that Beijing is always at the forefront of technological efficiency.

From the point of view of the pure technical efficiency and scale efficiency decomposed from the comprehensive technical efficiency, the main reason for the low ecological efficiency of the provinces which cannot reach the DEA efficiency is the restriction of pure technical efficiency. The scale efficiency of most provinces is above 0.9. Hebei, Henan, Hubei and other provinces show a decreasing trend of scale efficiency, which can properly reduce the economic scale, improve the coordination of economic development and the ecological efficiency of the province. The scale returns in Beijing, Tianjin, Inner Mongolia, Jiangsu, Zhejiang, Fujian, Shandong, Hunan, Guangdong and Shaanxi provinces remain unchanged. It shows that these provinces and municipalities have achieved optimization in the use of technology, can keep the scale efficiency unchanged, improve technology, and strive to change into a state of increasing scale, improve regional ecological efficiency. Other provinces are in the state of increasing scale, so we should expand the scale and realize the efficiency of DEA, so as to promote the improvement of regional ecological efficiency.

4.2. Redundancy Analysis

In order to understand the factors affecting the input-output ratio of scientific and technological talents, the paper makes a projection analysis on the non-DEA effective provinces and autonomous regions in 2015, and further explores the redundancy of input-output in order to provide a reference for the inefficient areas to allocate resources more scientifically and rationally.

Region	AQI	Energy Consumption	Land Input	Water Input	Human Input
Hebei	16.68	9.98			
Shanxi		12.73			16.01
Liaoning		218.42	213.52		
Jilin		76.84	163.59		
Heilongjiang		178.84	195.41	229.09	
Shanghai		753.76	780.05		22.54
Anhui			35.76	108.29	
Jiangxi		32.98		3.03	
Henan	42.96		48.70		115.99
Hubei			35.78		
Guangxi			1.83	117.36	
Chongqing			4.26		
Sichuan			37.49		
Guizhou			10.90		9.88
Yunnan			24.03	2.90	
Shannxi		43.99			93.98
Gansu			9.65	43.40	
Ningxia	10.22	180.92	167.16	36.57	

Table 3: Ecological Efficiency Analysis of Non-DEA Effective Provinces

From table 3, it can be seen that under the existing investment scale, the input redundancy of non-DEA effective decision-making units (provinces) and the AQI index of Hebei, Henan and Ningxia provinces show the input redundancy, indicating that the economic development level of these provinces is not directly proportional to the environmental damage, and the non-DEA efficient economy can be obtained by high-cost environmental pollution. Economic development should speed up economic transformation, improve resource utilization, reduce redundancy and improve ecological efficiency. Most provinces have shown redundancy in energy consumption and land input, indicating that most regions have too much input and too low output, and the conversion rate of input and output is low. Input should be reduced appropriately to improve input conversion rate and ecological efficiency. A few provinces invest too much in water resources and manpower, which leads to the shortage of water resources and the underutilization of human resources. The waste of resources reduces the local scale efficiency. Therefore, these provinces should pursue the rational use of human resources instead of flooding, rationally allocate water resources, reduce the loss of resources and improve livelihood. State efficiency.

5. Conclusion and Suggestion

Based on the cross-sectional data of 30 provinces and cities in 2015, this paper uses DEA model to calculate the ecological efficiency of each province and city, and draws the following conclusions:

The ecological efficiency gap between provinces is large. Beijing, Tianjin, Jiangsu, Zhejiang, Fujian, Shandong and Guangdong, as economically developed areas, have higher technological level, higher input-output conversion rate of resources than ordinary provinces, and can achieve rapid economic development on the basis of maintaining a lower level of environmental damage, so they are in a leading position in ecological efficiency. Most cities are in a state of increasing scale, which originates from the state's policy of "east-west linkage development" and "economically developed areas supporting economically underdeveloped areas" while taking into account the development of the central region. The gap between regions is gradually narrowed, and the Silk Road Economic Belt policy has led to the development of the central and Western regions. In the study, 18 provinces showed non-DEA effectiveness, of which Hebei, Henan and other regions did not have geographical advantages, and the support of national policies was not obvious, in environmental and economic coordination did not achieve good results. As a Western region, Ningxia's environmental pollution and economic output are not directly proportional to the backward technology level and the lack of management personnel. At present, the development mode of most cities is extensive. The state calls on all parts of the country to change the mode of economic development into intensive development. The policy is conducive to the improvement of ecological efficiency. However, in the process of transformation, there is a certain lag, and the current situation of high input and low output cannot be changed in a short period of time. This requires all regions to implement the national development policy, improve the utilization rate of resources, reduce the consumption of non-renewable resources, expand the proportion of renewable resources, rationally plan the land area, and realize the harmonious development of economy and ecology.

Technology is the primary productive force. At present, remarkable achievements have been made in the implementation of the strategy of "rejuvenating the country through science and education" nationwide, and measures for the construction of scientific and technological contingents have been gradually improved. Comprehensive technical efficiency is the key factor to determine the effectiveness of DEA in provinces and autonomous regions, and the change of comprehensive technical efficiency is affected by both pure technical efficiency and scale efficiency. In the study of 30 provinces and autonomous regions, most of the non-DEA effective provinces and autonomous regions are subject to pure technical efficiency factors. Therefore, it is necessary to increase investment in science and technology, introduce and train innovative talents, and optimize the technological innovation environment. The use of innovative achievements into productive forces has made remarkable progress in the input and output of resources, improved the ecological efficiency of various regions, transformed non-DEA effective areas into DEA effective through the improvement of pure technical efficiency, narrowed the gap between provinces and cities, thus improving the overall ecological efficiency of the country.

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