Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
e-ISSN: 2395-3454

Vol. 18 | No. 1 | pp. 175-182 | 2019

Original Research Paper

Open Access

Regional Environmental Performance Evaluation and Its Influencing Factors: A Case Study of Shandong Province, China

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 14-01-2019
Accepted: 16-02-2019

Key Words:
Regional environment
Environmental performance
Influencing factors
Shandong province

ABSTRACT

In recent years, all provinces in China have exhibited unprecedented economic development with high growth rates. However, the economic development of particular provinces is extensive, but unsustainable, and pollution problems have become increasingly prominent. Moreover, the rapid growth of productivity at the expense of resources and the environment outweighs the gain. Regional environmental performance evaluation and exploration of environmental performance factors are helpful to quantitatively analyse the impact of government management and economic and social factors on environmental efficiency. Taking Shandong Province in China as an example, this study summarizes the literature on existing regional environmental performance evaluation and constructs an analytical framework that combines data envelopment analysis - Malmquist and Tobit models. On the basis of panel data on 17 prefecture-level cities of Shandong Province from 2011 to 2016, regions are divided into those with high and low environmental efficiency, and the factors that influence the different environmental efficiencies are measured. Results show that environmental performance evaluation gradually expands from the environmental performance evaluation of an enterprise to the regional environment, specific industries, and influencing factors. The 17 prefecture-level cities under the jurisdiction of Shandong Province exhibit an increase in total factor productivity within the time frame of the investigation. Numerous factors, such as endowment structure, economic development, industrial structure, ownership structure, foreign investment, and government environmental management capabilities, have different impacts on the regional environmental performance of Shandong Province. The study results provide a positive reference for scientific and reasonable evaluations of regional environmental performance in different cities, identification of the effectiveness and shortcomings of regional environmental performance management, understanding the performance characteristics and distribution of regional environmental performance, and promoting environmental management in China.

INTRODUCTION

China's economic development models of "high input and low output" and "high pollution and high consumption" have inevitably caused serious environmental pollution problems. Although many provinces continuously increase their environmental investment, the environmental management effects remain unremarkable. Accelerating the construction of a performance-oriented government environmental management system is necessary to form a long-term and dynamic monitoring and evaluation system for environmental policy effects, and the most important part of such a system is environmental performance evaluation because it can promote environmental management in China. Environmental performance refers to a comparison of economic activities with environmental pollution or environmental resource consumption. If production activities can produce numerous goods and services under certain environmental resource consumption, the environmental economic performance will improve. Environmental economic performance is improved when minimal pollutant emissions and environmental damage are observed during the production of the same amount of goods and services.

As shown in Fig. 1, the economies of various regions of Shandong Province have recently achieved rapid development with high growth rates. However, several urban economies have developed in an extensive, but unsustainable manner, and environmental protection issues have become increasingly prominent. Improper handling of environmental resource constraints seriously weakens the sustainable development of the economy in various regions of Shandong Province. As a resource-rich province, Shandong has abundant natural resources, but its environmental sustainability is poor. The rapid growth of productivity at the expense of resources and the environment is not worth the loss. Therefore, measuring the environmental performance values of cities in Shandong Province and quantitatively analysing the relationship between environmental performance and its influencing factors are valuable in further increasing the

governance, protection, and management of environmental pollution and in updating environmental protection concepts in order to avoid the "pollution first, treatment later" model.

EARLIER STUDIES

Environmental performance evaluation refers to the measurement and evaluation of environmental management effectiveness by using appropriate indicators in a continuous, phased, quantitative manner. Environmental performance evaluation began when environmental information was released by enterprises in the late 1980s. It mainly pertains to an environmental performance evaluation of enterprises that focuses on how to improve such performance. Subsequently, relevant investigations have gradually increased, with focus on the exploration and application of environmental performance evaluation motivation, evaluation mode, and methods. Charnes et al. (1978) proposed an endogenous weighting system that did not consider direct production inputs and outputs, but focused on the weighting between value creation and its adverse side effects on the environment. Fare et al. (1994) divided the environmental performance index into two factors, namely, environmental technology change and relative eco-efficiency change. Fare et al. (1994) also decomposed the environmental technology change factor into quantity and environmental bias indices. The advantage of this approach was that the price information of emissions or environmental pressure was not required at any stage of the analysis. Sarkis & Talluri (2004) proposed to evaluate environmental performance by using the data envelopment analysis (DEA) method, studied the construction and application of the DEA model, and put forward many ecological assessment indicators. Nakashima et al. (2006) constructed a loop management system and used the DEA method to compare the environmental performance of different types of enterprises in a certain industry (Nakashima et al. 2006). Kortelainen (2008) proposed a general framework for analysing dynamic eco-efficiency by introducing the Malmquist index (Kortelainen 2008). Henri et al. (2008) indicated that environmental performance indicators contain key quantitative information for environmental management issues, which should include environmental management regulations, environmental management objectives, and public subsidies (Henri et al. 2008). Hindorff et al. (2009) constructed a set of environmental performance indicators for the public sector and applied it to the policy of the defence sector. Martinez (2012) combined economic benefits and environmental responsibility to study corporate environmental performance evaluation and believed that environmental management should be strategically placed in the production and operation of enterprises. Wang et al. (2013) proposed the use of the DEA window analysis method in the calculation of the energy and environmental efficiency of China's provinces. Adeel-

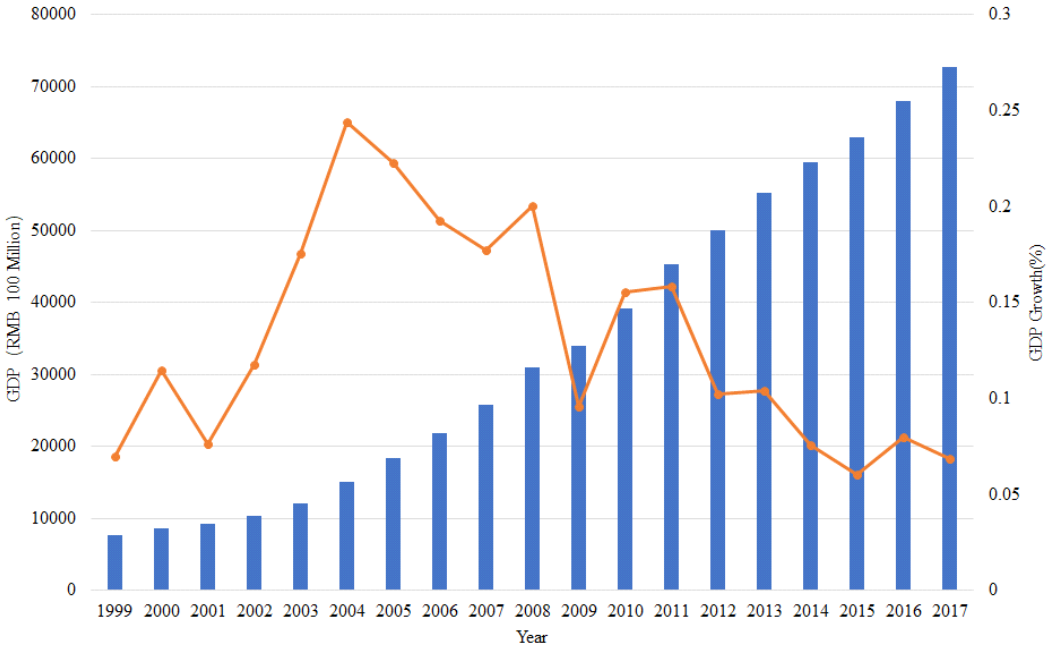

Fig. 1: GDP and GDP growth rate of Shandong Province from 1999 to 2017.
[Data from the EPS platform (http://olap.epsnet.com.cn/)]

Farooq et al. (2017) surveyed nine Asian developing countries and examined the impacts on their environmental performance in the aspects of green field investment, energy consumption, economic growth, and urbanization from 2003-2014. Pilouk & Koottatep (2017) assessed the sustainable development of eco-industrial real estate or industrial parks and showed that environmental performance was the key to the success of eco-industrial parks. Halkos & Zisiadou (2018) constructed an environmental performance index and compared Greece with the Mediterranean and other countries in Northern Europe. Xiao et al. (2018) tested green technology and environmental spillover performance through a panel data model and analysed the mechanism of green technology spillovers on environmental performance from a regional perspective. The results showed that external green technology spillovers had improved the internal environmental performance of enterprises and were driven by the weakening of internal environmental performance. Peiró-Palomino & Picazo-Tadeo (2018) analysed the relationship between social capital and the environmental performance of the European Union (EU) and found that the main driving force of environmental performance was economic development and per capita of GDP.

In summary, many studies have been conducted on environmental performance evaluation. The DEA method, which can reflect the advantages and characteristics of a certain method in performance evaluation applications, is widely used and provides references for the current research. On the basis of existing research, this study adopts a combination of DEA-Malmquist and Tobit models and uses Shandong Province of China as an example to study the changes and influencing factors of environmental performance at the municipal level. Corresponding counter-measures are presented.

INTRODUCTION TO THE MODEL

Introduction to the DEA-Malmquist Model

The DEM-based Malmquist index is generally used to determine total factor productivity (TFP) and its analysis factors. According to Fare et al. (1994), the Malmquist index, in reference to variable returns, outputs, t-time, and t+1 time, can be defined as:

$$M_{t,t+1}=\frac{D^{v}_{t+1}(x_{t+1},y_{t+1})}{D^{v}_{t}(x_{t},y_{t})}\times\left[\frac{D^{v}_{t}(x_{t},y_{t})}{D^{c}_{t}(x_{t},y_{t})}\div\frac{D^{v}_{t+1}(x_{t+1},y_{t+1})}{D^{c}_{t+1}(x_{t+1},y_{t+1})}\right]\times\left[\frac{D^{c}_{t}(x_{t},y_{t})}{D^{c}_{t+1}(x_{t},y_{t})}\times\frac{D^{c}_{t}(x_{t+1},y_{t+1})}{D^{c}_{t+1}(x_{t+1},y_{t+1})}\right]^{\frac{1}{2}} \quad ...(1)$$

Where, $D^{c}(x,y)$ is the distance function under a constant return of scale, and $D^{v}(x,y)$ is the distance function under a variable return of scale. $\frac{D^{v}_{t+1}(x_{t+1},y_{t+1})}{D^{v}_{t}(x_{t},y_{t})}$ denotes the pure technical efficiency changes, $\frac{D^{v}_{t}(x_{t},y_{t})}{D^{c}_{t}(x_{t},y_{t})}\div\frac{D^{v}_{t+1}(x_{t+1},y_{t+1})}{D^{c}_{t+1}(x_{t+1},y_{t+1})}$ is the scale efficiency change, $\left[\frac{D^{c}_{t}(x_{t},y_{t})}{D^{c}_{t+1}(x_{t},y_{t})}\times\frac{D^{c}_{t}(x_{t+1},y_{t+1})}{D^{c}_{t+1}(x_{t+1},y_{t+1})}\right]^{\frac{1}{2}}$ is for technological progress, and $\frac{D^{v}_{t+1}(x_{t+1},y_{t+1})}{D^{v}_{t}(x_{t},y_{t})}\times\left[\frac{D^{v}_{t}(x_{t},y_{t})}{D^{c}_{t}(x_{t},y_{t})}\div\frac{D^{v}_{t+1}(x_{t+1},y_{t+1})}{D^{c}_{t+1}(x_{t+1},y_{t+1})}\right]$ is the product of the first two representing the technological efficiency change.

When $M_{t,t+1}>1$, TFP progresses. When $M_{t,t+1}<1$, TFP regresses. When $M_{t,t+1}=1$, TFP does not change. When technical efficiency, pure technical efficiency, scale efficiency, or the technical level change is greater than 1, it is the source of TFP growth; otherwise, it is the source of TFP reduction. In a specific study on regional environmental performance measurement, TFP refers to the ratio of the total output to the weighted average of various input factors in the production activities of the entire regional socio-economic system. Technological progress (TECH) refers to the productivity improvement of the entire regional socio-economic system through scientific research, invention, technological improvement, and the spread of high technology. Technical efficiency (TE) is determined by two factors, namely, scale efficiency (SE) and pure technology efficiency (PECH). SE refers to the extent to which the entire regional socio-economic system deviates from the optimal scale in the production process. PECH originates from the entire regional socio-economic system through management methods, such as regional energy conservation, emission reduction, and social environmental governance. In this study, the TFP index that considers pollutant emissions is defined as the regional environmental efficiency, and the environmental performance of economic development in various regions of Shandong Province is studied geographically from the municipal level.

Tobit Model

The Tobit model is an econometric model proposed by the economist Tobin in 1958 when studying the demand for durable consumer goods. The standard Tobit model is shown in the following formula.

$$\begin{aligned} y_i^{*} &= \beta x_i + u_i \\ y_i^{*} &= y_i \ (y_i^{*} > 0) \\ y_i^{*} &= 0 \ (y_i^{*} \le 0) \end{aligned} \quad ...(2)$$

Where y_i^{*} is a latent dependent variable. When this latent variable is greater than 0, $y_i^{*}=y_i$; when the latent variable is less than or equal to 0, $y_i^{*}=0$. x_i represents the independent variable vector, β represents the coefficient vector, and the error term u_i is independent and obeys the nor-

mal distribution $u_i \square N(0,\sigma^2)$. The maximum likelihood estimation method is generally used to estimate the regression coefficient.

EMPIRICAL RESEARCH

Indicator Selection and Data Processing

In environmental performance measurement, according to the basic principles of the typical production function and by considering scientific and systematic data, this study selects industrial wastewater discharge, industrial waste gas emissions, industrial solid waste, industrial sulphur dioxide, and industrial chemical oxygen demand as input variables. The industrial added value is used as the output variable, and the annual industrial added value is converted by an annual GDP deflator. Panel data on the following 17 prefecture-level cities from 2011 to 2016 are calculated: Jinan, Dezhou, Liaocheng, Heze, Tai'an, Laiwu, Jining, Zaozhuang, Linyi, Rizhao, Qingdao, Weihai, Yantai, Weifang, Zibo, Dongying, and Binzhou. All data are obtained from the Shandong Statistical Yearbook and China Environment Yearbook.

In the analysis of the factors that affect environmental performance, this study divides the factors affecting the overall environmental efficiency of Shandong Province into endowment structure, economic development, industrial structure, ownership structure, foreign investment, and government environmental management capabilities on the basis of existing literature. The specific influencing factors are shown in Table 1. Areas with TFP larger than or equal to 1 are defined as having high environmental performance, and regions with TFP less than 1 have low environmental performance.

Regional Environmental Performance Results

Table 2 shows that the 17 cities under the jurisdiction of Shandong Province exhibit TFP growth within the time frame of the investigation. The TFP of Tai'an, Zaozhuang, Weihai, and Dongying is relatively high, whereas the TFP of Jinan, Dezhou, Liaocheng, Heze, and Binzhou is the lowest and does not exhibit growth. The five cities also suffer from serious environmental pollution. A considerable amount of heavy industry pollution leads to low environmental performance. The rest of the cities demonstrate low levels of pollution emission and energy use through improvements in environmental technology and continuous reductions in energy consumption per unit of GDP, thereby increasing the environmental TFP. The technical efficiency of Liaocheng, Heze, Zibo, and Dongying is low due to the ineffective implementation of environmental pollution control and the low efficiency of the input and output of environmental pollution control. Most cities in Shandong Province have not achieved growth in terms of technological progress. Given that Shandong is a large industrial province, the pillar industries are still non-ferrous metals, steel processing, petroleum smelting, and other enterprises that are highly resource-dependent with a large amount of pollutants. Moreover, the lack of gathered talents and funds and weak innovation awareness lead to a relatively backward development in terms of environmental protection. In terms of scale efficiency, Jinan, Laiwu, Jining, Zaozhuang, Qingdao, and Yantai exhibit more development than the rest of the cities. Several cities have not achieved scale efficiency growth probably due to their heavy reliance on industries to realize a prosperous local economy. However, the environmental quality in the production process deteriorates with economic growth, thus bringing increased external costs to the entire economy. The decline in efficiency in these cities constrained by resources and the environment indicates that environmental quality and productivity have not achieved a simultaneous win-win development.

Analysis of Factors that Affect Environmental Performance

Considering that environmental performance is a constrained dependent variable, traditional estimation meth-

Table 1: Factors that affect environmental performance.

Factor	Index	Variable symbol
Endowment structure	Logarithm of the ratio of capital to labor	K/L
Economic development	Actual per capita GDP	PGDP
Industrial structure	Added value of the secondary industry that accounts for the proportion of regional GDP	GYH
Ownership structure	Proportion of the total output value of state-owned holding enterprises to the total industrial output value	GYHBZ
Foreign investment	Foreign direct investment that accounts for the proportion of regional GDP	FDI
Government environmental management capacity	Amounts of environmental governance investment	ZFGL

Table 2: Environmental performance measurement results.

	Technical Efficiency	Technological Progress	Pure Technical Efficiency	Scale Efficiency	Total Factor Productivity
Jinan	1.005	0.994	1.000	1.005	0.999
Dezhou	0.953	0.953	0.987	0.966	0.908
Liaocheng	0.967	1.023	0.969	0.998	0.989
Heze	0.984	1.000	0.986	0.998	0.984
Tai'an	1.121	0.984	1.123	0.998	1.103
Laiwu	1.046	0.963	1.024	1.021	1.007
Jining	1.004	0.998	0.998	1.006	1.002
Zaozhuang	1.040	0.989	0.967	1.075	1.028
Linyi	1.101	0.913	1.105	0.996	1.005
Rizhao	1.004	0.999	1.005	0.999	1.003
Qingdao	1.019	0.999	0.996	1.023	1.018
Weihai	1.033	0.996	1.035	0.998	1.029
Yantai	1.037	0.999	1.002	1.035	1.036
Weifang	0.980	0.993	0.996	0.984	0.973
Zibo	0.998	1.012	0.998	1.000	1.010
Dongying	0.990	1.035	1.034	0.957	1.024
Binzhou	0.902	1.065	0.954	0.945	0.960
Mean value	1.011	0.995	1.011	1.000	1.005

Table 3: Factors that affect environmental performance.

Index	Shandong Province as a whole	Areas with high environmental performance	Areas with low environmental performance
C	1.314***	1.635***	0.564***
K/L	-0.006***	-0.675	-0.125***
PGDP	-0.352**	-0.654**	-1.254**
GYH	-0.163***	-0.478***	-0.204***
GYHBZ	0.145**	0.098**	0.258*
FDI	0.965***	1.685***	2.576
ZFGL	-0.896	-0.854	-0.653**

(Note: *, ** and *** indicate the significance level at 10%, 5% and 1%, respectively)

ods (e.g., least-squares regression) can result in bias in the estimation results. Therefore, this study uses the Tobit model proposed by Tobin (1958) to estimate the overall environmental efficiency impact factor model of Shandong Province. The results estimated by Eviews7 software are shown in Table 3.

Table 3 shows that the endowment structure (K/L) has a substantial negative effect on environmentally inefficient areas, but does not considerably affect the whole Shandong Province and environmentally efficient areas. Therefore, environmentally efficient areas should focus on developing capital and knowledge-intensive industries to increase their environmental efficiency. The actual per capita GDP has substantial negative effects on the improvement of environmental efficiency because Shandong Province is still in the stage of rapid economic development. Improving economic development is the primary task, and the conservation of resources and protection of the environment are neglected; therefore, the resource utilization efficiency is declining. The industrial structure (GYH) has substantial negative impacts on the environmental inefficiency of Shandong Province and environmentally inefficient areas. If the proportion of the industrial added value of these areas that accounts for the regional GDP increases by one unit, then Shandong Province and environmentally inefficient areas will increase by 0.163 and 0.204 units, respectively. This scenario indicates the strong dependence of Shandong Province on the secondary industry. However, the development of the tertiary industry is insufficient, and the industrial structure is unreasonable and relatively simple. Therefore, environment-friendly industries should be regarded as the priority development industry, thus minimizing the impact of pollution from industrial development on environmental efficiency. The ownership structure (GYHBZ) has

important positive impacts on the environmental efficiency values of Shandong Province and environmentally inefficient and efficient regions of the province. As a large industrial province, Shandong's state-owned enterprises have higher financial strength and more evident talent convergence effects than non-state-owned enterprises. Thus, state-owned enterprises are capable and aware of developing high-tech environmental protection technologies to improve environmental performance in the region. Foreign investment (FDI) has substantial positive impacts on the environmentally efficient regions and Shandong Province. In recent years, this province focused on the introduction of technology and capital-based foreign-invested enterprises. The advanced management experience and technology brought by these enterprises can offset the negative impact on the environmental efficiency, thereby increasing the overall environmental efficiency. Government environmental management capability (ZFGL) has remarkable negative impacts only on the environmentally inefficient areas of Shandong Province. The environmentally inefficient areas have weak economic strength, and the environmental management funds invested by the government cannot effectively improve the environmental performance. This finding shows that the government still needs to modify or even reform existing environmental regulations, incentives and punishment mechanism, and strengthen its ability to control environmental pollution.

POLICY RECOMMENDATIONS

Reasonable Adjustment of Industrial Structure and Control of Industry with Heavy Environmental Pollution

Adherence to the development of resource-saving and environment-friendly industries requires precise and careful work. The government conducts effective environmental supervision of enterprises in the process of industrialization. State-owned enterprises should take the lead in transforming production methods, actively exploring advanced environmental protection technologies, and developing other industries with high environmental efficiency and high added value to find new motivation for economic growth. Under the premise of strict screening of foreign environmental standards, we must endeavour to absorb and digest advanced foreign pollution control technologies and management concepts and produce products with high environmental efficiency and added value as much as possible to reduce pollution emissions and improve environmental efficiency. Optimizing the industrial structure, reducing industrial pollution, and focusing on developing strategic emerging, green, and low-carbon industries are required. We will follow a new path of industrialization that conforms to the trend of "Internet Plus", and integrate information and industrialization into the main line, and improve the level of technology and product quality, and promote smart green manufacturing, and reduce the impact of industrialization on the environment. The tertiary industry should be vigorously developed by promoting the advanced industrial structure and accelerating the formation of industrial systems conducive to environmental protection and resource conservation.

Strengthen Environmental Performance and Scientific Work and Establish an Environmental Performance Assessment Mechanism

The long-standing extensive economic development model has little influence on ecological environment governance, and economic costs cannot be used in exchange for environmental improvements. In addition to several surface approaches adopted in the past to mitigate the ecological crisis by reducing the emission of harmful substances, starting from the source of pollutants, is necessary. That is, the technical level must be improved to achieve clean combustion and reduce pollutant emissions, thereby effectively improving the environment to obtain good economic benefits. Developing new energy to replace the old one is required to efficiently use energy without generating harmful gases and eventually realize economic and environmental benefits. The ecological environment awareness of economic entities should be strengthened, and relevant national laws and regulations should be improved to ensure and supervise the implementation of government policies by forming a unified goal from the individual to the government and even to the country. An improved living environment for the people can then be achieved.

Strengthen government Environmental Regulation and Implement Regional and Enterprise Subsidy Policies on High Environmental Performance

The government's environmental regulation has remarkable effects on the improvement of environmental efficiency. In the formulation of environmental policies, administrative orders, such as mandatory closure and improvement of environmental penalties, can achieve good results to a certain extent. However, the formulation of environmental regulation policies must fully consider and integrate market economic mechanisms. Economic measures, such as the market trading system represented by pollution tax, are implemented to internalize environmental costs and encourage the micro-subjects of enterprises to maximize environmental efficiency, thus transforming the production concept of the enterprise from "dare not to pollute" to "cannot pol-

lute" and even to "be unwilling to pollute." Various factors cause uncertainty in terms of companies' attitude towards energy conservation, emission reduction, and development of environmental technologies. Therefore, the government must apply further measures to encourage enterprises to develop advanced environmental protection technologies and continue to maintain high environmental efficiency. These measures include encouraging enterprises to undertake efforts to absorb and digest advanced pollution control technology and management experience in developed areas and providing certain subsidies to enterprises that adopt environmental protection technologies on the premise of local financial affordability.

Improve Public Environmental Awareness and Change the Concept of Environmental Protection

Strengthening the construction of ecological civilization requires the public to change their awareness; it is not a sole task of the government to protect the environment. Achieving the desired effect of protecting the ecological environment by the government alone is difficult because ecological environmental protection is a typical public participation task. Only by working together we can fundamentally repair the polluted environment and continue to protect the unpolluted environment, thus maintaining and continuously improving the quality of the ecological environment. Performing relevant activities and strengthening publicity are necessary to raise public awareness of environmental protection. In addition to the implementation of national policies and the active cooperation of enterprises, the multiparticipation of families and individuals also plays a pivotal role in the process of ecological governance. As an independent economic entity, families and individuals can propose reasonable suggestions through a government-guided ecological governance program or actively participate in the environmental governance process by starting from the small things around them, such as advocating green travel.

CONCLUSIONS

As a developing country, China is currently in the stage of rapid industrialization, and ecological and environmental problems are inevitably encountered during economic development. In the various provinces of China, long-term high energy consumption, severe pollution problems, and other issues exist. In addition, the development of environmental performance is different, and the influencing factors are complicated. In this study, the DEA-Malmquist model is adopted to measure the environmental performance of 17 prefecture-level cities in Shandong Province. The Tobit model is used to analyse the influencing factors of environmental performance in each region. The research structure shows that the 17 prefecture-level cities under the jurisdiction of Shandong Province achieved TFP growth within the time frame of investigation. The influencing factors include the endowment structure, economic development, industrial structure, ownership structure, foreign investment, and government environmental management capacity, all of which exert different impacts on the regional environment performance of Shandong Province. Comprehensive investigations, including enriching the regional environmental performance evaluation index system, expanding the regional environmental performance influencing factors, spatial econometric analyses of regional environmental performance, and consideration of the impacts of micro-factors, such as enterprises, on environmental performance, could be conducted in the future.

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