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Analysis on the Environmental Governance Efficiency of Local Governments in China and Its Influencing Factors

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Abstract: In this paper, the Three-stage DEA model and Malmquist index method are used to measure the environmental governance efficiency and total factor productivity of 113 cities in China from 2014 to 2017. The empirical results of the Three-stage DEA model show that foreign investment, industrial structure, economic development level, population density, financial pressure and other external factors do have an impact on the efficiency of environmental governance of local governments in China, and seriously underestimate the comprehensive technical efficiency, pure technical efficiency and scale efficiency of environmental governance of local governments. After eliminating the influence of environmental factors and random interference, most cities still have efficiency loss caused by ineffective management. The results of DEA Malmquist index show that the total factor productivity of environmental governance of local governments in China is less than 1 during the sample observation period, which is mainly due to the fact that the comprehensive technical efficiency has not improved and the rate of technological progress has regressed during the observation period. Provincial capital cities suffer more losses than non provincial capital cities due to inefficient resource allocation and management. Therefore, in order to improve the efficiency of environmental governance of local governments in China, we should first improve the efficiency of resource allocation, attach importance to the rational allocation of the scale of resources invested in environmental governance, improve the efficiency of resource allocation and use, and avoid resource waste; secondly, improve the awareness of environmental protection of local governments, and reduce Finally, increase investment in technological innovation, encourage institutional innovation, improve the rate of technological progress, and promote the improvement of total factor productivity.

Keywords: Environmental Governance Efficiency, Three Stage DEA, Total Factor Productivity

1. Introduction

Since China's reform and opening up, the rapid economic development has created remarkable economic achievements, but behind the economic development of China is the serious damage to the ecological environment. The decline of the quality of ecological environment is not only bad for the sustainable development of national economy, but also bad for the physical and mental health of residents. In recent years, the Chinese government has attached great importance to the management and protection of the ecological environment, amended the environmental protection law, successively promulgated "ten articles of atmosphere", "ten articles of water" and "ten articles of soil", improved the requirements of environmental protection, increased the intensity of environmental governance, and promoted the local government to take a series of environmental protection measures while developing the economy. At present, the relationship between the central government and the local government can be described as "political centralization" and "economic decentralization". In China's environmental political system, the central government is mainly responsible for the formulation of environmental protection legislation and standards, while the local government is responsible for the specific implementation, which plays a key role in environmental protection and governance, and affects the actual implementation effect of the central policy.

Finance is the foundation and important expenditure of national governance. In recent years, China's economic development has entered a new normal, and its financial revenue has also changed from high-speed growth to medium and low-speed growth. At the same time, the rigid growth of financial expenditure has not changed, and the contradiction between fiscal revenue and expenditure is prominent. It is difficult to improve the efficiency of environmental governance by increasing environmental protection investment in the short term. Therefore, to improve the efficiency of environmental governance of local governments, we must study At present, the current situation of local government environmental governance, in-depth study of the efficiency of local government environmental governance, mining problems in the allocation and use of environmental protection resources, from the perspective of resource allocation and use, put forward effective ways to improve the efficiency of local government environmental governance.

Combing the relevant literature, we find that the existing literature on the efficiency of local government environmental governance mainly focuses on the following three aspects. First, establish an index system to evaluate the efficiency of local government environmental governance. Fang Qiaoling et al. (2010) [1] constructed a set of performance evaluation index system of environmental protection expenditure from the aspects of economy, compliance, resource allocation efficiency, fund use efficiency and environmental protection effect. Wang Limin et al. (2018) [2] constructed the evaluation index system of local government environmental governance from the evaluation content, evaluation stage, evaluation period, etc. Wang Jiajia et al. (2017) [3] constructed a set of local government environmental governance performance indicator system based on cost-benefit. Cheng Liang et al. (2010) [4] designed a set of evaluation index system specially for the central environmental protection special fund. Wang Bing (2012) [5] constructed a set of comprehensive evaluation model for the use efficiency of financial environmental protection funds from the perspective of financial environmental protection expenditure. The establishment of these evaluation systems is of great significance to the study of China's energy conservation and environmental protection expenditure efficiency. The second is to study and evaluate the efficiency of financial expenditure on energy conservation and environmental protection. Data envelopment analysis (DEA) is the most commonly used method to measure the efficiency of environmental protection. Sun Jing et al. (2019) [6] used super efficiency DEA model to calculate the air pollution control efficiency of Beijing, Tianjin, Hebei and the surrounding 27 environmental protection key cities, and further studied the impact of fiscal decentralization and policy coordination on air pollution control efficiency. WenYuechun et al. (2012) [7] calculated the environmental protection investment performance level of 30 provinces and regions in China from 2003 to 2009 based on DEA method, and classified the evaluation regions according to the environmental protection performance and economic development level. Yuan Haoming et al. (2018) [8] measured the efficiency of environmental protection investment of local governments in China, and found that although there are abundant environmental protection investment in developed regions, their fund use efficiency is at the end of the country, and a large number of environmental protection investment has not achieved corresponding output effect. Yang Qingshan et al. (2012) [9] calculated the environmental efficiency and energy efficiency of the three major urban agglomerations in the northeast, and found that the number of cities in the three major urban agglomerations in the northeast to reach DEA is relatively small, and proposed to further improve the environmental efficiency of the northeast. Liu Qianzhi et al. (2018) [10] used DEA Tobit two-stage model to calculate the financial environmental protection expenditure efficiency of 98 prefecture level cities in the Yangtze River economic belt, and explored the impact of fiscal decentralization, economic development level, population density and other factors on the environmental protection efficiency of local governments. Although these scholars focus on different issues, they all come to the conclusion that the environmental governance efficiency of local governments in China is not high. The third is to study the regional differences of environmental governance efficiency of local governments in China. Yang Jun et al. (2012) [11] used the data of 2004-2008 to study China's regional environmental governance and found that the differences of China's regional environmental governance efficiency exist and gradually expand, and the efficiency of the western region is far from the Middle East. Mao Hui et al. (2014) [12] conducted an empirical test on the relationship between investment in environmental governance and environmental quality, and found that the effect of environmental governance in the central region was the most obvious, followed by that in the western region. These studies show that there are obvious differences in the geographical location, economic development and other aspects among regions in China, which leads to obvious differences in energy conservation and environmental protection expenditures. Zhang Juntao et al. (2019) [13] measured the environmental governance efficiency of 30 provinces dynamically and statically, and found that there were significant differences in environmental governance efficiency among the four economic sectors.

To sum up, the existing literature has laid a good foundation for this study, but there are still deficiencies. First, most of the existing research results verify the current situation of China's environmental governance from the national or provincial level, but the main undertaker of environmental protection work is the grass-roots government, and the lower the level of local government, the higher the proportion of environmental governance work undertaken. Therefore, compared with the provincial government, the research on environmental governance of municipal government can more truly reflect the actual situation of China's environmental protection work. Second, many literatures are based on the traditional DEA model, ignoring the impact of external environmental factors and random interference factors on the efficiency of environmental governance. However, China is a vast country, and the economic and social development between regions is extremely unbalanced. Without removing the external environment and random interference factors, it cannot truly reflect the input-output level of local government environmental governance. Third, the ultimate goal of environmental governance is to improve the living environment, but the existing research output indicators are limited to the treatment of industrial pollution, ignoring the establishment of residents' living environment indicators. In this paper, based on the existing research, the panel data of 113 prefecture level cities and above in China are used to construct the evaluation index system of local government environmental governance. The Three-stage DEA is used to eliminate the influence of external environment and random interference on the evaluation results, and the Malmquist index method is used to calculate the total factor productivity of local government environmental governance, so as to provide the government with environmental governance Resource allocation and use provide useful reference.

2. Research and Design

2.1. Sample Selection

In 2012, China revised and promulgated the ambient air quality standard, and then implemented it in stages nationwide. The new air standard added the requirement of PM2.5 concentration, which made the excellent days under the new and old standard system not comparable. In order to prevent the inflection point of the research data, this paper takes the cities that monitored PM2.5 and released air quality information in 2014 as samples. According to the data availability, 113 cities at prefecture level and above are finally determined as the research objects, including 37 eastern cities, 40 central cities, 25 western cities and 11 northeast cities.

2.2. Variable Selection and Measurement

Previous literature research shows that government investment in environmental governance usually includes human and financial resources, so this paper chooses financial energy conservation and environmental protection expenditure and environmental management practitioners as input variables. In order to reflect the local government's treatment of major pollutants and improvement of environmental quality, this paper selects four output indicators from the perspective of environmental pollution treatment and ecological environmental quality to reflect the supply level of local government's environmental protection services. Specifically, it selects the sewage discharge per unit of industrial output value and the comprehensive utilization rate of industrial solid waste to measure environmental pollution treatment, among which the unit of industrial output value is selected The sewage discharge is a negative output index, which is treated in the reciprocal way; the days when the air quality reaches or is better than the second level and the green coverage rate of the built-up area are selected to represent the ecological environment quality.

The efficiency evaluation after eliminating environmental factors and random interference factors can more accurately reflect the environmental governance efficiency of decision-making units. Environmental variables should be factors that affect the environmental governance efficiency of local governments but not within the subjective control range of local governments. Based on the existing research, this paper chooses: 1) foreign investment. Foreign investment is an important engine to stimulate economic development and an important target of local government competition. There has been a “pollution paradise” hypothesis in academia, which holds that local governments will relax environmental regulations and increase environmental pollution in order to compete for foreign investment. This paper uses the annual average exchange rate in China Statistical Yearbook to adjust FDI to RMB measurement to eliminate the impact of exchange rate changes. 2) industrial structure. Industrial structure is an important factor affecting environmental quality. Compared with the first industry and the third industry, the industrial production process has the largest pollutant emissions, which is harmful to the ecological environment. 3) population density. Population density is closely related to environmental pollution. Generally speaking, cities with high population density have higher efficiency in environmental pollution control than those with low population density due to the corresponding scale. In this paper, the permanent population per square kilometer is used to represent population density. 4) economic development. The Environmental Kuznets curve shows that when the level of economic development is low, economic growth is accompanied by the increase of environmental pollution. However, when the level of economic development reaches a certain level, the demands of the residents for the quality of ecological environment will gradually increase. Economic growth is negatively related to the discharge of pollutants, and the degree of environmental pollution will gradually slow down. In this paper, the GDP is used to measure a regional economy Economic development level; 5) financial pressure. The greater the fiscal pressure is, the more local governments attach importance to the stability of financial resources and economic growth, and it is easy to relax the work of local environmental protection and governance, resulting in the low efficiency of local government environmental governance. This paper chooses the ratio of fiscal revenue gap to fiscal revenue to measure the fiscal pressure. [14] In order to reduce the multicollinearity between variables, this paper takes the logarithm of FDI and GDP as usual.

All data sources of this paper are China Statistical Yearbook, China Environmental Yearbook and China Urban Yearbook over the years, some of which are obtained by consulting relevant regional statistical yearbooks. The descriptive statistical analysis results of variables are shown in Table 1.

Table 1. *Statistical description of research variables.*

Indicator type	Variable name	Variable definition	Mean value	Variance	Maximum value	Minimum value
Input variables	Environmental expenditure	Energy saving and environmental protection expenditure (Million yuan)	8460.000	1.734×10^{12}	21304.000	18.950
	Environmental management practitioners	Employees in water conservancy, environment and public facilities management (Thousand Persons)	798.000	856.357	56.263	0.798
Output variables	Comprehensive utilization rate of industrial solid waste	Comprehensive utilization rate of general industrial solid waste (%)	80.451	491.850	100.000	14.400
	Sewage discharge per unit industrial output value	Industrial wastewater discharge / added value of secondary industry (Ton / Yuan)	2895.300	4.83×10^{7}	1.349×10^{5}	87.633
	Air quality	Days of air quality reaching or better than level II (Days)	253.712	3528.761	401.000	79.000
	Green coverage	Green coverage rate of built-up area (%)	41.186	19.736	57.940	20.325
Environ ment variables	Foreign investment	Actual amount of foreign investment used in the current year (Thousand yuan)	6.288	0.611	7.831	2.970
	Industrial structure	Output value of secondary industry/GDP (%)	0.466	0.008	0.732	0.181
	Population density	Permanent population persquarekilometer (Person/km^2)	532.739	1.277×10^{5}	2648.110	50.810
	Economic development level	GDP (Million yuan)	5.324	0.167	6.352	3.911
	Financial pressure	(Local fiscal expenditure-Local fiscal revenue)/General public budget revenue (%)	0.767	3.066	34.953	-0.351

2.3. Method Introduction

Data envelopment analysis (DEA) is an efficiency evaluation method proposed by operations researcher Charnes, copper & Rhodes (1978). Its advantage is that it can evaluate the relative efficiency of decision-making units with multiple inputs and outputs at the same time. However, the traditional DEA model assumes that all decision-making units are in the same external environment and luck level, which can not reflect the influence of the external environment and random interference on efficiency measurement. Therefore, fried combines the traditional DEA model with the stochastic frontier analysis (SFA) to establish a Three-stage DEA model, which enables the calculation of efficiency value to eliminate the influence of external environmental factors and random interference factors, and truly reflects the internal management level of the decision-making unit. The traditional DEA model is to evaluate the production efficiency of the decision-making unit for a certain time of production technology, and its efficiency value cannot be compared across years. Caves combines Malmquist index with DEA model to calculate the efficiency of decision-making units with different observation values at multiple time points, and can further analyze the changes in productivity, technical efficiency and technological progress, so as to realize the reflection of the changes in the cross period efficiency of decision-making units.

3. Calculation Results of Environmental Protection Efficiency of Local Governments

3.1. Efficiency Value of DEA Model in the First Stage

Based on the above analysis, this paper uses deap2.1 software to select the input-oriented BC2 model to calculate the environmental protection efficiency of 113 cities in China from 2014 to 2017. From the calculation results, the average comprehensive technical efficiency of 113 cities is increasing year by year. In 2015, the efficiency value of environmental governance in all regions of the country has been greatly improved. The reason may be that the most stringent environmental protection law in history has been officially implemented, and the Chinese government has the sharpest weapon in environmental governance. At the same time, the central department brings the top leaders of local governments into the “interview”object, which directly increases the pressure of local governments on environmental protection, effectively improves the attention of local governments on environmental governance, and improves the low efficiency of environmental governance. In general, although the efficiency of local government environmental governance has improved significantly during the sample observation period, the efficiency value is still at a low level.

Further analysis shows that (Table 2) the low comprehensive efficiency of environmental governance of local governments in China is caused by the ineffectiveness of pure technical efficiency and scale technical efficiency. Although the growth rate of pure technical efficiency is not large during 2014-2017, the scale efficiency is greatly improved, which is the main reason for promoting the effective improvement of comprehensive technical efficiency. In terms of different regions, the environmental governance efficiency of local governments in the four regions has been significantly improved during the sample observation period, with the most significant increase in scale efficiency.

Table 2. *Environmental governance efficiency of local governments by Region.*

Region	2014			2015			2016			2017		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
Whole country	0.101	0.433	0.281	0.357	0.506	0.763	0.379	0.466	0.849	0.430	0.547	0.816
East	0.070	0.501	0.204	0.353	0.588	0.659	0.367	0.520	0.758	0.417	0.604	0.743
Central	0.120	0.435	0.331	0.376	0.513	0.798	0.407	0.460	0.900	0.449	0.535	0.848
West	0.134	0.386	0.343	0.382	0.448	0.847	0.357	0.405	0.895	0.408	0.488	0.859
Northeast	0.058	0.307	0.219	0.241	0.337	0.793	0.366	0.444	0.867	0.452	0.532	0.845

Note: crste: comprehensive technical efficiency; vrste: pure technical efficiency; scale: scale efficiency, crste=vrste×scale.

From the perspective of each city (Table 3), a total of 18 cities ranked in the top 10 of environmental governance efficiency of local governments in 2014-2017, among which Huaibei, Sanya and Panzhihua were the most efficient, ranking in the top 10 four times, and Tongchuan, Tongling, Zigong, Zhenjiang and Changzhou were ranked in the top 10 in three years. At the same time, from the perspective of the last ten cities in the efficiency value ranking, the vast majority of cities in the last ten ranking are provincial capitals, that is to say, compared with non provincial capitals, provincial capitals have low efficiency in environmental governance and waste of resources.

Table 3. *Ranking of environmental governance efficiency of local governments.*

Ranking	2014				2015			
	City	crste	vrste	scale	City	crste	vrste	scale
Top 10 cities in comprehensive efficiency	Xianyang	1	1	1	Huaibei	1	1	1
	Huaibei	0.519	1	0.519	Liuzhou	1	1	1
	Sanya	0.502	1	0.502	Sanya	1	1	1
	Tongchuan	0.38	1	0.38	Panzhihua	1	1	1
	Tongling	0.299	1	0.299	Mianyang	1	1	1
	Yangquan	0.29	0.639	0.453	Tongchuan	1	1	1
	Panzhihua	0.283	1	0.283	Yangquan	0.971	1	0.971
	Sanmenxia	0.234	0.689	0.339	Yangzhou	0.965	1	0.965
	Huangshan	0.225	1	0.225	Zhenjiang	0.887	0.903	0.982
	Zigong	0.224	0.505	0.443	Changzhou	0.858	0.965	0.889
The last ten cities in comprehensive efficiency	Zhengzhou *	0.028	0.05	0.565	Tangshan	0.104	0.105	0.984
	Suzhou	0.027	0.26	0.104	Xi'an*	0.091	0.111	0.823
	Weifang	0.026	0.09	0.286	Guangzhou*	0.086	0.12	0.716
	Xi'an*	0.021	0.061	0.344	Chengdu*	0.082	0.097	0.846
	Chengdu*	0.02	0.039	0.51	Weifang	0.079	0.08	0.991
	Harbin *	0.018	0.095	0.192	Wuhan*	0.078	0.168	0.465
	Wuhan*	0.018	0.132	0.14	Shenyang*	0.064	0.066	0.971
	Hangzhou*	0.017	0.038	0.459	Shijiazhuang*	0.06	0.14	0.431
	Shenyang*	0.015	0.059	0.253	Zhengzhou*	0.059	0.063	0.945
	Guangzhou*	0.011	0.047	0.23	Hangzhou*	0.049	0.051	0.962

Table 3. *Continued.*

Ranking	2016				2017			
	City	crste	vrste	scale	City	crste	vrste	scale
Top 10 cities in comprehensive efficiency	Lianyungang	1	1	1	Nantong	1	1	1
	Huaibei	1	1	1	Lianyungang	1	1	1
	Tongling	1	1	1	Zhenjiang	1	1	1
	Sanya	1	1	1	Huaibei	1	1	1
	Zigong	1	1	1	Tongling	1	1	1
	Panzhihua	1	1	1	Chizhou	1	1	1
	Tongchuan	1	1	1	Sanya	1	1	1
	Changzhou	0.987	1	0.987	Zigong	1	1	1
	Nantong	0.953	1	0.953	Panzhihua	1	1	1
	Zhenjiang	0.882	0.931	0.947	Changzhou	0.985	1	0.985

Ranking	2016				2017			
	City	crste	vrste	scale	City	crste	vrste	scale
The last ten cities in comprehensive efficiency	Xi'an*	0.112	0.134	0.831	Hangzhou*	0.104	0.116	0.898
	Taiyuan*	0.108	0.122	0.88	Guangzhou*	0.104	0.136	0.766
	Weifang	0.093	0.099	0.936	Tangshan	0.098	0.101	0.969
	Wuhan*	0.083	0.105	0.798	Taiyuan*	0.096	0.125	0.772
	Tangshan	0.08	0.103	0.769	Shenyang*	0.095	0.114	0.838
	Hangzhou*	0.079	0.079	0.991	Wuhan*	0.095	0.142	0.666
	Shenyang*	0.075	0.076	0.988	Xi'an*	0.083	0.085	0.971
	Chengdu*	0.064	0.075	0.856	Chengdu*	0.078	0.09	0.872
	Shijiazhuang*	0.063	0.063	0.997	Shijiazhuang*	0.058	0.062	0.945
	Zhengzhou*	0.062	0.071	0.875	Zhengzhou*	0.046	0.05	0.926

Note:"*"means the provincial capital city.

3.2. The Results and Analysis of SFA Model in the Second Stage

Taking the slack variables of energy conservation and environmental protection expenditure and employees of environmental management industry obtained from DEA model in the first stage as dependent variables, foreign investment, industrial structure, population density, economic development and financial pressure as explanatory variables, a stochastic frontier analysis model was constructed, and regression results were obtained by FRONTIER4.1 software (Table 4).

Table 4. *SFA regression results in the second stage.*

Explanatory variable	Slack variable of environmental protection expenditure	Slack variables of employees in environmental management
Constant term	-4835.36*** (-5.63)	-154.50*** (-4.42)
Foreign investment	132.26*** (116.00)	0.98*** (2.535)
Industrial structure	-925.46*** (-3.72)	-1.48*** (-6.54)
Population density	-0.12 (0.02-0.57)	-0.002*** (-2.280)
Economic development	875.05*** (4.08)	2.73*** (3.87)
Financial pressure	18.41*** (18.29)	-0.05 (-0.70)
δ^2	3.30×10^{6}***(1.15×10^{6})	1.132×10^{8}*** (1.132×10^{8})
γ	0.649*** (25.380)	0.949*** (239.804)
log likelihood function	-3850.51	-1141.57
LR test of the one-sided error	133.81	715.56

Note: (1) the number in brackets is T statistic; (2)***, ** and * were significant at the levels of 1%, 5% and 10%, respectively.

First of all, analyze the practicability of the stochastic frontier model. From table 4, it can be seen that both regressions pass the generalized unilateral likelihood ratio test, so the SFA model has applicability. Secondly, the impact of environmental factors and random interference on the input relaxation variables of environmental governance is analyzed. The regression equation of the relaxation variable of environmental protection expenditure is 0.649, which is significant at the level of 1%, indicating that the ineffective internal management or investment scale leads to the relaxation of 64.9% of environmental protection funds, and the impact of external environment and random interference is 35.1%; the regression equation of the relaxation variable of environmental management personnel is 0.949, which is significant at the level of 1%, indicating that the ineffective internal management or investment scale leads to the employees of environmental management industry The main reason of relaxation variable, but the external environment and random interference factors still affect 5.1% of relaxation variable. The regression results show that environmental variables and random interference do have an impact on the calculation of local government environmental governance efficiency, so it is necessary to eliminate the impact of environmental variables and random interference, so that all cities in the same environmental conditions and luck conditions to re measure the real efficiency of local government environmental governance.

The following analysis of the environmental variables on the local government environmental governance input slack variables. First, the regression coefficient of foreign investment to environmental protection expenditure and environmental protection personnel relaxation variables is significant and positive, which indicates that the increase of foreign direct investment will cause the increase of environmental protection investment relaxation variables, that is to say, local governments still have the primary goal of attracting foreign investment to develop the economy, giving up or taking negative environmental governance behaviors, and ultimately leading to the reduction of environmental governance efficiency. This conclusion and prediction The second is that the regression coefficient of industrial structure to the two slack variables is significant and negative. Although this result is contrary to the expectation, the higher the proportion of secondary industry is, the more the number of industrial enterprises that may be large-scale is, the higher the environmental protection standard of large-scale industrial enterprises is, and the easier the local government manages large-scale industrial enterprises, the better the effect of industrial pollution control is The higher the efficiency of environmental governance; the third is that the population density is not ideal for the significance of the slack variable of environmental protection expenditure, but it has a significant and negative impact on the slack of environmental protection practitioners, which indicates that the more dense the urban population is, the more likely the environmental protection practitioners are to concentrate on the treatment of pollutants discharged, and the work efficiency of environmental protection workers can be effectively improved, and the population density increases It will bring the scale effect of environmental protection and greatly improve the environmental governance efficiency of local governments; Fourth, the economic development level has a significant and positive impact on the relaxation variables of environmental protection investment, which shows that most cities in China are still in the stage before the turning point of Environmental Kuznets curve, that is, environmental pollution tends to increase with economic growth; fifth, financial pressure has no significant impact on the relaxation of environmental protection practitioners, but has a significant and positive impact on the relaxation of environmental protection expenditure, that is to say, face to face In the face of greater financial pressure, the local government will choose to protect the economy and abandon the environmental protection, use more resources to support the regional economic development, relax the governance of pollution behavior of large enterprises with high energy consumption and high pollution tax payment, resulting in the aggravation of local environmental pollution and the reduction of government environmental governance efficiency.

3.3. Adjusted Environmental Governance Efficiency of Local Government

It can be seen from table 5 that after the influence of external environment and random interference factors are eliminated, the environmental protection efficiency of local governments has been significantly improved, that is to say, the environmental variables and random interference items cause the underestimation of the environmental governance efficiency of local governments, so it is necessary to add the adjustment of the second stage of SFA. Comparing the three efficiency improvement ranges, it is found that after adjustment, the pure technical efficiency increases the most, that is to say, the improvement of comprehensive technical efficiency is mainly brought about by the improvement of pure technical efficiency; the scale efficiency also improves greatly, which shows that the actual local governments have better scale management of environmental protection investment resources. From the perspective of different regions, the environmental governance efficiency of the four regions after adjustment is significantly higher than that of the first stage, which shows that the efficiency measured in the first stage cannot really reflect the environmental governance efficiency of local governments, environmental factors and random interference factors will cause the underestimate of the regional efficiency value, and cannot truly reflect the management and control of local governments on environmental protection funds and personnel. After eliminating environmental factors and random interference, the average efficiency of local government environmental governance in different regions is relatively close, and there is no significant regional difference, which shows that the level of environmental governance, management system and management technology in the four regions are similar, which is in line with the current situation of China's unified administrative system. Further analysis shows that the comprehensive technical efficiency of the eastern region ranks first in the observation period, and is significantly higher than the other three regions, which indicates that the eastern region has the least waste and loss of resources due to ineffective management in the use of environmental protection funds and the allocation of environmental protection practitioners.

Table 5. *Comparison of efficiency values of the first stage and the third stage.*

Year	Region	Stage one			The third stage		
		crste	vrste	scale	crste	vrste	scale
2014	Whole country	0.101	0.433	0.281	0.914	0.967	0.944
	East	0.07	0.501	0.204	0.955	0.979	0.975
	Central	0.12	0.435	0.331	0.887	0.964	0.918
	West	0.134	0.386	0.343	0.906	0.952	0.95
	Northeast	0.058	0.307	0.219	0.891	0.967	0.922
2015	Whole country	0.357	0.506	0.763	0.919	0.967	0.949
	East	0.353	0.588	0.659	0.951	0.977	0.972
	Central	0.376	0.513	0.798	0.901	0.966	0.932
	West	0.382	0.448	0.847	0.918	0.96	0.956
	Northeast	0.241	0.337	0.793	0.877	0.956	0.917
2016	Whole country	0.379	0.466	0.849	0.925	0.969	0.954
	East	0.367	0.52	0.758	0.952	0.977	0.973
	Central	0.407	0.46	0.9	0.905	0.962	0.939
	West	0.357	0.405	0.895	0.92	0.966	0.952
	Northeast	0.366	0.444	0.867	0.919	0.97	0.946
2017	Whole country	0.43	0.547	0.816	0.915	0.951	0.961
	East	0.417	0.604	0.743	0.949	0.968	0.98
	Central	0.449	0.535	0.848	0.891	0.934	0.953
	West	0.408	0.488	0.859	0.906	0.948	0.955
	Northeast	0.452	0.532	0.845	0.902	0.959	0.94

It can be seen from table 6 that after removing environmental factors and random interference, most local governments' environmental governance is still in an invalid state, only 18% of the city's comprehensive technology is effective, 31% of the city's pure technology is effective, and 19% of the city's scale is effective. Comparing the efficiency of the first stage and the third stage, we can see that the number of cities in the front of production in the third stage is more than that in the first stage. Comparing the results of scale reward, it can be seen that after the influence of external environment and random interference factors is eliminated, the investment scale of most provinces will change from decreasing to increasing, that is to say, external environment and random interference will lead to misjudgment of the investment scale of environmental protection resources. Cities in the increasing stage should continue to increase the investment of environmental protection to further improve the efficiency of environmental governance, which is similar to that in China The current situation of insufficient investment in environmental governance is consistent.

Table 6. *Number of cities with effective technical efficiency in different years.*

Year	The First Stage					The Third Stage				
	TE	PTE	SE			TE	PTE	SE		
			-	↑	↓			-	↑	↓
2014	2	22	1	1	111	22	30	20	81	12
2015	7	22	11	25	77	20	38	23	70	20
2016	8	19	11	33	69	21	43	27	73	13
2017	10	21	15	19	79	17	30	19	80	14
Meanvalue	7	21	10	20	84	20	35	22	76	15

Notes: "-" means the stage of constant;"↑" means the stage of increasing; "↓" means the stage of decreasing.

Further analysis of the areas where the technical efficiency effective cities are located (Figure 1) shows that the number of cities with the environmental comprehensive technical efficiency of local governments in the eastern region is the largest, indicating that the overall environmental governance efficiency in the eastern region is still high. The number of comprehensive technical efficiency and effective cities in the other three regions is close, and the environmental governance of local governments in these three regions is similar.

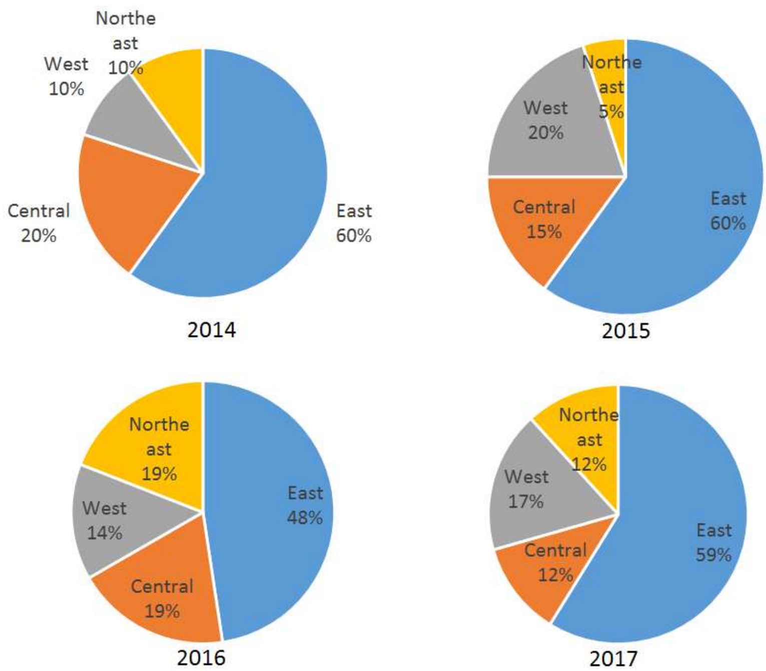

Figure 1. *Effective city distribution of TE.*

After adjustment, the ranking of data efficiency values has changed greatly (Table 7). In 2014-2017, the cities in the central region ranked 25 times in total, accounting for 62.5% of all rankings, which is far higher than the proportion of the central region in the sample cities, indicating that the urban environmental governance efficiency in the central region is low. After adjustment, the environmental governance efficiency of provincial capital cities is still low, and 13 times in the sample observation period appear in the bottom ten of the efficiency ranking, which shows that compared with non provincial capital cities, provincial capital cities do not have high management technology of environmental governance funds, and there is a lot of waste of resources.

Table 7. *The last ten cities in technical efficiencyin recent years.*

Year	City
2014	Yichang (0.771) Hohhot*(0.766) Zhengzhou*(0.754) Jiaozuo (0.741) Baoji (0.736) Anshan (0.732) Linfen (0.731) Tangshan (0.728) Jingzhou (0.719) Xinzhou (0.688)
2015	Yinchuan* (0.773) Linfen (0.764) Taiyuan* (0.757) Tangshan (0.756) Jiaozuo (0.749), Anshan (0.736), Zhengzhou* (0.724), Xinzhou (0.718) Jingzhou (0.704) Jilin (0.686)
2016	Yangquan (0.796), Linfen (0.79), Shuozhou (0.788), Xinzhou (0.78) Jingzhou (0.765), Shijiazhuang* (0.746), Taiyuan* (0.726), Shenyang* (0.722) Zhengzhou* (0.714) Tangshan (0.647)
2017	Jingzhou (0.8), Xianyang (0.799), Luliang (0.797), Xi'an* (0.786) Linfen (0.751), Tangshan (0.744), Xinzhou (0.724), Shijiazhuang * (0.719) Zhengzhou* (0.659) Taiyuan* (0.636)

Note: “*”means the provincial capital city.

3.4. Analysis Based on DEA Malmquist Index

In order to further explain the dynamic change of environmental governance efficiency of local governments in China in 2014-2017, Malmquist index is calculated with the adjusted data, and the technical efficiency (effch), technical progress rate (techch), pure technical efficiency (Pech), scale efficiency rate (sech) and total factor productivity (tfpch) are obtained in each period. In general (Table 8), the total factor productivity of environmental governance of local governments during the observation period is lower than 1, which means that the total factor productivity of environmental governance of local governments in China presents a downward trend. Further to the total factor productivity decomposition analysis, the mean value of scale efficiency is greater than 1, the mean value of pure technical efficiency is less than 1, the increase of scale efficiency just offsets the decline of pure technical efficiency, and the mean value of technical efficiency during the final sample period is 1, that is to say, in general, the environmental governance efficiency of local governments in China has not changed significantly in four years; the technological progress rate is less than 1, which means that from the perspective of technological progress It can be seen that there is no growth effect brought by technological progress in environmental governance of local governments in China during the sample period.

Table 8. *National Malmquist index and its decomposition.*

Period	Malmquist *index*decompositionof adjusted data				
	effch	techch	pech	sech	tfpch
2014-2015	1.005	0.988	1	1.006	0.993
2015-2016	1.007	1.018	1.002	1.006	1.025
2016-2017	0.989	0.961	0.981	1.008	0.95
Mean value	1.000	0.989	0.994	1.007	0.989

Note: tfpch=effch×techch, effch=pech×sech

According to Malmquist index, in 2014-2017, there were 36 local governments with total factor productivity greater than or equal to 1, accounting for only 32% of the sample number, which means that nearly 70% of local governments with total factor productivity less than 1, that is to say, the environmental governance efficiency of these local governments decreased at the rate of 2.42% per year, even if the local governments kept the human and financial input of environmental governance unchanged, environmental governance The effect will be worse and worse. Further decomposition found that during the sample observation period, 66 local governments' technical efficiency index was greater than 1, and nearly half of the local governments' environmental governance efficiency gradually approached the frontier, with “catch-up effect”; only 22 local governments' technical progress index was greater than 1, which was less than 20% of the sample number, that is to say, the main reason for hindering the improvement of the local governments' environmental governance efficiency was the technology recession Local governments in China should further improve the efficiency of local environmental governance through technological investment and innovation.

In terms of different regions (Table 9), TFP of the four regions is less than 1, that is, during the sample observation period, the efficiency of environmental governance in all regions has regressed. In terms of technical efficiency, except for the eastern region, the technical efficiency indexes of other regions are all greater than 1, indicating that the environmental governance efficiency of local governments in other regions is gradually approaching the front. The scale efficiency of environmental governance in the four regions is greater than 1, and the pure technical efficiency is less than 1, indicating that the improvement of technical efficiency is mainly due to the increase of scale efficiency. Among the four regions, the central region has the highest scale efficiency index, which is 1.013, indicating that local governments in the eastern region have the most effective control over the scale of investment in environmental governance. From the perspective of the rate of technological progress, the four regions have experienced different degrees of technological retrogression during the sample observation period, which shows that it is necessary to improve the local government's attention to environmental protection technological progress and management system innovation.

Table 9. *Malmquist index and its decomposition in different regions.*

Region	effch	techch	pech	sech	tfpch
East	0.998	0.997	0.996	1.002	0.995

Region	effch	techch	pech	sech	tfpch
Central	1.002	0.983	0.989	1.013	0.985
West	1.001	0.988	0.998	1.002	0.989
Northeast	1.005	0.984	0.997	1.008	0.989

In terms of the ranking of urban efficiency (Table 10), there is a big difference in the total factor productivity of environmental governance of local governments in China. The total factor productivity of Sanya, ranking first, is 1.149, with an average annual growth of nearly 15%. The total factor productivity of Taiyuan, ranking last, is 0.882, with an average annual decline of 17.8%. The difference between the two is 0.267, which is quite significant. Further analysis shows that the difference between the top ten and the bottom ten is greater than the difference of technology progress index, that is, the change of technology efficiency index is the main reason for the difference of total factor productivity of local governments. From the perspective of urban political status, only 2 of the top 10 cities are provincial capitals, and 5 of the last 10 are provincial capitals, which indicates that the total factor productivity of most provincial capitals is not high, and the technical level of environmental governance and management innovation are weaker than those of non provincial capitals, which is consistent with the previous DEA regression results.

Table 10. *Malmquist index ranking of local government environmental governance.*

Top ten	effch	techch	tfpch	The last ten	effch	techch	tfpch
Sanya	1	1.149	1.149	Zhengzhou*	0.956	0.995	0.952
Shenzhen	1.041	1.038	1.08	Shijiazhuang*	0.955	0.994	0.949
Tongling	1.045	1.001	1.046	Xi'an*	0.958	0.989	0.947
Changchun*	1.034	1.007	1.04	Chuzhou	0.956	0.988	0.945
Jinzhong	1.032	1.004	1.036	Deyang	0.966	0.977	0.944
Ma'anshan	1.031	1.005	1.036	Chizhou	0.972	0.97	0.943
Chifeng	1.033	1.001	1.033	Jinzhou	0.949	0.985	0.935
Shantou	1.021	1.011	1.032	Yinchuan*	0.983	0.952	0.935
Hohhot*	1.051	0.978	1.028	Xianyang	0.945	0.979	0.925
Anshan	1.063	0.966	1.027	Taiyuan*	0.923	0.956	0.882
Mean value	1.035	1.016	1.051	Mean value	0.956	0.979	0.936

Note: * indicates the provincial capital city.

4. Conclusions and Suggestions

In this paper, firstly, Three-stage DEA model and Malmquist index model are used to eliminate the impact of environmental variables and random errors on the environmental governance efficiency of local governments, and the environmental governance efficiency and total factor productivity of 113 cities at or above the prefecture level in China in 2014-2017 are calculated and analyzed. The research conclusions are as follows:

1. Comparing the efficiency values of the first stage and the third stage, we can see that the traditional DEA model does underestimate the efficiency of environmental governance of local governments in China. After eliminating the influence of environmental variables and random errors, the efficiency of local government environmental governance has been comprehensively improved.
2. Using the adjusted data, it is found that the efficiency difference between the four regions does not show the obvious characteristics of high in the East and low in the west, the efficiency value is relatively close, and the management level of local governments is not much different. However, during the sample observation period, the efficiency value of the eastern region ranked first, indicating that the management level of resources invested in environmental governance in the eastern region is slightly higher than that in other regions.
3. The second stage regression results show that foreign investment and economic development have a significant positive impact on the relaxation variables of local environmental protection investment, industrial structure has a negative impact on the relaxation variables of local government environmental protection investment, population density has a negative impact on the relaxation of employees in environmental protection industry, and financial pressure has a positive impact on the relaxation of environmental protection expenditure.
4. The results of the third stage show that the efficiency of most local environmental governance is still lower than 1, that is to say, after eliminating the influence of environmental variables and random interference factors, most local governments still have efficiency loss caused by ineffective management. From the perspective of urban nature, no matter from the perspective of local government environmental governance efficiency or total factor productivity, provincial capital cities are not as efficient as non provincial capital cities in terms of environmental protection funds and personnel management.
5. During the sample observation period, the average of total factor productivity of local government environmental governance is less than 1, with an average annual decrease of 1.1%, which is mainly caused by the lack of significant increase in technical efficiency and decrease in the rate of technological progress during the sample observation period.

Inorder to further improve the environmental governance efficiency and total factor productivity of local governments, this paper puts forward the following suggestions:

1. Attach importance to the efficiency of resource allocation. Although there is no obvious regional difference in the efficiency of environmental governance of local governments in China, the significant efficiency difference between provincial capital cities and non provincial capital cities reflects the unreasonable allocation of resources in China. Provincial capital cities use political advantages to occupy a large number of resources and cannot use them reasonably, resulting in a large loss of human and financial resources. In the future, in the allocation of resources, in addition to considering political factors, the use efficiency should also be included in the influencing factors of resource allocation, increase the proportion of efficient urban resource allocation, and improve the efficiency of national environmental governance.
2. Improve the environmental protection awareness of the government. Although external environmental factors are uncontrollable, the adverse effects of environmental factors on local environmental governance should be reduced. First of all, the central government can improve the environmental protection awareness of local governments by increasing supervision and environmental pressure, stimulate the enthusiasm of local governments to balance the relationship between economic development and ecological environmental protection, put an end to local governments' loosening of environmental regulations for the purpose of attracting foreign investment, stabilizing tax sources, developing economy, etc., and exchange the environment for short-term economic growth The appearance of the elephant. Secondly, it is estimated that the local government can effectively use the scale effect, encourage industrial enterprises to centralize and develop on a large scale, reasonably improve the urban population density, give full play to the intensive advantages, form the scale effect of environmental protection of the local government, and improve the environmental protection efficiency.
3. Increase investment in environmental protection technology and innovation of management system. The low rate of technological progress is the main reason for the decrease of TFP and environmental governance efficiency of local governments. Therefore, in the process of environmental governance in the future, local governments should not only pay attention to the management of the scale of environmental governance input factors, but also increase the investment in technological research and development and the innovation of management system, and improve management by introducing advanced science and technology, innovating management concepts and improving management Level, and finally realize the improvement of technical progress and technical efficiency.

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