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The Regional Environmental Performance of China from 2004 to 2009

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Abstract: Undesirable output is the major factor which affects the environmental performance,in this paper,the non-radial undesirable output DEA model is used to appraise the regional environmental performance of China from 2004 to 2009,and the trend and affecting factor is also considered based on DEA-malmquist productivity index. The result shows that the environmental performance of the most regions is relative lower, and they has a further decreasing trend, the technological efficiency is the major factor which affects the environmental performance while the technical progress slow down the declining trend of the environmental performance in a certain extent.

Keywords: undesirable output; environmental performance; non-radial DEA-malmquist productivity

1 Introduction

Energy and environment are the fundamental material for the existence and development of our human society, to a certain extent, with a continuous growth of the population and a rapid increase in the economy, many problems of the energy and environment starts to show up, for example; blindly exploit and use of the resource, discharging the pollutants indiscriminately, and so on. It is well known that all the problems are serious threats to the future survival and development of human society. In order to maintain a good social environment and settle the related environmental problems, we should make efforts to protect the environment. In reality, problems of environmental protection include the assessment of the environmental performance, energy efficiency and energy technology, technology and policy of pollution disposal and so forth. The effective assessment of the environmental performance is not only helpful for people to understand the regional environmental performance and the difference between the regions, but also provides the detailed and accurate information for the formulation and implementation of the environment micro-management policies and energy policies. Therefore, it is significant to evaluate the environmental performance.

Many scholars have done a lot of research on the evaluation of the environmental performance. Färe et al (1989) put forward a non-linear method to evaluate the environmental performance, as for the evaluation of the environmental performance, it is estimated that the larger the desirable output and the smaller the undesirable output, whereas the traditional radial measure method is based on the same proportion expand the desirable output and undesirable output, it can not distinguish the desirable output and undesirable output effectively, but the aim of curve measure method is to measure the performance of the desirable output based on the radial measure and to measure the performance of the pollutants using the countdown (curve), therefore it can solve the problem of radial measure, that means, it can resolve the measurement of the problem of increasing desirable output while reducing pollutant emissions. Haynes,Ratick and Cummings-Sexton(1997) constructed the production frontier of the environmental protection based on DEA method to study the environmental performance, in their paper they took the pollutants as the input indexes. Reinhard,Lovell and Thijssen (2001) applied the DEA method to analyze the environmental performance of the Netherlands' dairies, and compared to the performance evaluation of the random production frontier method. Halilu and Veeman(2001) adopted the DEA method to analyze the environmental performance of the Canada's paper industry. Wang,Zhang and Wang (2002) studied the environmental performance of the decision-making unit while taking the pollutants as input indexes, and proved that the result is equivalent to the paret efficient solution of the multi-objective planning method. Chung, Färe and Groddkopf(1997) took into account the weakly disposed property of the pollutants and put forward a new DEA model based on distance function to analyze the environmental performance. Zhou et al(2007) constructed a non-radial DEA-based model based on traditional

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DEA method and applied the model to evaluate the environmental performance of the OECD countries, the result shows that the new model has a higher discriminating power than radial ones in environmental performance comparisons etc.

In this paper, the authors take the pollutants as the undesirable output and apply the non-radial DEA model to evaluate the inter-provincial environmental performance of China from 2004 to 2009 based on the previous study, and apply the malmquist productivity index model to study the factors which affect the environmental performance of China dynamically, the aim of this paper is to provide a theoretical basis and practical support for the government to control the regional environmental pollution and implement the corresponding policies of the environment protect. The second part is to summarize methodology, the third part is the result and discussion, conclusions and policy implications is in the last part.

2 Methodology

Assuming that there are n decision making units (DMU), and each DMU has m types of input X, s types of the desirable outputs Y and k types of undesirable output U, and $X_j = (x_{1j}, x_{2j}, \cdots, x_{mj})^T > 0$,$Y_j = (y_{1j}, y_{2j}, \cdots, y_{sj})^T > 0$,$U_j = (u_{1j}, u_{2j}, \cdots, y_{kj})^T > 0$,$x_{ij}$ is the ith input of the DMU_j,y_{rj} is the rth desirable outputs of DMU_j,u_{rp} is the pth undesirable output, $(j = 1, 2, \cdots n; i = 1, 2 \cdots m; p = 1, 2, \cdots k, r = 1, 2 \cdots s)$. Assuming that the number of the input and output is following: $x_0 = x_{j_0}, y_0 = y_{j_0}, k_0 = k_{j0}, 1 \le j_0 \le n$,thus, the formula of the non-radial C^2R model based on input with undesirable output of DMU_{j_0} is expressed in model (1) (Zhou et al,2007).

$$D(x_0, y_0, u_0) = \min[\sum_{j=1}^{J} a_j\theta_{bj} - \varepsilon(\sum_{i=1}^{m} s_i^+ + \sum_{r=1}^{s} s_r^+)]$$

$$\text{s.t.}\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{ij_0}, i = 1, 2, \cdots, m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_i^+ = y_{rj_0}, r = 1, 2 \cdots s; \quad 1$$

$$\sum_{j=1}^{n} \lambda_j u_{pj} - s_r^+ = \theta_j u_{pj_0}, p = 1, 2 \cdots k;$$

$$\lambda_j \ge 0, j = 1, 2, \cdots n s_i^+ \ge 0, s_r^+ \ge 0.$$

However, the inter-period dynamic changes of the environmental performance is not only related to the change of the technological efficiency but also related to the change of technological progress of the corresponding environment control, thus it should combine the model (1) with malmquist productivity index to study the affecting factor and the dynamic change of the environmental performance. From the theory of fisher ideal index, Caves, Christensen and Diewert(1982) constructed malmquist productivity index from t to t +1, the formula is expressed in model (1).

$$M_{j,t+1}(x_j^t, y_j^t, u_j^t, x_j^{t+1}, y_j^{t+1}, u_j^{t+1}) = \frac{D_j^{t+1}(x_j^{t+1}, y_j^{t+1}, u_j^{t+1})}{D_i^t(x_j^t, y_j^t, u_j^t)} \left[\frac{D_j^t(x_j^{t+1}, y_j^{t+1}, u_j^{t+1})}{D_j^{t+1}(x_j^{t+1}, y_j^{t+1}, u_j^{t+1})} \frac{D_j^t(x_j^t, y_j^t, u_j^t)}{D_j^{t+1}(x_j^t, y_j^t, u_j^t)}\right]^{1/2} \quad (1)$$

From model (1), it is shown that the model(1) can be decomposed into two parts, the formula is following:

$$TEC_j^{t+1} = \frac{D_j^{t+1}(x_j^{t+1}, y_j^{t+1}, u_j^{t+1})}{D_j^t(x_j^t, y_j^t, u_j^t)} \quad (2)$$

$$FS_j^{t+1} = \left[\frac{D_j^t(x_j^{t+1}, y_j^{t+1}, u_j^{t+1})}{D_j^{t+1}(x_j^{t+1}, y_j^{t+1}, u_j^{t+1})} \frac{D_j^t(x_j^t, y_j^t, u_j^t)}{D_j^{t+1}(x_j^t, y_j^t, u_j^t)}\right]^{1/2} \quad (3)$$

The TEC stands for the technological efficiency change of the environmental performance during the period from t to t +1, and FS signifies the technological progress change of the environmental performance during the period from t to t +1, it reflects the progress in the production and management mainly, the M_j reflects the inter-period dynamic changes of the environmental performance.

3 Results and discussion

3.1 Data and indicators

During the previous study, scholars usually adopt a number of integrated indicators to evaluate the environmental performance, such as: the total energy / GDP, CO emissions / GDP, CO^2 emissions / GDP, SO^2/GDP, etc. Because the DEA method is based on the theory of the input-output, the result will be a comprehensive index, thus it should consider all the relevant factors affecting the environment when using the DEA model to calculate the environmental performance, such as: Zaim and Tahkin (2000a,2000b), Zofil and Prieto (2001), Ramanathan,R.(2005), Zhou,Ang and Poh (2006) , Zhou et al(2007) etc.

In order to obtain the environmental performance of all the region of China, this paper selects the total energy consumption and the total population as input indicators, and the desirable output indicator is the total GDP, the undesirable output indicators are the total industrial waste gas emissions, the total industrial wastewater discharge and the total output industrial solid waste. All the number of the above indicators is during the period from 2004 to 2009, all the them are mainly from ”China Statistical Yearbook 2010” and ”China Energy Statistical Yearbook 2010.”. Because the socio-economic system of the Tibet is differed from other regions, this paper does not contain the Tibet.

3.2 Empirical result

The value of table 1 and 2 is obtained by using LINGO8.0 software based on the above model and related indicators. As can be seen from Table 1, the average environmental performance value of Beijing and Shanghai is located on the production frontier from 2004 to 2009, it indicates that compare to other regions these two regions have better quality of their environment, and they have certain advantage in their environmental management, clean technology and the corresponding environmental policies, also these two cities can control the emission level of the pollutants reasonably. The following province is Guangdong and Hainan, the average value is 0.99 and 0.90 respectively, and the average value of Guangdong is 0.92 in 2009, it illustrates that the environmental quality of Guangdong Province in 2009 is declined compared with the previous years, the main reason is that the increase in Guangdong province’s total energy consumption is relatively fast in 2009, the increase is amount to 13.70%, while the corresponding increase of the desirable output GDP is lowest in the selected period. It means that the environmental performance of Guangdong province is not only failed to improve but also a certain degree of decline in 2009, and the level of environmental performance does not change in the other years. As for Hainan province, the level of environmental performance is located on the production frontier before 2007, but there was a more obvious downward trend in 2008 and 2009, the values are 0.66 and 0.71, therefore the relevant government should pay more attention to this phenomenon. There are four areas, the environmental performance value of which is larger than 0.60 and smaller than 0.90, namely, Jiangsu, Fujian, Zhejiang and Tianjin, it indicates that the environmental performance of the four areas is at a medium level, and there are some room for improvement on the corresponding ability of the environment control, the corresponding energy technology and environmental policy, from a regional point of view over these areas are the eastern region. As for the areas where the environmental performance is smaller than 0.60, generally, they belong to the central and western regions, the worst areas of them is Shanxi Province, the annual average value is 0.18, from the raw data we can see that the total energy consumed by Shanxi Province ranks the fifth of all the regions in 2009, and its industrial wasting water, industrial emissions and industrial solid wasting emissions is larger than the average emissions of all the provinces, while the corresponding desirable output is smaller than the average value of all the regions, such as: Guangxi, Guizhou and other areas, we can see that the environmental governance capacity of these areas is relatively poorer and their energy technology is also in a relatively lower state, in a certain sense, it means that there are some problem in their corresponding environmental policies and the specific implementation of the policies, therefore it is the time for them to
strength their environmental control ability to improve their environmental performance. Table 2 is the mean value of the intertemporal dynamic regional environmental performance index from 2005 to 2009, it can be seen from table 2 that the malmquist index of the six regions is larger than 1, the six regions which are Beijing, Jiangsu, Guangdong, Hainan, Gansu and Ningxia. It means that the environmental performance of the six areas are changing to the good direction from the overall trend of the dynamic changes, and the malmquist index values of Ningxia and Gansu is 1.16 and 1.00 respectively, it indicates that the overall environmental performance of the two areas is improved during the study period. From the views of the major
affecting factor, it is clear to see that the improvement of the environmental performance is caused by the improvement of the technological efficiency, but the corresponding environmental management technology and energy technology of the two areas doesn’t get upgrade effectively, because the technological efficiency index of the two areas are 1.30 and 1.20 respectively, both of them are greater than 1 and the technological progress index of them are 0.87 and 0.91 respectively,

Table 1: Table1 2004∼2009 Static regional environmental performance

Region	2004	2005	2006	2007	2008	2009	average	Region	2004	2005	2006	2007	2008	2009	average
Beijing	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Henan	0.44	0.43	0.40	0.41	0.26	0.27	0.37
Tianjin	0.83	0.69	0.70	0.76	0.41	0.41	0.63	Hubei	0.51	0.51	0.47	0.43	0.26	0.26	0.41
Hebei	0.37	0.32	0.28	0.21	0.14	0.13	0.24	Hunan	0.53	0.55	0.47	0.47	0.33	0.39	0.46
Shanxi	0.25	0.21	0.17	0.17	0.14	0.11	0.18	Guangdong	1.00	1.00	1.00	1.00	1.00	0.92	0.99
Neimenggu	0.37	0.29	0.24	0.22	0.18	0.15	0.24	Guangxi	0.26	0.27	0.23	0.20	0.17	0.19	0.22
Liaoning	0.36	0.34	0.28	0.28	0.15	0.14	0.26	Hainan	1.00	1.00	1.00	1.00	0.66	0.71	0.90
Jilin	0.46	0.46	0.43	0.40	0.26	0.29	0.38	Chongqing	0.44	0.46	0.43	0.39	0.27	0.23	0.37
Hilongjiang	0.55	0.54	0.51	0.55	0.35	0.35	0.48	Sichuang	0.42	0.39	0.38	0.38	0.25	0.25	0.35
Shanghai	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Guizhou	0.29	0.27	0.23	0.22	0.19	0.14	0.22
Jiangsu	0.60	1.00	1.00	1.00	0.38	0.37	0.73	Yunnan	0.44	0.38	0.32	0.29	0.21	0.20	0.31
Zhejiang	0.82	0.77	0.78	0.82	0.54	0.53	0.71	Shanxi	0.46	0.38	0.34	0.81	0.22	0.26	0.41
Anhui	0.44	0.43	0.39	0.40	0.25	0.24	0.36	Gansu	0.34	0.23	0.23	0.68	0.18	0.20	0.31
Fujian	1.00	1.00	0.86	0.87	0.31	0.34	0.73	Qinghai	0.4	0.41	0.35	0.62	0.16	0.14	0.35
Jiangxi	0.50	0.47	0.38	0.39	0.24	0.24	0.37	Ningxia	0.21	0.19	0.17	0.58	0.10	0.11	0.23
Shandong	0.57	0.58	0.53	0.50	0.32	0.33	0.47	Xinjiang	0.61	0.55	0.49	0.46	0.30	0.29	0.45

smaller than 1. The malmqust index values of Beijing and Jiangsu are1.04 and 1.10, and the technical efficiency index of the two regions both are 1, however the technological progress change of them are more than 1, 1.04 and 1.07 respectively, it indicates that there is an increasing trend in the environmental performance of Beijing and Jiangsu, it is obvious that the technological progress is the major reason which leads the improvement of their environmental performance. The malmqust index values of Guangdong and Hainan is also larger than 1, but the affecting factor is differ from Beijing and Jiangsu greatly, because their technical progress is larger than 1 and technical efficiency is small than 1, it shows that the

Table 2: Table2 2005∼2009 Mean value of the dynamic regional environmental performance index

Region	TEC	FS	Malmquist index	Region	TEC	FS	Malmquist index
Beijing	1.00	1.04	1.04	Henan	0.92	1.00	0.92
Tianjin	0.89	1.05	0.94	Hubei	0.89	1.01	0.89
Hebei	0.82	1.01	0.82	Hunan	0.96	0.99	0.94
Shanxi	0.85	0.99	0.84	Guangdong	0.98	1.08	1.07
Neimenggu	0.84	1.00	0.84	Guangxi	0.95	0.99	0.93
Liaoning	0.85	1.00	0.85	Hainan	0.95	1.08	1.02
Jilin	0.93	1.01	0.93	Chongqing	0.89	1.01	0.89
Hilongjiang	0.93	1.00	0.93	Sichuang	0.91	1.01	0.92
Shanghai	1.00	0.92	0.92	Guizhou	0.87	1.00	0.87
Jiangsu	1.00	1.07	1.10	Yunnan	0.86	1.00	0.86
Zhejiang	0.93	0.95	0.88	Shanxi	1.11	0.85	0.91
Anhui	0.90	1.00	0.90	Gansu	1.20	0.91	1.00
Fujian	0.86	0.98	0.86	Qinghai	0.96	0.90	0.85
Jiangxi	0.88	1.01	0.88	Ningxia	1.30	0.87	1.16
Shandong	0.91	1.03	0.93	Xinjiang	0.87	1.01	0.88

technological progress is the major factor which causes the improvement of the overall environmental performance, therefore,it is significantly important for the two regions to strengthen the corresponding technical applying capacity because it is the major method to improve their technical efficiency. The environmental performance of the other 24 areas declined in various degrees, but the range is not large, and most of them are caused by the decline of the technical efficiency while technological progress mitigates the decline in the environmental performance in a certain extent, such as: Tianjin, Hebei, Jilin, Heilongjiang and other areas, thus in order to improve the environmental performance of the areas it is initiative to increase the overall use of the related technologies and improve the ability to absorb the corresponding technologies

4 Conclusions and policy implications

According to our empirical analysis, there are three main outcomes: Firstly, the evaluation of the environmental performance with undesirable output is solved effectively by using non-radial DEA model, and it can deal with the problem with desirable output and undesirable output comprehensively, and the conclusion is consistent with the realistic regional characteristics. Secondly, from the result of the environmental performance of the region, we know that the environmental performance of the eastern part is better than the central and western regions; the highest environmental performance is Beijing and Shanghai, while Shanxi's is worst of all the region. Third, from the dynamic trend of the regional environmental performance we know that all the environmental performance of the regions is declined in various degrees except for Beijing, Jiangsu, Guangdong, Hainan, Gansu and Ningxia, but the decreasing range is not large. From the specific affecting factors we know that the decline of the most of the region's environmental performance is caused by the decline of the technological efficiency, while the technological progress smoothes the decreasing trend in a certain extent.

As can be seen from the above conclusions, we should divide the district into four types main function according to their own characteristic, namely: priority development, key development, restricted development and prohibited development. It is the most effective way to improve the environmental performance of the region by closing the program which is high-pollution and endanger. At the same time, in order to eliminate the impact of the low environmental performance, the government of the backward areas should increase the human capital investment, expand the opening to the outside world, enhance the level of industrialization and promote the technical absorbing capacity of the backward areas, and the western region should be continuously strengthened the subsequent advantages and narrow the differences with the developed areas.

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