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Evaluation on Sustainable Development Capability of Sichuan Province Base on DEA

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Abstract: *Data envelopment analysis (DEA) is a method of analyzing the relative effectiveness of planning. In this paper, DEA model is applied to evaluate the sustainable development capability of Sichuan province for the period 2001-2010 and the projection analyses are given. The results show that the sustainable development capability of Sichuan province gets improvement in the research period, and corresponding suggestions are presented to coordinate the developments relation with population, resources and environment.*

Keywords: *Sustainable development; Data envelopment analysis; Efficiency evaluation*

1. Introduction

With the development of human society and the advancement of civilization, the issue of sustainable development had been increasingly noticed and accepted by many researches. The United Nations World Commission on Environment and Development (WCED) report "Our Common Future" provided the most-quoted definition of sustainability. Sustainable development should meet the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, the sustainability which is one of kernel problems of economy development has become the important national strategic goal of every country in the world.

As a province with large population, rich resource and strong economy, Sichuan province plays an important strategic role in the connection of northwest, southwest and central part. Initialization of China's West Development Strategy has brought up very precious opportunities for Sichuan province. And its sustainable development can improve the overall competitiveness of the western region.

According to the sample data, Data Envelopment Analysis (DEA) employs mathematical programming to obtain the efficiency evaluation of Decision Making Units (DMU). DEA is a new system analysis method based on the conception of evaluating the relative efficiency, and it is widely used in input-output efficiency analysis. Wu and He (2006) used the DEA model to evaluate the sustainability of Beijing based on the input-output matrix, and they considered that it was necessary to advance the recycling economy for Beijing's sustainable development [1]. The application of the theory of DEA in the capacity evaluation of sustainable development was discussed in Huang (2007) [2], and some useful advices were put forth to improve the utility of manpower, material and resource. In Quan et al (2008) [3], the sustainable development capability of nine state-ranked high-tech zones

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with six years data from lateral and longitudinal angle was evaluated. From the perspective of efficiency, a DEA method of the enterprise sustainable growth evaluation was provided, and the corresponding index system was built in Zhu and Ma (2008) [4]. Based on some sustainable development indictors, Zhao et al (2010) analyzed the sustainable development capability of Chengdu city [5].

DEA model is used to evaluate the sustainable development capability of Sichuan province and analyze the efficiency of input-output indexes for the period 2001-2010. Finally some corresponding suggestions are also given.

2. Data Envelopment Analysis（DEA）Model

The CCR model introduced by Charnes, Cooper and Rhodes in 1978 generalized the single output to single input classical engineering-science ratio definition to multiple outputs and inputs without requiring preassigned weights [6]. Banker, Charnes and Cooper presented a new separate variable to make it possible to determine whether operations were conducted in regions of increasing, constant or decreasing returns to scale. Then many generalized models were studied, including C^2GS^2 model, FG model, C^2W model, C^2WH model and stochastic DEA model. In this paper, the classical CCR model will be applied to evaluate the sustainable development capability of Sichuan province

Assume that there exist *n* Decision Making Units (DMUs), and x_j and y_j are the observed vectors of inputs and outputs, respectively.

$$x_j = (x_{1j}, x_{2j}, \ldots, x_{mj})^T \quad , \quad y_j = (y_{1j}, y_{2j}, \ldots, y_{sj})^T \quad ,$$

$$j = 1,2,\ldots,n \qquad (1)$$

where $x_{ij} > 0$ ($i = 1,2,\ldots,m$) is the *i*th input index of DMU_j, and $y_{lj} > 0$ ($l = 1,2,\ldots,s$) is the *l*th output index of DMU_j.

Then the CCR model including slack variables can be written as the following problem:

$$\begin{cases} \min \quad \theta - \varepsilon(e_1^T s^- + e_2^T s^+) \\ s.t. \quad \sum_{j=1}^{n} \lambda_j x_j + s^- = \theta x_0 \\ \qquad \sum_{j=1}^{n} \lambda_j x_j - s^+ = y_0 \\ \qquad \lambda_j \geq 0, j = 1,\ldots,n \\ \qquad s^- \geq 0, s^+ \geq 0 \end{cases} \qquad (2)$$

Where θ denotes the total efficiency value of sustainable development, $\varepsilon > 0$ is a small "non-Archimedean" quantity, e^T denotes the unit vector, $e_1 = (1,\ldots,1)^T \in R^m$, $e_2 = (1,\ldots,1)^T \in R^s$ and s^-, s^+ are the slack variables. Then model (2) can be used to evaluate the efficiency of each DMU. According to Huang(2007), the judgment criterion of DEA efficiency can be obtained with the optimal solution values $\theta^*, s^{*-}, s^{*+}, \lambda^*$.

（1）If $\theta^* = 1$ and $s^{*-} = s^{*+} = 0$, then this DMU is DEA efficiency, and the structure of input-output is optimal. Unless adding new input or reducing other output, the DMU will not add any output.

（2）If $\theta^* = 1$, then this DMU is weak DEA efficiency. The DMU can maintain the output even if it reduces s^{*-} unit of input, or the DMU can add s^{*+} unit of output even if it maintains the input.

（3）If $\theta^* < 1$, then this DMU is non DEA efficiency.

（4）Let $k = \sum \lambda_j^*$, then $k = 1$ means the constant returns to scale, $k < 1$ means the decreasing returns the scale, and $k > 1$ means the increasing returns the scale.

（5）In a dynamic DEA model, if $\theta^*(t-i) < \theta^*(t)$ for any $i > 0$, then the system is on the sustainable development path. The efficiency of input-output can be improved over time. If $\theta^*(t-i) = \theta^*(t)$, then the system is slightly weaker than the sustainable development path. If $\theta^*(t-i) > \theta^*(t)$, then the system is weaker than the sustainable development path.

Because of the simple model and complete theory, DEA is widely used to evaluate the complex system with various factors. Sichuan

province has special natural and geographical conditions, and the economic environment and social development becomes complex. The system has the multiple outputs and inputs. Then the selection of input and output indexes is very important to obtain the final result. The indexes will be discussed in Section 3.

3. Selection of input and output indexes

In the DEA model each DMU should have the same type, and in general the number of DMU is no less than the doubled number of all input-output indexes. To evaluate the sustainable development capability of Sichuan province, the situation of each year can be considered as a single DMU. Sun and Liu (2003) thought that the evaluation index system consisted mainly of economy, society, population, resource, environment, science and technology, state institution. According to the study on the evaluation of Chengdu city's sustainable development capability in Zhao et al (2003), this paper chooses the input and output indexed from the first five elements (economy, society, population, resource and environment).

（1）Economy. The per capita GDP can reflect a country or a regional scale and level of economic development objectively, so we choose the per Capita GDP of Sichuan province as the first output index.

（2）Society. Annual per capita consumption reflects the satisfaction level of people's material and cultural needs, and it will be the second output index.

（3）Population. There exists the phenomenon of large population base and large population growth in Sichuan province. The number of employed persons can be selected as one of the output indexes.

（4）Resource. Since energy plays a vital role in the development of whole region, the electricity consumption will be the second input index.

（5）Environment. The national environment protection expenditure item was listed officially into national and local financial expenditure. It showed that the environment got a more and more important position on the national and local development. And we choose the amount of investment in the treatment of industrial pollution as the third input index.

Then we have ten DMUs, and select five key indexed from five evaluation index systems respectively as the input-output indexes. Figure 1 shows the relationship of the indexes of DEA model.

The foundation function of DEA model is to evaluate, especially the relative effectiveness of multiple DMUs with the same kind. This paper compares the sustainable development capability of ten different years. Strong capability means that the equal resource consumption, equal environment protection expenditure and equal number of employed persons will bring more economic and societal benefit.

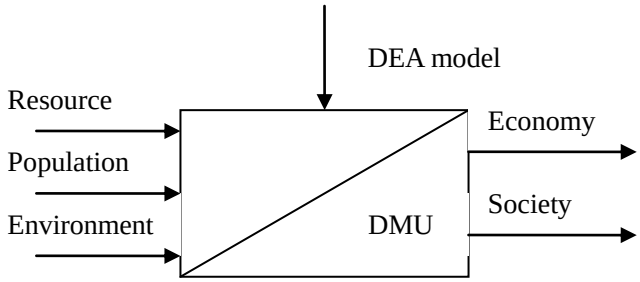

Figure 1. The relationship of the indexes of DEA model

4. Result analysis and corresponding suggestion

The data of input and output indexes are obtained based on "Sichuan province statistical yearbook" and "China statistical yearbook". And CCR model (2) can be solved through Matlab or DEAP 2.1. Table 1 shows the evaluation results of the sustainable development capability of Sichuan Province from 2001-2010.

Table 1. The sustainable development capability of Sichuan Province

Year	θ	Efficiency	Scale efficiency	Sustainable development path
2001	0.869	non DEA efficiency	scale increasing	-
2002	0.835	non DEA efficiency	scale increasing	weaker
2003	0.798	non DEA efficiency	scale increasing	weaker
2004	0.808	non DEA efficiency	scale increasing	weaker
2005	0.830	non DEA efficiency	scale increasing	weaker
2006	0.804	non DEA efficiency	scale increasing	weaker
2007	0.846	non DEA efficiency	scale increasing	weaker
2008	0.950	non DEA efficiency	scale increasing	on the path
2009	0.981	non DEA efficiency	scale increasing	on the path
2010	1.000	DEA efficiency	scale invariant	on the path

From Table 1, it is obvious that only one DMU of 2010 is DEA efficiency for Sichuan province during the ten years, and the effectiveness of input and output fails to meet the optimal situation during other years. But overall, the development of Sichuan province has been accelerated noticeably and the capability of sustainability development has been improved significantly since the launch of China's Grand Strategy of Developing the West. To improve effectiveness of input and output, the local government has stronger strategic target in making policy and pays more attention to coordinate the whole system.

The returns to scale under multiple input and multiple output situations is increased during these years. In order to improve the returns of output, the management strengthening is equally important to the increasing input for local government. And the DMUs of 2008-2010 are on sustainable development path which shows that strong self-regulation of Sichuan province can optimize the input-output structure. The radial movement and slack movement should be further analyzed for the DMU with non DEA efficiency. Table 2 gives the slacks of different input-output indexes.

Table 2. The slacks of input-output indexes

Year	Input slacks			Output slacks	
	Electricity Consumption（100 million kwh）	Investment in the Treatment of Industrial Pollution（10000 yuan）	Number of Employed Persons（10000 persons）	Annual per Capita Consumption (yuan)	per Capita GDP (yuan)
2001	0	0.707	2476.111	0	1632.415
2002	0	3.120	2199.128	0	1654.929
2003	0	5.102	1869.820	0	1670.030
2004	0	14.694	1656.179	0	1570.366
2005	0	13.008	1491.425	0	1632.172
2006	0	12.388	1166.988	0	1039.430
2007	0	12.173	932.823	0	651.781
2008	0	13.095	960.981	0	224.519
2009	0	3.427	662.623	0	428.302
2010	0	0	0	0	0

Table 2 shows that the amounts of investment in the treatment of industrial pollution and number of employed persons have redundancy to a different degree, which suggest that the input allocation of Sichuan province should be optimized. From the output index of annual per capita consumption, it has a high living standard, and per capita GDP can be improved to increase the output level. Table 3 gives the evaluation result of DMU 2009 to explain how to adjust the input and output indexes.

Table 3. Evaluation result of DMU 2009

	Electricity Consumption	Investment in the Treatment of Industrial Pollution	Number of Employed Persons	Annual per Capita Consumption	per Capita GDP
Original value	1324.610	9.619	4756.620	6863.000	17339.000
Radial movement	-25.295	-0.184	-90.834	0	0
Slack movement	0	-3.427	-662.623	0	428.302
Projected value	1299.315	6.008	4003.162	6863.000	17767.302

It is easy to see that both radial movement and slack movement of annual per capita consumption are zero which means that this index reaches the optimum state. And the rest of indexes need to be improved. In general radial movement is the radial distance from the frontier for DMU excluding the slack movement.

$$\text{Radial movement} = -\text{Original value} \times (1 - \text{Total efficiency value}) \quad (3)$$

And s^{*-} and s^{*+} are slack movements in the model. The amount of investment in the treatment of industrial pollution and the number of employed persons are influenced by radial movement and slack movement in 2009. Therefore the projected value should be adjusted according to these two movements. This paper takes the amount of investment in the treatment of industrial pollution as an example:

Projected value (6.008) = Original value(9.619)-
Radial movement(0.184)- slack movement(3.427)

After adjusting the input indexes, the effectiveness of output can be improved. The projected value of per capita GDP will increase from 17339 yuan to 17767.302 yuan. The other DMU with non DEA efficiency can be improved by the same manipulation. The traditional development pattern which is at the expense of resources and environments in previous years should be changed. We come to recognize the importance of environmental protection and ecological balance. Then the sustainable development target of Sichuan Province can be met in deed.

5. Conclusion

The CCR model is used to evaluate the sustainable development capability of Sichuan province for the period 2001-2010. The results show that the sustainable development capability of Sichuan province gets improvement since the launch of China's Grand Strategy of Developing the West. The input-output structure of Sichuan province is optimized after input-increasing and self-regulation. And the DMU with non DEA efficiency can be adjusted according to the radial movement and slack movement. Furthermore, the selection of input-output indexes and DMU is quite important, and we will investigate analysis for other situation in our future works.

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