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Regional Environmental Performance Evaluation: A Case of Western Regions in China

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Abstract

According to a majority of static evaluation and without common significance problems of regional environmental performance evaluation, evaluation indicator system of regional environmental performance is established in view of evaluation indicator system design principle, which is composed of environmental investment, operational performance, environmental condition and environmental profit. A dynamical model on regional environmental performance evaluation is put forward in this paper, which is combined with the basic idea of DEA and fuzzy integral assessment method. In order to provide the reasonable basis for local government to take corresponding measures to improve their environmental performance level, we carry through empirical analysis about regional environmental performance of 8 typical western regions in china and draw conclusion.

Keywords: Environmental performance, DEA, Fuzzy integral, Dynamical evaluation model

1. Introduction

With the sustained development of economy in China, it is increasingly outstanding for the contradiction between economic growth and environment protection, environment and development are brought into uniform framework. It means environment protection will be paid attention when economics is developed. Thus, environmental resource allocation efficiency has gradually become the focus of public concern. Regional environment performance has become one of determinants to affect different region core competition in China. From the existed literature, the foreign scholars had made lots of research. Haynes et al.[1] regarded pollution as input indicators, and put forward a production frontier of environment protection based on DEA to study environmental performance. Considering the weak treatability of pollutants, Chung et al.[2] used the directional distance function method to environmental performance evaluation. Reinhard et al.[3] analyzed the environmental performance of Holland dairy by DEA, and compared with stochastic production frontier. Halilu[4] analyzed the environmental performance of Canadian pulp and paper industry by DEA. However, at present, the domestic scholars only made less

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research on regional environment performance. Liang et al.[5] made an analysis on the environmental efficiency of 17 cities in China Anhui by improved DEA.

According to above analysis, the current regional environmental performance research has the following problems. One is to lack in a scientific and effective evaluation indicator system, the selected indicators of many research can not objectively respond regional environment performance. The other is to make a static evaluation on environmental performance data of one year, which is not able to study it from a dynamic perspective. Therefore, according to indicator system design principle, this paper establishes regional environment performance evaluation indicator system. On the basis, the dynamic evaluating mode with DEA and fuzzy integral is established, in order to evaluate regional environment performance scientifically and rationally, make government obtain some verifiable information related to environmental performance management by sustainable manner, and find existed problems and its subjective effective effort degree in environmental performance management.

2. Construction of Regional Environmental Performance Evaluation Index System

This paper constructs regional environment performance evaluation indicator system, which includes environment input, operation performance, environment condition and environment benefit. At the same time, the second level indicators are divided into some third level indicators to describe regional environmental performance, as is shown in Table 1.

Table 1. Regional Environmental Performance Evaluation Index System

Region environment performance evaluation	Environment inpout	environment infrastructure construction investment
		industrial pollution treatment investment
		"three simultaneous" project environmental protection investment
		ratio of environmental pollution control investment to GDP
	Operation performance	industrial solid waste utilization rate
		industrial wastewater discharge compliance rate
		industrial soot emissions compliance rate
		domestic garbage harmless treatment rate
	Environment condition	solid waste generation amount
		waste water discharge amount
		waste gas emission amount
		the days of air quality above grade two
		the cumulative loss of natural disasters
		environmental pollution incident number
		urban noise equivalent sound level
		forest coverage rate
	Environment benefit	"Three cost" comprehensive utilization products output
		energy consumption per unit output

3. The Dynamic Evaluation Model Based on DEA and Fuzzy Integral

3.1. The thought of model construction

As regional environmental performance has diversity and complexity, this paper put forward the benefit dynamic evaluation model with DEA and fuzzy integral integration based on the thought of DEA and fuzzy integral. In the evaluating process, firstly, previous regional environment performance is evaluated by fuzzy integral method, which can obtain reference performance reflecting the superiority or inferiority of regional objective basis condition. At the same time, the current environmental performance is evaluated by same indicator system and method, which can obtain current performance. The data array

combined with reference and current performance is defined as the performance status of regional environmental performance. Secondly, in view of the basis principle of DEA that the different inputs are corresponding to different performance status front projection, this paper makes the reference performance as input and current performance as output, then determines the dynamic evaluation of regional environmental performance by DEA, so that the purpose is attained that the objective foundation condition superiority or inferiority effect is eliminated, and the subjective endeavor degree of regional government managers can be reflected in the implementation of environmental performance management, which can provide the quantitative basis for decision makers to find the disadvantage of regional environmental performance and to formulate corresponding measures.

3.2. Fuzzy integral method

The specific steps of comprehensive evaluation method based on fuzzy integral are following:

Step 1 Determination of qualitative indexes Conformity formula is as following:

$$\tilde{x}_{H_i} = \frac{1}{k} \otimes \left\{ \tilde{x}_{H_{i1}} \oplus \tilde{x}_{H_{i2}} \oplus \Lambda \oplus \tilde{x}_{H_{ik}} \right\} \tag{1}$$

Thereinto, $\tilde{x}_{H_{ik}}$ refers to index of H layer decided by k expert; $\tilde{x}_{H_i}$ refers to fuzzy value.

(4) Obtaining the qualitative index values through solving fuzziness operation. This paper uses 3 methods to solve fuzziness, including relative distance formula (M_1), core-value method(M_2) and center of gravity value method(M_3)to transform fuzzy value to definite value.

$$f(X_i^k) = \frac{M_1(\tilde{f}(X_i^k)) + M_2(\tilde{f}(X_i^k)) + M_3(\tilde{f}(X_i^k))}{3} \tag{2}$$

Step 2 Calculating evaluation value of every evaluated layer through fuzzy integral

(1) Determination of importance and the value λ. On the basis of questionnaire, relevant experts give importance and value λ of evaluated indexes according to enactment criteria of importance and the value

(2) Rearranging the indexes under bottom layer according to the big or small sequence

(3) Calculating fuzzy measure of every index under the second layer and operating unitary removal :

$$\begin{aligned} g_\lambda(\{x_1, x_2, \cdots, x_n\}) &= \sum_{i=1}^{n} g(x_i) + \lambda \sum_{i_1=1}^{n-1} \sum_{i_2=i_1+1}^{n-1} g(x_{i_1}) g(x_{i_2}) + \cdots + \lambda^{n-1} g(x_1) g(x_2) \cdots g(x_n) \\ &= \frac{1}{\lambda} \left| \prod_{i=1}^{n} (1 + \lambda g(x_{i-1})) - 1 \right| \quad \lambda \in (-1, \infty) \quad \lambda \neq 0 \end{aligned} \tag{3}$$

(4)Calculating some index value under the second layer through using fuzzy integral formula:

$$E = f \int \lg = f(x_n) g(x_n) + [f(x_{n-1}) - f(x_n)] g(x_{n-1}) + \cdots + [f(x_1) - f(x_2)] g(x_1) \tag{4}$$

(5) Repeating the step from (2) to (4) until all index values under the second layer are calculated.

Step 3 Comprehensive evaluation

First the relevant experts determine the importance and the value λ of all indexes under the first layer, which is combined with the calculated evaluation values of all indexes under the second layer, and then the evaluator can calculate the comprehensive evaluation value of regional environmental performance in western regions by fuzzy integral method.

3.3. Construction of dynamic evaluation model

The geometry explanation of dynamic evaluation model on regional environment performance is showed in Fig. 1. In Fig. 1, the reference performance is the X-coordinate, and the current performance is

the Y-coordinate. Suppose there are three objects to be evaluated and their performance states are $A(X_1, Y_{1)}$, $B(X_2, Y_2)$, $C(X_3,Y_3)$ respectively.

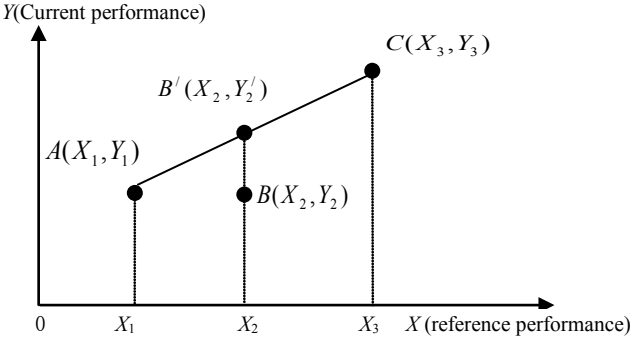

Fig.1. Geometry Explanation on Dynamic Performance Evaluation Model

The reference performance of evaluated object B is between the object A and C, that is $X_1<X_2<X_3$. If the performance state $B(X_2,Y_2)$ of evaluated object B is under the line being between $A(X_1, Y_1)$ and $C(X_3, Y_3)$, the effective subjective endeavor of evaluated object B is not as much as evaluated object A and C. The line between A and C can be viewed as the relatively effective frontal surface of A, B, C, the projection of B on this frontal surface is $B/(X_2,Y/2)$, then the ratio of Y_2 to $Y/2$ η is the dynamic performance evaluation reflecting the effective subjective endeavor of B.

The concepts of performance state and its possible set are introduced. Supposing X_j , Y_j are the reference performance and current performance in region j respectively, $(X_j, Y_j) \in E_1$, E_1 is the set of regional environment performance which is measured by the fuzzy integral comprehensive evaluation method, so the data array(X_j, Y_j) is the performance state of region j, and is called as the convex set.

$$T=\left\{(x_j,y_j)\left|\sum_{j=0}^{n}\lambda_j x_j\le x,\sum_{j=0}^{n}\lambda_j y_j\ge y,\sum_{j=0}^{n}\lambda_j=1,\lambda_j\ge 0,j=0,1,2,\cdots n\right.\right\} \quad (5)$$

T is the performance states possible set composed of performance states(X_j, Y_j), thereinto, $(X_o, Y_o)=(0,0)$. The output BCC model of DEA is following:

$$\max \mathbf{Z} \qquad \text{s.t.}\sum_{j=0}^{n}\lambda_j x_j\le x_{j0},\sum_{j=0}^{n}\lambda_j y_j\ge zy_{j0},\sum_{j=0}^{n}\lambda_j=1,\lambda_j\ge 0,j=0,1,2,\cdots,n \quad (6)$$

If the optimal value $Z^*=1$, then the region is on the frontal surface of possible states set T. If $Z^*>1$, then the region is not on the frontal surface. Supposing $\overline{X}_{j0}=X_{j0}$, $\overline{Y}_{j0}=Z'Y_{j0}$, apparently, $(\overline{X}_{j0},\overline{Y}_{j0})$ is on the frontal surface of$T$, then $(\overline{X}_{j0},\overline{Y}_{j0})$ is called as the projection of (X_{j0},Y_{j0}) on the frontal surface of possible states set T. Above the synthesis condition, $\eta=1/Z^*\times 100\%$ is called as the dynamic environment performance evaluation of j_0. From $1/Z^*=Y/\overline{Y}$, the dynamic environment performance evaluation is the ratio of the current performance to the possible maximum that can be reached under the same conditions. The concrete steps are as follows:

(1) Determing reference performance, current performance and performance state possible set In order to describe difference between the objective basis conditions of a region, the method on fuzzy integral is adopted to evaluate its previous environmental performance, which index not only reflects its strength, but also reflects its objective basis condition superiority or inferiority, so this result is called reference performance. And the same method is used to evaluate its current environment performance,

which result is called current performance. The data array composed of the reference and current performance is called as its performance state possible set.

(2) Calculating dynamic environment performance evaluation. According to the change of the performance state, the effective subjective endeavor degree can be reflected. This is a relative evaluation process by DEA on the basis of fuzzy integral comprehensive evaluation, which is called as the dynamic environmental performance evaluation. Specifically, reference performance as input and current performance as output are substituted to the BCC model of DEA, then the frontal surface of performance state is constructed. According to the negative degree to deviate from the frontal surface, the dynamic environment performance evaluation is calculated to reflect its effective subjective endeavor degree.

4. Example Analysis on Regional Environment Performance Evaluation

The regional environment performance of 8 western typical regions from 2008 to 2009 is evaluated by the dynamic evaluating model on regional environment performance, which data come from "China Environment Yearbook". The results are shown in Table 2 and Fig.2.

Table 2. Regional Environmental Performance Danamic Evaluation result

Region name	2008	2009		2008～2009	
	Reference performance	Current performance	order	Dynamic performance evaluation value	order
Sichuan Province	0.8942	0.9601	4	1	1
Guizhou Province	0.8236	0.8164	8	0.9013	8
Shanxi Province	0.8721	0.8778	6	0.9308	7
GansuProvince	0.8283	0.8486	7	0.9331	6
Neimenggu Autonomous Region	0.9772	0.9478	5	0.9477	5
Guangxi Autonomous Region	0.9757	1	1	1	1
Chongqing city	0.9734	0.9836	2	0.9847	3
Yunnan province	1	0.9732	3	0.971	4

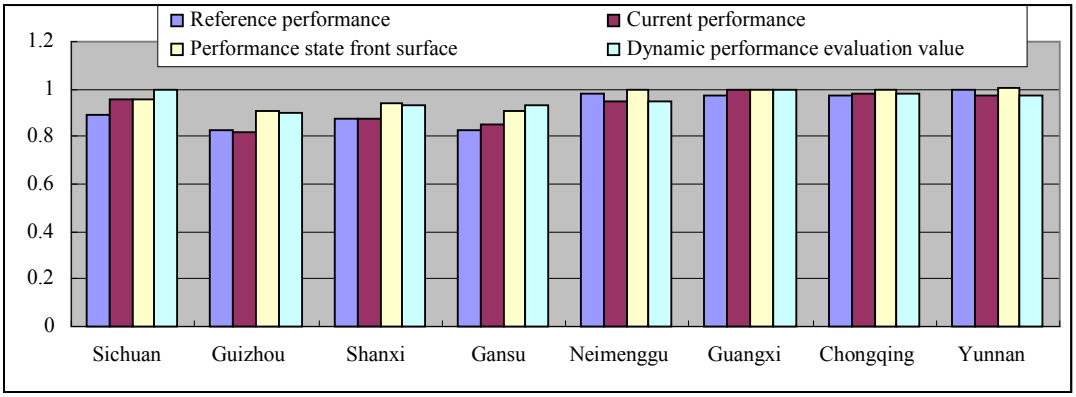

Fig. 2 Regional Environmental Performance Danamic Evaluation

In order to determine the factors influencing on the rank of 8 region environment performance, the histogram of comprehensive index of regional environment performance is made as a histogram to reflect the change during years. From evaluating results, the dynamic evaluation of regional environment performance mainly reflects the regional environmental performance deviating from performance status

front surface. As it is harder for regions with better condition to improve the same ratio than regions with worse condition, so the dynamic performance of Chongqin and Guangxi is almost not improved, but its states is closed to the frontal surface, its rank is still high. Recently, Sichuan's economic development environment has been improved, although it past condition is worse, its current performance in 2009 is relatively backward, from dynamic performance evaluation, it rank is raised rapidly. For Shanxi and Yunnan, as their industries are developed rapidly, and increases the environmental pollution degree, the environmental benefits are affected seriously, which leads to its dynamic performance rank decreasing. For Gansu region, its economic development level and developing chance is relatively stable, and its objective environment is same to the past, although it dynamic performance evaluation has a certain increasing, it still deviates from dynamic performance front surface, it rank is lower.

5. Conclusion

This paper compares with the ranks of comprehensive evaluation and dynamic performance evaluation of 8 western regions, which helps them to analyze main problems and measures the decision makers' roles in this process. According to Table 2 and Fig.2, the changes of comprehensive evaluation and dynamic performance evaluation have 4 conditions: the first is that the region with better objective foundation condition can still obtain better environmental performance if it keeps up; the second is that the region with worse foundation condition can also sustain performance level increasing if it makes continuous efforts; the third is that the performance rank of the region with better foundation condition can lower if it ignores the environmental protection investment and attention; the fourth is that the region with worse foundation condition can form a vicious spiral if it continues to ignore environmental protection. In general, the governments and other organization can not only depend on the current environmental performance of every region to illustrate whether environment performance management is implemented, and they can make an objective analysis on their actual conditions and objective evaluation on current environmental performance. At the same time, it will help decision makers to find their dynamic and relative position, and supervise and inspire every region effectively.

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