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Zhang Fanyong[1,2*]，Du Yueping[1]

[1]School of Economics and Management，Xi'an Shiyou University，Xi'an Shaanxi 710065，China

[2]School of Economics & Management, Xidian University, Xi'an Shaanxi, 710126, China

[*]Corresponding author's e-mail: 38389509@qq.com   TEL:18691456159

Abstract. Based on the three-stage DEA-Windows method, we evaluated the environmental regulation efficiency of 30 provinces in China from 2000-2015. Environmental regulations were efficient, with a fluctuation of about 0.66, following the order eastern regions > central regions > western regions, with significant differences between provinces. In addition，regulation efficiency was affected by the level of the local economic development, the industry structure, the FDI index, the population density, and the marketization level. Efforts should be made to strengthen environmental regulations, formulate adequate policies, and coordinate the relationship between economic development, industrial structure, FDI, and environmental regulation.

1. Introduction

Since the 1990s, with the rapid development of the economy, environmental problems, such as excessive exploitation of resources and wanton destruction, have been intensifying in China. The government has launched a number of economic development concepts such as "scientific development" and "green development" and formulated environmental policies and regulations, including *Regulations on the Collection and Use of Pollutant Discharge Fee* and the *New Environmental Protection Act*, in order to regulate economic activities and to promote the coordinated development of the environment and the economy. However, environmental problems in China are still severe, and studies on the efficiency of environmental regulations have become a focus of academic research.

In general, three different methods can be used to investigate the efficiency of environmental regulations. The first method implies the use of the Environmental Kuznets Curve, such as the research of Dasgupta et al. [1]. The second method consists of a metrological model to analyze the efficiency of environmental regulations in terms of emission reduction, such as the research of Hettige et al. [2]. The third method considers that the environmental regulation efficiency is equivalent to the input-output efficiency of environmental regulations, advocating the investigation of environmental regulation efficiency via a cost-benefit analysis, such as the research of Robert [3]. In China, research on environmental regulation efficiency is commonly performed via cost-benefit analysis, using the data envelopment model to measure environmental regulation efficiency. Xu et al. [4] employed the super-efficiency DEA model to measure the environmental regulation efficiency of various provinces and cities in China. Wang [5] analyzed the development status of China's environmental regulation

efficiency, based on the DEA model and the spatial autoregressive model. Huang and Gao [6] considered that environmental regulations were indeed efficient, albeit the efficiencies of different provinces varied.

Related studies generally use the cost-benefit method and the DEA model to build the input- output index system to measure the efficiency of environmental regulations. However, the output indices are generally relative indices (e.g. Xu et al. [4], Chen et al. [7]), it will lead to deviation efficiency measurements from reality from actual situations. Hence, more accurate measuring methods are required to supplement the existing research. In this context, we selected absolute indices to build the corresponding input-output index system and employs the three-stage Window-DEA model to analyze input and output data during 2000-2015 in 30 provinces and cities in China. On this basis, we evaluated the environmental regulation efficiency and propose corresponding countermeasures and suggestions.

2. Establishment of the input-output index system and variable selection

2.1 Establishment of input indices
Considering quantifiability and data availability, in this article, we selected the quantifiable indices "human input", "material input", and "financial input" from three dimensions as the input indices of environmental regulations.

(1) Human input index: Human input is measured by the total number of staff in the environmental protection system. The data were derived from the *China Environment Yearbook.*

(2) Material input index: Material input is measured by the number of specific facilities. The data were obtained from the statistical summation of industrial wastewater treatment facilities and exhaust gas treatment facilities in the *China Environment Yearbook.*

(3) Financial input index: Financial input is measured by the aggregate investment into environmental pollution mitigation. The data were derived from the statistical summation of infrastructure investment for municipal environment, investment for treating industrial pollution sources, and the environmental protection investment for "three simultaneous" projects.

2.2 Establishment of output indices
In this study, we selected data for five indices from the *China Environment Yearbook*, including the removed amount of industrial fumes, the removed amount of industrial dust, the removed amount of industrial SO_2, the comprehensively use amount of industrial solid waste, and the volume of industrial wastewater discharged to measure the output of environmental regulations. Although these five indices cannot accurately reflect all the improvements, they can basically represent the environmental improvement as a consequence of environmental regulations.

2.3 Selection of environmental variables
Referring to previous studies, this article selected five environmental variables, as follows:

(1) Regional economic development level. We employed the regional GDP per capita to measure the regional economic development level, using data from the *China Statistical Yearbook*.

(2) Industrial structure. We employed the proportion of regional industrial output value to the total output value to measure the regional industrial structure, using data from the *China Statistical Yearbook*.

(3) Foreign direct investment (FDI) index. In this article, we employed the natural logarithm of the foreign direct investment to measure the FDI index, using data from the *China Statistical Yearbook*.

(4) Population density. We employed the ratio of permanent population to land area to measure population density, using data from the *China Regional Economy Statistical Yearbook.*

(5) Marketization level. The marketization level was measured by the ratio of the industrial output value of state-owned and state-holding enterprises to the gross industrial output value, using data from the *China Statistical Yearbook*.

3. Empirical results and analysis

In this article, panel data of provinces in China from 2000 to 2015 were selected for the analysis of the environmental regulation efficiency and its influencing factors. In this study, Pearson's correlation analysis was used for further testing, and the results are shown in Table 1. The coefficients of three input variables and five output variables were positive, passing the significance test at a level of 1%.

Table 1. Pearson's correlation coefficients of regulation efficiency measures

Variables	Amount of removed industrial emissions	Amount of removed industrial dust	Amount of removed industrial SO_2	Amount of industrial solid waste	Volume of industrial wastewater discharged
Human input	0.783*** （0.000）	0.785*** （0.000）	0.576*** （0.000）	0.761*** （0.000）	0.741*** （0.000）
Material input	0.715*** （0.000）	0.775*** （0.000）	0.522*** （0.000）	0.732*** （0.000）	0.866*** （0.000）
Financial input	0.682*** （0.000）	0.546*** （0.000）	0.556*** （0.000）	0.678*** （0.000）	0.584*** （0.000）

Note: ***, **, and * represent significant correlations at 1, 5, and 10% respectively; figures in brackets correspond to P values.

3.1 Window-DEA efficiency analysis in the first stage

By using the input variable as the guide and setting the window width as *d = 3*, the *DEA-SOLVER Pro5.0* software was used to measure the environmental regulation efficiency of every provincial-level administrative region from 2000 to 2015 in China, under the assumption of variable returns to scale. In this stage, environmental factors and random factors were included.

(1) Overall variation of environmental regulation efficiency

Figure 1 shows the overall variation of environmental regulation efficiency in China. From 2000 to 2015, the environmental regulation efficiency fluctuated considerably, with an uncertain direction. Overall, from 2000 to 2015, environmental regulation efficiency in China fluctuated around a level of 0.85.
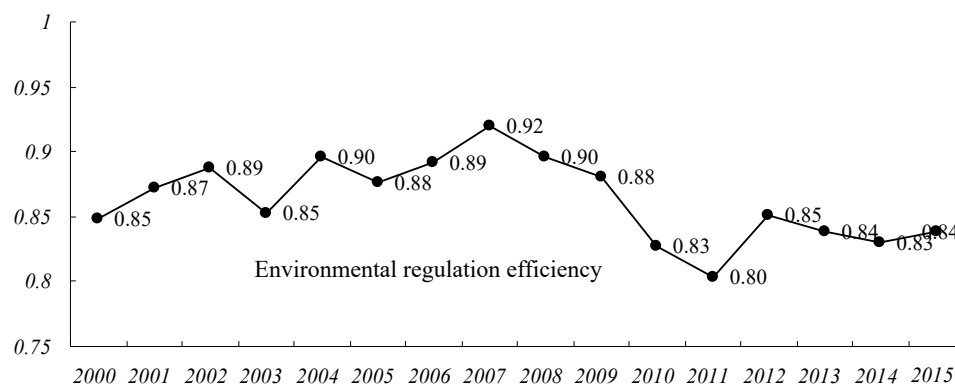

Fig 1. Overall changes in environmental regulation efficiency in China during 2000 to 2015.

(2) Regional variation of environmental regulation efficiency in China

According to the traditional regional division method, the selected 30 provinces and cities were divided into eastern, central, and western regions (Table 2) to analyze the regional differences of the environmental regulation efficiency in China. Figure 2 shows the regional variation in environmental regulation efficiency in eastern, central, and western China. Overall, the variation trends were similar for the three regions. In a regional context, the regulation efficiency was relatively high in central regions, but with high fluctuations.

Table 2. Division of areas and provinces in China.

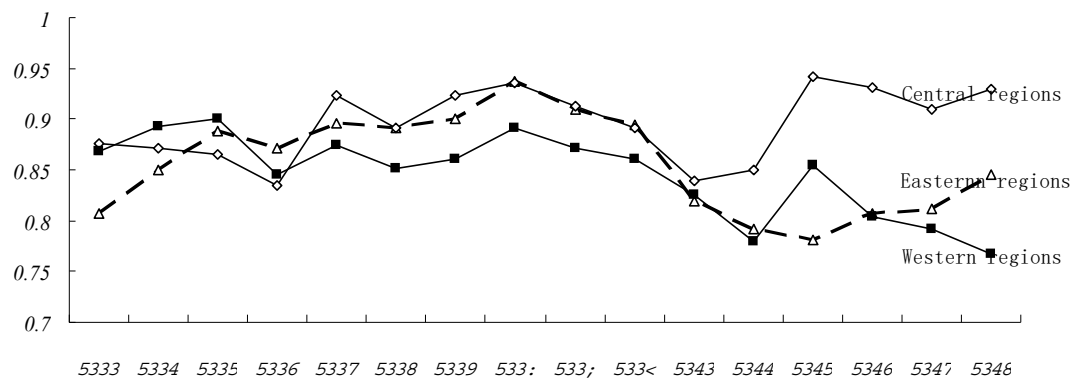| Regional division	Involved provinces
Eastern regions	Beijing, Tianjing, Hebei, Liaoning, Shandong, Shanghai, Jiangshu, Zhejiang, Guangdong, Fujian,Hainan
Central regions	Shanxi, Jilin, Heilongjiang, Anhui, Henan, Hubei, Hunan, Jiangxi
Western regions	Chongqin, Shichuan, Yunnan, Guangxi, Xinjiang, Neimenggu, Ganshu, Shanxi, Ningxia, Qinghai,Guizhou

Fig 2. Initial values of Sub regional environmental regulation efficiency

3.2 Stochastic Frontier Approach panel regression analysis in the second stage
Table 3 shows the SFA panel regression results, which passed the general unilateral likelihood ratio test at the significance level of 1%, indicating that it is feasible to conduct a stochastic frontier analysis on the environmental variables by input slack variables of environmental regulations.

Table 3. SFA panel regression results for the second stage.

	Human input	Material input	Financial input
Constant term	-156.95*** (0.000)	-280.35*** (0.000)	-72.94*** (0.000)
Regional economic development level	-0.59*** (0.000)	-0.84*** (0.000)	0.18** (0.029)
Industrial structure	4866.35*** (0.000)	7021.64*** (0.000)	1934.57*** (0.000)
FDI index	27.38* (0.069)	78.43** (0.037)	-13.70** (0.025)
Population density	1743.42 (0.557)	-2464.34** (0.012)	-1512.29 (0.785)
Marketization level	-106.98*** (0.006)	802.19 (0.347)	645.35 (0.146)
η	0.000	0.019*** (0.000)	0.023*** (0.000)
σ^2	88290.00	34642.00	21420.00
γ	0.394	0.517	0.999
LR unilateral errors	56.43***	52.36***	15.24***
TI or TVD	Time-invariant model	Time-varying recessive model	Time-varying recessive model

Note: ***, **, and * represent that the hypothesis testing is significant at the significance levels of 1, 5, and 10%, respectively; figures in brackets are the corresponding P values.

Table 4 shows that the regression coefficients of the regional economic development level for the variables human input and material input were both negative, passing the significance test at 1%. The regression coefficient of the regional economic development level for the variable financial input was positive, passing the significance test at 5%. These results indicate that the regional economic development level has varying effects on different environmental regulation inputs.

The regression coefficients of industrial structure for the three variables human input, material input, and financial input were positive, passing the significance test at 1%. These results indicate that the higher the proportion of regional industrial economy in the economic aggregate, the higher the consumed resources in the industrial production, resulting in higher amounts of waster water,

emissions, and rubbish.

The regression coefficients of the FDI index for the variables human input and material input were both positive, passing the significance test at 10 and 5%, respectively. The regression coefficient of the FDI index for the variable financial input was negative, passing the significance test at 5%. These results indicate that the FDI index has different effects on different environmental regulation inputs.

Population density had no significant influences on the variables human input and financial input. However, the regression coefficient of population density for the variable material input was negative, passing the significance test at 5%. The marketization level had no significant influences on the variables material input and financial input, but the regression coefficient of the marketization level for the variable human input was negative, passing the significance test at 1%.

3.3 Window-DEA efficiency analysis after excluding interference factors in the third stage

According to the adjustment results for the three variables human input, material input, and financial input, we used the input variables as the guide and set the window width at $d = 3$. Under the assumption of variable returns to scale, the environmental regulation efficiency of every provincial-level administrative region from 2000 to 2015 in China was measured after excluding the interferences from environmental and random factors. The specific steps are as follows:

(1) Overall variation of the environmental regulation efficiency

As shown in Figure 3, after excluding the environmental and the random factors, the overall level of environmental regulation efficiency presented a somewhat decreasing trend as compared to that in the first stage, with a smaller fluctuation range. Overall, from 2000, environmental regulation efficiency showed a trend of fluctuating increase [8].
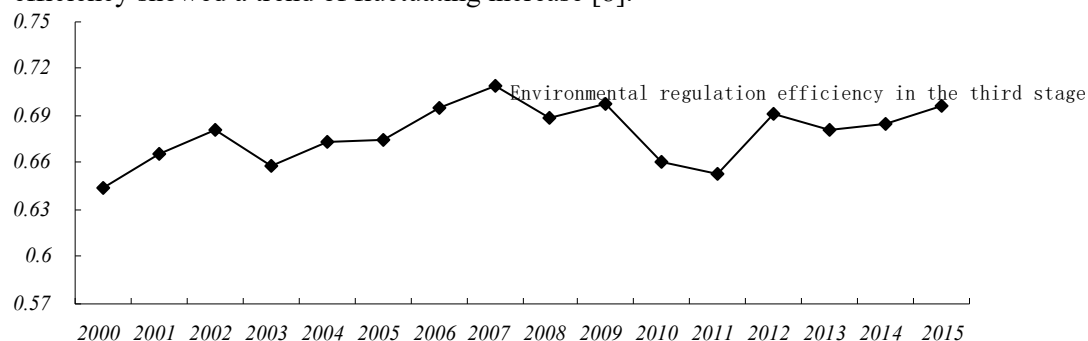

Fig 3.Environmental regulation efficiency in China after eliminating interference factors.

(2) Regional variation of environmental regulation efficiency in China

Figure 4 shows the regional variation of environmental regulation efficiency in the three studied areas after excluding the interference factors. Overall, the variation trends of the regulation efficiency in the three regions were consistent. In a regional context, after excluding the influences of environmental and random factors, environmental regulation efficiency in the eastern regions was significantly higher than in the central or western regions. These results indicate that the environmental regulations in the eastern regions were superior to those in the central and western regions in terms of management, facilities, and technological level. On the other hand, the allocation of resources such as human input, material input, and financial input in eastern regions was more reasonable. Our results also indicate that the strength of environmental regulations in the eastern regions was higher than that in the central regions, while that in the central regions was slightly higher than that in the western regions [9].
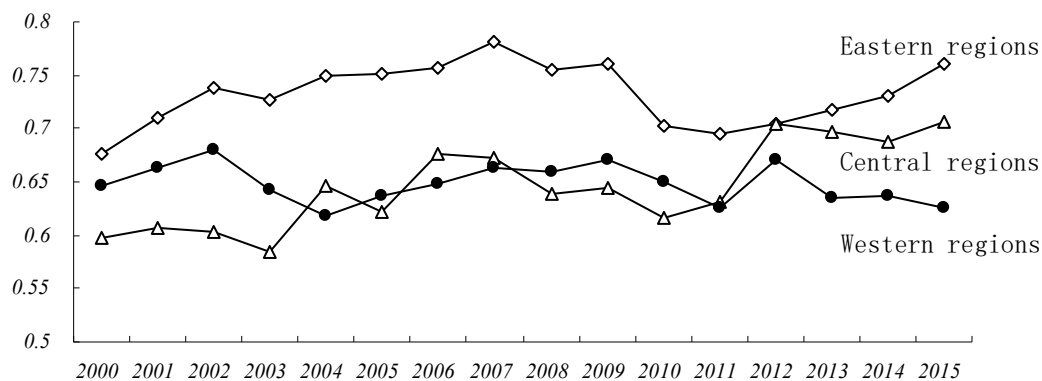
Fig 4. Sub regional Environmental regulation efficiency in China after eliminating interference factors.

4. Conclusions and policy recommendations

4.1 Conclusions
In summary, the environmental regulation efficiency in China was measured by the Three-Stage Window-DEA method, based on panel data for 30 provinces and cities during 2000-2015. We can draw the following conclusions:

(1) According to the national-scale observation on the environmental regulation efficiency in the first and the third stage, the environmental regulation efficiency in China was still at a low level, but environmental regulations were effective, and the efficiency slowly increased. This slow increase could be attributed to the continuous enhancement of environmental regulation strength in China.

(2) According to the regional-scale and provincial-scale observations on the environmental regulation efficiency in the first and the third stage, there were obvious differences between the different regions and between provinces and cities in the same region. This is mainly related to the differences between these regions and provinces in terms of management levels, facilities, and technological levels.

(3) Based on the SFA panel regression analysis in the second stage, factors such as the regional economic development level, the industrial structure, FDI, population density, and marketization level significantly impacted environmental regulation efficiency.

4.2 Policy recommendations
Based on our analysis results, the Chinese Government should pay considerable attention to environmental regulation efficiency, based on the following aspects:

(1) Further enhancing the strength of environmental regulations

It is important to further improve environmental protection efforts with adequate laws and regulations, increase various inputs into environmental regulations, and optimize the implementation of environmental regulations, thus promoting the improvement of environmental regulation efficiency. Particularly, it should be pointed out that the environmental regulation efficiency depends not only on whether the related law and regulation system is strict, but also whether these laws and regulations can be implemented effectively.

(2) Formulating reasonable differentiated environmental regulation policies

The differentiation of environmental regulation efficiency suggests that different regions or even different provinces should implement specific environmental regulations and policies. First of all, the level, the facilities, and the technologies, as well as the corresponding resource allocation efficiency, in the central and western regions should be improved. Secondly, the power of environmental regulations and the policy arrangement should be region- or province-specific. Finally, diversified and compound environmental regulation policy tools should be adopted, and region-specific environmental supervision system should be established.

(3) Coordinating the relationships between economic development, industrial structure, or FDI and

environmental regulation

We should strive to first promote the regional economic development level and avoid extensive growth at the expense of environmental protection. Secondly, when the industrial structure is adjusted, industries causing greater environmental harm should be avoided as far as possible, or, alternatively, measures should be taken to reduce environmental impacts. Thirdly, local governments should supervise the introduction of FDI and prohibit the establishment of industries causing high levels of pollution.

References
[1]   Dasgupta S, Laplante B, Wang H, et al. (2002) Confronting the Environmental Kuznets Curve [J]. Journal of Economic Perspectives, 16(16):147-168.
[2]   Hettige H, Mani M, Wheeler D. (2000) Industrial Pollution in Economic Development: The Environmental Kuznets Curve Revisited [J]. Journal of Development Economics, 62(2):445-476.
[3]   Robert S. (2009) Is Benefit-Cost Analysis Helpful for Environmental Regulation? [J]. Clotwothy Belfer Center, Kennedy School, Harvard University, (4), 219-229.
[4]   Xu chenglong，Ren jianlan，Chen yu. (2014) Influence Factors and Temporal-Spatial Evolution of Environmental Regulation Efficiency in Shandong [J]. Economic Geography，34(12)：35-40.
[5]   Wang Minggang. (2015) A Study on the Regional Difference and Influence Factors of Environmental Regulation Efficiency in China：Based on Analysis of Fixed Effect Model of Spatial Panel Durbin[D].Hangzhou：Zhejiang University of Finance and Economics，2015.
[6]   HUANG Qinghuang，GAO Ming. (2017) Study on the Energy-Saving and Emission-Reducing Effect of Environmental Regulation: Based on the Empirical Analysis of the Panel Quantile [J]. Science of Science and Management of S.&.T.，38(1)：30-43.
[7]   Chen yu，Ren jianlan，Chen yanbin. (2016) Spatial evolution and driving mechanism of China's environmental regulation efficiency[J]. Geographical research，35(1)：123-136.
[8]   Song lin，Lv jie. (2017) Regional difference measurement of environmental regulation intensity in China based on Theil index[J]. Shandong Social Sciences，31(7)：140- 144.
[9]   Wang hongmei. (2016) Comparison and selection of environmental regulation policy in China: based on Bayesian model averaging approach[J]. ,China Population,Resources and Environment，26(9)：132- 138.