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Analysis of the Efficiency of Public Environmental Expenditure Based on Data Envelopment Analysis (DEA)-Tobit Model: Evidence from Central China

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ABSTRACT

The increasing noticeable economic development that impact the environment increases attention on environmental protection and governance as observed by the government. Public finance expenditure on environmental protection has played an important role in controlling environmental pollution and protecting ecological environment. To explore the defects in the fiscal spending on environmental protection using Data Envelopment Analysis (DEA) model and Tobit regression, the efficiency of public environmental expenditure in Central China from 2007 to 2015 was evaluated, and the factors that influence the efficiency of fiscal spending on environmental protection were discussed. Results reveal that fiscal spending on environmental protection in the remaining five provinces is technically inefficient, except for Hubei Province in Central China. Moreover, large differences exist among provinces in a different stage of scale return. The GDP per capita has a significant positive impact on the efficiency of fiscal expenditure on environmental protection, whereas the level of urbanization and industrialization has a significant negative impact on the efficiency of fiscal expenditure on environmental protection. The conclusions provide a decision-making reference for improving the efficiency of public environmental expenditure.

INTRODUCTION

The rapid growth of China's economy in the last 30 years did not only improve people's living standard, but also increased the overall strength of China's economy while conversely paying a huge cost on resources and environment. Long-term extensive mode of development has partially resulted in excessive consumption of resources and serious destruction of ecological environment in the process of economic development, which brought huge resources and environmental pressure to China. The coordinated development of ecological environment and economic society has become a key problem that requires urgent solutions in economic construction. This issue is also the core content in China's attempt to attain sustainable development. To solve the imbalance of regional economic development and the problem of "the collapse of the central region", in 2016, China issued the 13th Five-Year plan to promote the rise of the central region by comprehensively endorsing the economic construction. The plan emphasized the development method of low-carbon green, thereby strengthening the strict control of environmental pollution by increasing environmental protection investment as the focus of public expenditure with the dramatic increase in expenditure scale. Based on the Central China as example, the fiscal environmental expenditure of six central provinces in 2007 was 249.99 billion RMB. In 2015, the expenditure increased to 716.01 billion RMB. Expenditure increased three times within nine years. However, the large amount of financial funds for environmental governance and protection attracted significant attention in terms of the efficiency of environmental protection expenditure. Although China's environmental investment has a positive impact on environmental performance (Lin 2010), the efficiency of environmental protection expenditure was relatively low from the view of the service efficiency of funds (He et al. 2011). Significant differences exist between different regions as well (Jin et al. 2011). In addition, most scholars employed Data Envelopment Analysis (DEA) to evaluate the efficiency of environmental expenditure. However, a lack of discussion exists on factors that affect the efficiency of environmental expenditure, especially in the Central China. This study attempts to evaluate the efficiency of public environmental expenditure in the six central provinces from 2007 to 2015, and to analyse the reasons that affect efficiency difference in the financial environmental expenditure. It is hoped that the relevant conclusions can provide a decision-making reference for improving the efficiency of public environmental expenditure.

STATE OF THE ART

Environmental expenditure is an important part of the government's financial expenditure. In view of the efficiency of government fiscal expenditure, existing literature gener-

ally utilized the DEA method to evaluate overall efficiency. Lovell et al. (1993) evaluated the efficiency of government expenditure in some cities of Belgium using non-parametric boundary DEA methods. Local tax rate, educational level, and the characteristics of the political environment affected the efficiency of fiscal expenditure. Worthington (2000) analysed the overall efficiency of the municipal government's fiscal expenditure in Australia, whereas Balaguer-Coll et al. (2002) evaluated the efficiency of the municipal government's fiscal expenditure in Spain, both studies found that a significant difference existed in the efficiency among different cities. Wei (2009) analysed the structural and scale efficiencies of China's government expenditure and found that China's fiscal expenditure was inefficient in the past between 1991 and 2005. On the basis of establishing the government financial input-output index system, Liu (2009) empirically analysed the efficiency of fiscal expenditure in China's provinces using the DEA method.

Citizen demand for environmental quality increased with the continuous improvement of social development. The government must annually invest a significant amount of financial funds to tackle the problem of environmental pollution; thus, the efficiency of financial environmental expenditure also became a hot topic. Halkos et al. (2015) found that the US government played a positive role in improving the environmental quality by increasing the public expenditure of the health and environmental sectors from 1973 to 2013. Bernauer et al. (2006) also found that the populist government would increase public investment to enhance environmental protection, thereby improving the quality of the people's living environment. By contrast, the ongoing public investment of a dictatorial government only reflects the interests of the ruling class, which frequently causes inefficiency in the environmental protection input; such an effect from elitist governance will further exacerbate the degree of environmental pollution and subsequently lead to the decline in the living environment of the public (Bernauer et al. 2006). Zhao et al. (2011) used the SBM model to analyse the efficiency of environmental governance and its changing situation from various cities in Jiangsu Province; they classified the efficiency output of different regions according to the calculation results. Wu et al. (2006) evaluated the efficiency of environmental protection expenditure of Hebei Province in China through the DEA method and found the existing problem on environmental expenditure, which was seriously taking effect but despising efficiency (Wu et al. 2006). Sun et al. (2016) evaluated the efficiency of financial environmental protection expenditure on the municipal government in Jilin Province using the DEA-Tobit two-stage model; they found that obvious differences existed among fiscal expenditure efficiency values of environmental protection in different regions (Sun et al. 2016).

Existing research showed that the DEA method is a practical way of analysing the efficiency of government financial environmental protection expenditure. Therefore, under the realistic background of the construction of the Central Plains Economic Region in China. This study employs the DEA method to estimate fiscal expenditure efficiency of environmental protection in six central provinces, and constructs a Tobit regression model to analyse the factors that influence the efficiency of public environmental protection expenditure to offer decision reference when establishing scientific and reasonable insurance expenditure policy.

METHODOLOGY

Model setup: DEA is a nonparametric boundary analysis method frequently used to solve efficiency problems in multiple input and output (Banker et al. 1984). If n decision units exist in the DEA model, each decision unit has p input and q output. X_i and y_i represent the input column vector and output column vector of the Ith decision unit respectively. X and Y represent the input matrix of the order and the output matrix of the order, respectively. Therefore, the technical efficiency of the Ith decision unit can be obtained using formula (1) as follows:

$$\begin{cases} Max_{\theta,\lambda}\theta \\ s.t. -y_i + Y\lambda \geq 0 \\ \theta x_i + X\lambda \geq 0 \\ \lambda \geq 0 \end{cases} \quad ...(1)$$

Technical efficiency θ measures the distance between the decision unit and the efficiency front. When $\theta<1$, the ith decision unit does not reach the frontier of efficiency and the efficiency is low. When $\theta=1$, the ith decision unit is in the frontier of efficiency. λ denotes $(n \times 1)$ order of constant vector. The decision unit maps the weight to the efficiency front.

Based on the above process, this study establishes the input-output DEA model to evaluate the efficiency of fiscal environmental expenditure of six provincial governments in the Central China. This research option is consistent with the idea proposed by Sun et al. (Sun et al. 2016), which considers the government fiscal expenditure for environmental protection as input indicators and annual wastewater treatment capacity, garbage disposal, and industrial sulphur dioxide emissions, as output indicators. Using the value of efficiency evaluated by the DEA model as the dependent variable and its influencing factors as the independent variable, we construct the Tobit regression model and discuss

the main factors affecting the efficiency of the government's environmental expenditure in the Central China. This process includes selecting the influencing factors based on the method proposed by Cheng et al. (2017), the influencing factors are the economic development level of the local government, urbanization level, and industrialization level.

The Tobit regression model is a linear probability model with limited variables. The regression analysis of the related factors is used to avoid the problem of data truncation. The Tobit regression equation is illustrated using formula (2):

$$Y_{jt} = \alpha X_{jt} + \beta_j + \varepsilon_{jt} \quad ...(2)$$

Where, Y_{jt} represents the efficiency of public finance environmental expenditure in the Central China; ε_{jt} is a random disturbance; X_{jt} represents the factors affecting the efficiency of environmental expenditure, including per capita GDP, urbanization level, and industrialization level. Urbanization level is measured by the proportion of non-agricultural population in cities and towns. Industrialization level is measured by the proportion of industrial production in each city. To reduce the heteroscedasticity of regression, the per capita GDP is taken as a natural logarithm.

Data: China adjusted the subject of environmental pollution control expenditure since 2007. The subject of environmental protection expenditure is incorporated into the budget. Therefore, based on the availability of data, this study selects years from 2007 to 2015 as the research period. The original data used, is from the statistical yearbook of China from 2007 to 2015. The descriptive statistics of the variables are shown in Table 1.

RESULTS ANALYSIS AND DISCUSSION

Analysis of comprehensive efficiency value: In this study, nonparametric estimation model-DEA based on variable scale returns is used to measure the comprehensive efficiency of local governments' environmental investment in the Central China based on output orientation. Calculation is implemented using Deap 2.1 software. The results are shown in Table 2.

Results from the analysis of Table 2 are explained as follows:

First, from the perspective of regional dimension, only Hubei's efficiency of fiscal environmental expenditure is effective in Central China. The fiscal environmental expenditure in the other five provinces generally manifests the phenomenon of technical inefficiency. The efficiency of the five provinces has further improvement space. Five provinces demonstrate the phenomenon of inefficiency in the financial environmental expenditure from 2007 to 2015. In particular, Jiangxi Province has a high comprehensive utilization rate of environmental protection funds with an average efficiency of 0.983, which is at the forefront of technology. Anhui Province is at the lowest level of comprehensive efficiency in the fiscal environmental expenditure, with an average efficiency of only 0.788.

Second, from the perspective of time dimension, significant differences exist in the efficiency of fiscal environmental expenditure from 2007 to 2015. The average comprehensive efficiency of the fiscal environmental expenditure in the Central China in 2010 is higher than that in other periods with an efficiency value of 0.985. The average comprehensive efficiency in 2007 is only 0.736, which is significantly lower than in other periods. This phenomenon is probably caused by the Chinese government's inclusion of environmental protection expenditures into the budget only from 2007. Subsequently, the average comprehensive efficiency of the fiscal expenditure for environmental protection in the Central China slowly increased. This finding is connected with China's focused attention to those not in line with the highly coordinated development of the environment and economy in recent years from the government to the common people. The comprehensive efficiency of financial environmental protection expenditure in the Central China significantly improved since 2007, but a small fluctuation occurred in 2010, which may be related to the rapid growth of the fiscal environmental expenditure and the mismatch among the environmental governance facilities of the provinces.

Third, from the perspective of returns to scale, Henan, Shanxi, and Hubei Provinces in Central China are at the stage of constant returns to scale. Anhui, Jiangxi, and Hunan have increasing returns to scale. Thus, the provinces of Anhui, Jiangxi, and Hunan still have not reached the optimal scale in this regard, which provides them room to improve efficiency. They can continue to increase the intensity of fiscal expenditure for environmental protection and take corresponding measures to improve the comprehensive efficiency of the government's fiscal expenditure on environmental protection.

Tobit regression analysis: Through calculation via the DEA model, obvious differences exist in the efficiency of government financial environmental protection expenditure in the Central China. The difference in the efficiency of environmental expenditure is explained as follows: Apart from the factors of input and output, existing research also found that the level of economic development, urbanization level, and industrialization level will affect the efficiency of the fiscal expenditure on environmental protection. First, the continuous improvement of the level of eco-

nomic development prompted the public to shift their attention to the coordinated development of the ecological environment and the economy, thereby increasing the demand and expectation of environmental governance and promoting the improvement of environmental governance level (López et al. 2014). Economic growth simultaneously provides sufficient financial support for environmental governance. Second, the continuously progressing urbanization and the accelerated flow of population cause the increase in domestic waste and traffic pollution, which increased the burden of environmental governance (Andreoni et al. 2001). Finally, the construction of the Central Plains Economic Region in China and the industrial transfer from the Eastern China to the Central China caused the slow increase of industrial output of the central region. Industrial development drives the economic development, but it also brings significant pressure and challenge to the environment. Industrialization level also affects the efficiency of financial environmental expenditure (Pan 2013). Therefore, the present study further analyses the reasons affecting the difference in the efficiency of the government's environmental investment in the Central China.

Combined with this view, we use the fiscal environmental expenditure efficiency as a dependent variable by considering the influencing factors as independent variables, including the level of economic development, urbanization level, and industrialization level, to establish the Tobit regression model.

$$Y_{jt} = \alpha_1 Lngdp_{jt} + \alpha_2 City_{jt} + \alpha_3 Industry_{jt} + \beta_j + \varepsilon_{jt} \quad ...(3)$$

In formula (3), j represents six central provinces, including Henan, Shanxi, Anhui, Hubei, Jiangxi, and Hunan; t means time, that is, from 2007 to 2015. β is a constant term; *Lngdp* means the logarithm value of the per capita gross product; *City* shows urbanization level; *Industry* shows industrialization level; ε is the random error term of the regression equation. The analysis results of the Tobit regression model are shown in Table 3.

Table 3 gives that the coefficient of *Lngdp* is 0.014, which is significant at the level of $p < 0.001$. This finding means that the level of economic development in the central region has a significant positive impact on the efficiency of fiscal environmental expenditure. The result is consistent with the findings of Pan (2013), which proves that with the continuous growth of the economy, the efficiency in the fiscal environmental expenditure in the Central China is also increasing. The coefficient of urbanization level and industrialization level is -1.281 and -0.223, respectively, which is negatively significant at $p < 0.01$ level. This result mean that the urbanization level and industrialization level in the Central China has a significant negative impact on the efficiency of fiscal expenditure on environmental protection; this result is consistent with Zhu et al. (2014). In the process of urbanization, the continuous influx of rural population into the city will significantly increase the emissions of domestic waste and traffic vehicle emissions. This phenomenon will result in a reduced efficiency in the fiscal expenditure for environmental protection in the Central China. With the increasing scale of industrial production, the growth of pollutant consumption and the discharge of pollutants, such as industrial wastewater and exhaust gas, also partially lead to a decline in the efficiency of financial environmental expenditure in the central region.

Based on the above analysis results, we can further improve the efficiency of fiscal environmental expenditure in the Central China from the following aspects. First, the scale of fiscal expenditure in the Central China can be adjusted and the efficiency of using fiscal expenditure should be improved. Henan, Shanxi, and Hubei Provinces can maintain the level of the existing financial environmental protection expenditure, and Anhui, Jiangxi, and Hunan Provinces should increase their fiscal environmental protection expenditure to improve and increase the efficiency of financial environmental protection expenditure. Second, the structure of fiscal environmental expenditure in the Central China should be optimized and the supervision of the use of funds should be strengthened. The results in Table 2 show that, apart from Hubei Province, the other five provinces in the Central China have a problem of low efficiency in fiscal environmental protection expenditure. Therefore, the transparency of using the government's financial environmental expenditure and the supervision of the use of funds should be strengthened. Third, the industrial structure can be adjusted and the transformation of the mode of economic growth should be realized. From 2007 to 2015, the Central China slowly reduced the proportion of the first and second industries and increased the proportion of the third industries. Based on this finding, governments should guide financial funds to the fields of energy conservation, environmental protection, and service industry. Moreover, governments should encourage the development of industries with high technology content and energy-saving and emission reduction characteristics. For example, Henan Province takes Zhengzhou as the head of the provincial capital to fully maximize the advantages of its exhibition tourism industry. Fourth, the scale of urban development should be reasonably controlled. The rapidly progressing urbanization caused a large influx of population, which creates the problems of population congestion, and traffic jam. These issues increase the difficulty in environmental governance. There-

Table 1: Descriptive statistics of variable index.

	Variable	Mean	Maximum	Minimum deviation	Standard
Input index	Government investment in environmental protection (billion RMB)	83.67	119.34	41.67	24.91
Output index	Annual discharge of waste water (ten thousand tons)	244284.26	285081.6	202718.5	30270.31
	Garbage disposal (10000 tons)	409.01	459.24	374.49	26.35
	Industrial sulphur dioxide emissions (tens of thousands of tons)	842467.12	959196.52	736644.06	63753.51
Influencing factors	Natural logarithm of per capita GDP	10.24	10.60	9.62	0.35
	Urbanization level	0.46	0.52	0.4	0.04
	Industrialization level	0.44	0.47	0.4	0.02

Source: author's calculation.

Table 2: Comprehensive efficiency of environmental protection expenditure in central China from 2007 to 2015.

Province	2007	2008	2009	2010	2011	2012	2013	2014	2015	Mean	Returns to scale (2015)
Henan	0.366	0.745	1	1	1	0.791	1	1	1	0.878	-
Shanxi	0.689	1	1	1	1	1	1	1	1	0.965	-
Anhui	0.496	0.542	0.882	0.989	0.749	0.877	0.848	0.830	0.881	0.788	IRS
Hubei	1	1	1	1	1	1	1	1	1	1	-
Jiangxi	1	0.907	1	1	1	1	0.994	0.988	0.959	0.983	IRS
Hunan	0.864	1	1	0.923	0.874	0.916	0.849	0.737	0.874	0.893	IRS
Mean	0.736	0.866	0.980	0.985	0.937	0.931	0.949	0.926	0.952	0.918	

Note: "-" in the table means that the returns of scale are constants, and "IRS" means increasing returns to scale.

Table 3: Analysis results of the Tobit regression model.

Influencing factors	Coefficient	Standard error
β	0.391	0.7
Lngdp	0.014***	0.106
City	-1.281**	0.830
Industry	-0.223**	0.452

Note: *indicates p<0.05, **indicates p<0.01, ***indicates p<0.001.

fore, pursuing urbanization necessitates holistic planning of the urban infrastructure of all provinces.

CONCLUSION

This study used six provinces in the Central China as examples and employed the DEA-Tobit model to evaluate the efficiency of fiscal environmental expenditure from 2007 to 2015. Empirical analysis is conducted to study the influence degree of the economic development level, urbanization level, and industrialization rate on the efficiency of the fiscal environmental protection expenditure. The following conclusions are then obtained:

1. Except in Hubei Province, the financial environmental expenditure in the remaining five provinces in Central China manifests technical inefficiency. Large differences exist among the provinces. Hubei, Shanxi, and Jiangxi are relatively at the forefront of technological efficiency, and the efficiency of environmental input is relatively high. The remaining three provinces are relatively inefficient and environmental governance funds have not been fully utilized.
2. The provinces in the Central China are in different stages of returns to scale. In particular, the three provinces of Henan, Shanxi, and Hubei are in the stage of constant returns to scale. Anhui, Jiangxi, and Hunan have increasing returns to scale. Thus, the input and optimal input of environmental protection in Henan, Shanxi, and Hubei Provinces are roughly equivalent.
3. The average GDP per capita in the Central China has a significant positive impact on the efficiency of fiscal expenditure on environmental protection, whereas urbanization and industrialization levels have a significant negative impact on the efficiency of fiscal environmental expenditure.

The conclusion of this study can offer a certain theoretical reference and decision support to improve the efficiency of government public environmental protection expenditure, but shortcomings still exist in the selection of factors that affect the efficiency of the financial environmental expenditure. In future studies, we will consider the relation-

ship among openness level, educational level, population density, and the efficiency of fiscal expenditure on environmental protection. Moreover, we intend to explore the influence of different factors on the efficiency of fiscal environmental expenditure.

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