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Industrial Pollution Governance Efficiency and Big Data Environmental Controlling Measures: A Case Study on Jiangsu Province, China

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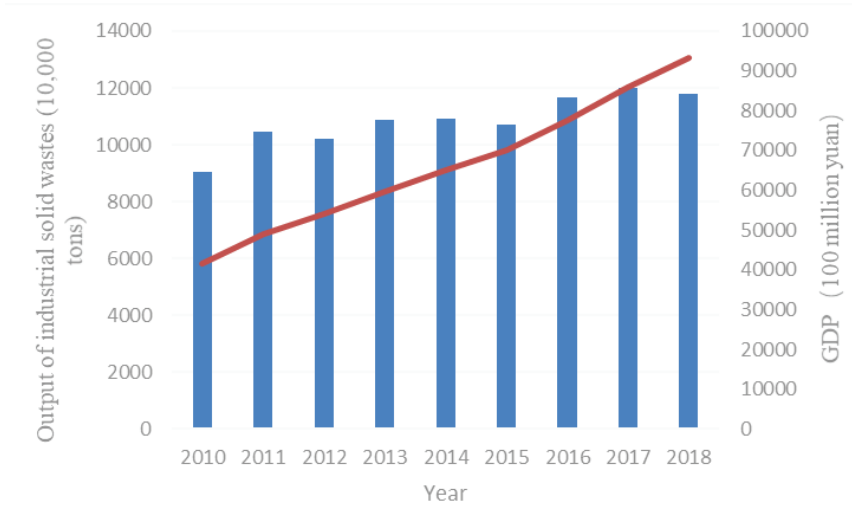
ABSTRACT

Industrial economic development, which is characterized by high input, high pollution, high consumption, and low benefits, causes environmental pollution problems to be prominent due to the increase of industrial pollutants every year. Blind expansion of investment scale regardless of governance efficiency of industrial pollution can lead to a certain amount of resource wastage. Thus, improving the governance efficiency of industrial pollution is an important method to solve industrial pollution. In particular, applying big data on environmental protection for environmental pollution management can improve the efficiency and quality of pollution control, and ensure comprehensive examination and governance of environmental pollution. In this study, research on industrial pollution governance efficiency in foreign developed countries was reviewed. Furthermore, industrial pollution governance efficiency in Jiangsu Province, China was calculated and certain measures were proposed to prevent and control industrial pollution by applying big data on environmental protection. Results demonstrate that the trend in which industrial pollution governance of emerging technologies, such as big data, penetrate into environmental protection and human capital input can significantly decrease industrial wastewater and industrial solid wastes. Technological innovation makes remarkable contributions to industrial waste gas control. To increase industrial pollution governance efficiency, this study proposes certain measures, such as establishing a scientific and highly efficient big-data monitoring network system for ecological environment, fully utilizing block-chain technological advantages in industrial pollution control, constructing a perfect big-data sharing and processing platform for environmental protection, and increasing sharing and application values of big data on environmental protection. Research conclusions can provide important references to reduce industrial pollutant emissions, increase the efficiency of industrial pollution governance, increase applications of big-data on environmental protection, and construct and perfect a big-data sharing platform for environmental protection.

INTRODUCTION

China's economic development model of "high consumption, high pollution, and low output" has been formed over a long period at great cost to the country's natural and ecological resources. Rapid industrial development has brought pollution problems in recent years, which has become one of the main factors that influence the living conditions of humans. Environmental damage caused by industrial pollution accounts for most pollution outcomes. Atmospheric, water and solid waste pollution are the major types of industrial pollution. Controlling industrial pollutant emissions and increasing the efficiency of industrial emission reduction is vital to improve economic development and raise people's standard of living. With the gradual maturity of big data technology, using big data on environmental protection to control environmental pollution not only can increase the control efficiency and quality but also can establish a perfect environmental governance system for comprehensive examination and management of environmental pollution.

Jiangsu is an economically developed province in China. Although it has achieved rapid economic growth, it faces significant threats from environmental pollution (Fig. 1). As industrialization is accelerated in Jiangsu Province, environmental pollution caused by industrial development has posed great threats to human health. Although various theoretical requirements and specific measures of ecological environmental protection have been implemented, the Province cannot avoid the intensifying pollution problems caused by economic development. Effects of industrial development on ecological environmental damage and natural resource consumption cannot be ignored even though it can drive economic development. Therefore, finding a new way to control environmental pollution caused by industrial development is necessary. Applications of big data on environmental protection are based on Internet



(Data source: *http://olap.epsnet.com.cn/*)

Fig. 1: GDP and output of industrial solid waste in Jiangsu Province in 2010-2018.

technology and the development of data technology, which lay a solid technological foundation for environmental pollution prevention and control. Big data sharing for environmental protection can help realize nationwide networking of environmental pollution problems, identify common environmental pollution problems, and offer centralized analysis and processing of such problems, thereby enabling an increase in environmental governance efficiency. Furthermore, big data sharing for environmental protection can provide real and reliable control in regions with serious environmental pollution, enable the public to learn advanced philosophies and techniques for environmental protection management in China, change environmental pollution status in local areas, and ensure comprehensive prevention and strong control of pollution-related problems.

PAST STUDIES

Industrial pollution has intensified continuously in Western countries since the Industrial Revolution, and has brought major challenges as a result of the Second Industrial Revolution. Thus, ecological environmental governance has attracted close attention in many developed countries. Studies on industrial pollution control began early in Western countries and achieved certain outcomes. In particular, the increasing maturity of big data theory and extensive applications of big data on environmental protection has raised the complexity of industrial pollution control. Using big data on environmental protection to implement pollution control not only can increase environmental pollution controlling efficiency and quality, but also can set up a perfect environmental governance system for a comprehensive examination and management of environmental pollution behaviours. With respect to industrial environmental pollution improvement and applications of big data on environmental protection, Dellink & Ierland (2006) introduced a dynamic application general equilibrium model with bottom-up important emission reduction information on environmental theme and conducted an empirical study on effective emission reduction strategies in the Netherlands. Results showed that environmental pollution status can be improved effectively through technological measures of emission reduction, economic restructuring, and temporary economic slowdown. Larsson & Telle (2008) measured the validity of DEA to pollution governance efficiency of energy enterprises in Norway based on panel data. He found that after the European Union (EU) implemented the Regulations for Comprehensive Pollution Prevention and Control, pollution governance efficiency of energy enterprises was improved significantly. Moreover, advanced pollution governance technologies that were beneficial to reduce emissions of greenhouse gases and acid substances were proposed. Zhao et al. (2009) believed that industrial water pollution was intensifying day by day as a result of rapid economic development in China; thus, he proposed a factory-level clustering method to estimate the spatial distribution of industrial water pollution pressure in the next five years. Moreover, he evaluated regional effect and spatial fairness from the perspective of government and industries and proposed specific measures to relieve industrial pollution. Jia & Zhao (2012) constructed an evaluation model space for industrial pollution control performance and used it to evaluate the industrial pollution control performance in 30 provinces in China in 2003-2010. According to evaluation results, China's pollution governing performance improved quickly, but the great regional imbalance of pollution governing performance occurred in the eastern, middle, and western parts of the country. Specifically, pollution-governing performance in middle and eastern China was significantly higher than that in the middle and western parts of the country. Kanada et al. (2013) analyzed the benefits of pollution control policies in Kawasaki, Japan, finding that aviation pollution control policy has a great impact on industrial energy resources, thereby significantly decreasing the energy intensity of the manufacturing industry. Maria & Patrik (2014) believed that industrial pollution accounted for a very high proportion of global pollution and analyzed the validity of industrial pollution-control measures through the issuance of licenses for industrial plants in Sweden. Cao & Ramirez (2020) deemed that the rapid industrialization in China led to serious deterioration of air quality, and created a method to measure government policies for air pollution control; he concluded that government policies did not influence industrial production greatly when it decreased air pollution. Thuy et al. (2020) pointed out that environmental pollution caused by wastewater from an industrial park in Vietnam was a new problem that brought great pressure to the government. Moreover, different calculation methods of sewage in the industrial park were assessed and specific measures to control industrial sewage were proposed. Main theoretical studies and applications of big data on environmental protection are introduced as follows. Wu et al. (2016) pointed out that big data are widely applied as one of the strongest driving forces to promote productivity and increase efficiency and supporting innovation; he also discussed the relationship between big data and the new generation of the green revolution. Bibri & Elias (2017) believed that big data constitutes an important method to optimize energy efficiency and relieve impacts on the environment. Big data applications can play a key role in improving environmentally sustainable development. Song et al. (2018) reviewed the latest developments in environmental management based on big data technology and found that big data applications on practical environmental performance evaluation can provide scientific references and guidance in formulating environmental protection policies. Shan (2018) classified environmental protection projects effectively based on big data techniques. According to experimental results, studies on environmental pollution classification based on big data technology can complete the classification of abundant environmental data in a short period at extremely high precision. It is vital to the further development of environmental protection projects. Cheng & Yuyu (2018) collected abundant search data on public networks through the big data method and discussed influences of public concerns on environmental performances of enterprises in heavy-pollution industries; he concluded that enterprises with higher public concern have better environmental performances, which are conducive to the promotion and maintenance of China's environmental protection measures. Applying big data mining method, Liu et al. (2020) determined the orientation trend of food delivery service providers and the expansion trend of environmental pollution loads in the Beijing-Tianjin-Hebei region. He pointed out that food delivery service platforms, which are the bridge between food delivery service providers and consumers, can enhance the environmental protection mechanism. He also suggested strengthening environmental protection awareness of the public, changing the consumption mode of people, and achieving coexistence between resource utilization and environmental protection. Existing studies have shown that research on industrial pollution governance in foreign developed countries has been mature, and emerging technologies such as big data have gradually penetrated the environmental protection field. In China, limited studies have focused on industrial pollution governance. Most studies have emphasized administrative technologies, methods and pollution control, but applications of new technologies such as big data to environmental protection fields have not been sufficiently examined. Thus, we have conducted a case study on Jiangsu Province, China. Industrial pollution governance effect in the province was estimated and specific measures were proposed from big data applications of environmental protection to explore how such applications in environmental protection can contribute to pollution prevention and control. In this way, the value of big data can be maximized in environmental protection. Policy suggestions are proposed to formulate corresponding environmental protection schemes with consideration of practical environmental pollution conditions in China.

INTRODUCTION TO MODELS AND DATA SPECIFICATIONS

Models

Based on the improvement of the Cobb-Douglas production function, this study constructed a model (Eq. 1) to study the influencing factors of industrial pollution governance efficiency.

$$E_t = \beta_0 I_t^{\beta_1} L_t^{\beta_2} T_t^{\beta_3} S_t^{\beta_4} \quad (1)$$

According to some scholars, the influences of various factors are often hysteretic for generally one or two phases. For instance, the increased investment may not bring production ability immediately in the current phase and an increased workforce takes a process of training and adaptation. Thus, explanatory variables were treated for one-phase hysteresis. Moreover, natural logarithms of all data were collected to ensure data stationarity. Finally, the used model was obtained as follows (Eq. 2) :

$$LnE_{t+1} = \beta_0 + \beta_1 LnI_t + \beta_2 LnL_t + \beta_3 LnT_t + \beta_4 S_t + \phi_t \qquad (2)$$

Where E_{t+1} represents industrial pollution governance efficiency characterized by removal rate of industrial COD, the removal rate of industrial SO_2 and comprehensive utilization of industrial solid wastes (*SOLID*). I_t denotes capital inputs and is characterized by the finished amounts of investments to industrial wastewater control (I_{cod}), industrial waste gas control (Iso_2), and industrial solid control (*Isolid*). L_t refers to labour inputs and is characterized by the number of staff in the environmental protection system (*Labour*). T_t implies technological innovation and is characterized by number of patent authorizations to industrial enterprises (*Tech*). S_t refers to the industrial structure and is characterized by the proportion of industrial value-added in GDP for a particular year (*Strc*). b_0 is a constant term. b_1, b_2, b_3, and b_4 are elasticity coefficients, and f_t is the error term.

Data Specifications

All data were collected from past *Environmental Statistics Yearbook of China* and *Statistical Yearbook of Jiangsu Province*, which were available on the EPS data platform. The data in 2001-2018 were used as the explained variable and the explanatory variable. To eliminate influences of price factors, we deflated the finished amounts of investments to industrial pollution governance according to the price index of investment in fixed assets in Jiangsu Province.

RESULT ANALYSIS

Models were established according to Eqs. 1-2. Model regression results based on EViews 9.0 software are listed in Table 1.

Table 1 shows that the three models have good regression fitting. The adjusted R-squared is higher than 0.85 and the F statistics are significant at 1% level. Labour input in the environmental protection system causes positive significant effects on industrial wastewater and industrial solid wastes. This result is related to the fast labour implementation of the environmental protection system in Jiangsu Province. This condition fully reflects that Jiangsu Province pays attention to industrial environmental protection, introducing professional industrial environmental protection talent vigorously, and increasing the efficiency of industrial environmental pollution governance. Technological innovation has positive and significant effects on industrial waste gas governance, indicating that Jiangsu Province has achieved great technological breakthroughs in industrial SO_2 governance and applied new technologies extensively. Industrial structure, a control variable, has negative effects on industrial wastewater governance but has positive impacts on industrial waste gas control. The reason may be that the industrial restructuring of Jiangsu Province focuses on closure and transformation of factories with heavy dependence on coal, which is a main SO_2 source, but it ignores restructuring with consideration for industrial wastewater. Environmental governance investment exerts a slight impact on industrial pollutant governance efficiency, which might be related to the small investment scale of environmental pollution governance. As a result, increasing investment in industrial environmental pollution governance in the future is suggested.

Table 1: Regression results of the models.

Variable	COD	SO_2	SOLID
Labour	0.891^{***}	0.436	0.182^{**}
Tech	0.023	0.128^{***}	0.015^{**}
Strc	-0.512^{**}	1.987^{**}	0.184^{*}
Icod	–0.875	-	-
Iso_2	-	0.713^{*}	-
Isolid	-	-	–0.856
b_0	-8.012^{*}	–3.298	-2.391^{***}
Adjusted R-squared	0.901	0.887	0.851
F-Measure	43.987^{***}	65.786^{***}	27.629^{***}

(*, **, and *** mean that T statistics are significant on 10%, 5%, and 1% levels, respectively.)

INDUSTRIAL POLLUTION GOVERNANCE MEASURES BASED ON BIG DATA OF ENVIRONMENTAL PROTECTION

Establishing a scientific and high-efficiency big data monitoring network system for the ecological environment: The big data on environmental monitoring is the basis for scientific, accurate, and effective environmental protection. Coverage and index items of existing ecological environmental monitoring networks cannot meet demands for evaluation, assessment, and alarm of environmental quality. Networking layouts of surface water and underground water have yet to be integrated and the environmental monitoring network layouts of atmosphere, soil, acoustic environment, ecology, and radiation have to be perfected. To ensure authenticity, accuracy, and comprehensiveness of environmental monitoring data, economic and environmental management departments have to improve their 24-hour/7-day monitoring network system by observing the integrity, systematic character, and internal laws of the ecosystem. The application values of big data on environmental protection can only be developed as long as real, accurate, and representative environmental monitoring data are collected.

Making full use of the advantages of block-chain technologies in industrial pollution management: Internet technology is the main basis for big data at present. Internet and multimedia platforms are necessary for better environmental pollution control. With the support of Internet technology, acquiring big data on environmental protection can be achieved comprehensively and conveniently. The public can understand the current conditions of ecological environmental pollution governance through multimedia or mobile applications. In this way, universal participation in environmental pollution control is increased, thereby further promoting ecological environmental pollution management. In addition, big data on environmental protection should fully utilize the advantages of block-chain technology and attention should focus on development and applications of scientific research innovation, united efforts in technological breakthrough, settle down and applications and achievement transformation. This approach not only increases the quality of big data on environmental protection but also supports scientific decision-making in environmental management while promoting economic and social development.

Constructing a big-data sharing and processing platform for environmental protection: Big data on environmental protection requires data management based on monitoring equipment during the application process. A higher requirement for data storage function of monitoring equipment is proposed due to diversified and real-time data updates. To improve the innovation effect of environmental pollution governance, a perfect environmental protection data processing platform can be constructed by combining Hadoop and Spark technologies and through distributed processing of big data on environmental protection. The platform can be used for comprehensive processing of various types of abundant environmental protection data. At present, China's big data processing platform for environmental protection has a high automation level and can provide effective data management services to existing environmental protection business, thereby significantly increasing the application effect of environmental protection data. Establishing an adaptive big-data sharing and processing platform for environmental protection can improve the sharing, processing, and service functions of environmental protection data, and realize effective integration and processing of data information related to environmental protection. As a result, environmental protection departments in all regions have to work together to set up a common data information library to realize service functions of data storage, management, and maintenance. On this basis, explicit interfaces between data management and services can be provided effectively.

Increasing big data sharing and application values of environmental protection: The coming era of big data not only provides guarantees to acquire environmental protection data but also ensures reasonable use of environmental protection data, thereby developing the role of big data technology in promoting environmental pollution control. Targeted integration of big data is needed, which not only increases the sharing effect of environmental protection data but also raises the application efficiency of big data in environmental pollution management. Using big data technology for environmental protection in environmental pollution governance aims to strengthen integration and correlation of data, thereby enabling to increase utilization of such data and providing data support for environmental pollution prevention and control. Therefore, relevant workers have to pay attention to increase the application values of big data on environmental protection, including meteorological, air quality, and meteorological monitoring data. Applying these data to environmental pollution governance does not only combine them simply but also develops their values fully through research. Combining various types of data effectively in specific environmental pollution control can improve the use of data validity.

CONCLUSIONS

Heavy industrial pollution remains in China. As a result, the environment has deteriorated and resources are increasingly depleted as extensive development occurs. Controlling industrial pollution emission and increasing the efficiency of emission reduction are important in supporting the economy and increasing living standards. Applying big data on environmental protection for environmental pollution management can significantly increase the efficiency of pollution control. It not only avoids waste of environmental protection data but also greatly improves the accuracy of environmental protection. In this case study on Jiangsu Province, China, industrial pollution governance efficiency is estimated and relevant industrial protection control measures based on big data technology are proposed. Results show that the trend of industrial pollution control for emerging technologies (e.g., big data) in the environmental protection field and labour input can considerably decrease industrial wastewater and industrial solid waste. Technological innovation has significant effects on industrial waste gas control. Finally, some environmental protection measures based on big data technology are proposed, including establishing a scientific and high-efficiency big-data monitoring network system for the environment, fully utilizing block-chain technological advantages in industrial pollution control, constructing a perfect big-data sharing and processing platform for environmental protection, and increasing the sharing and application values of big data on environmental protection. Further in-depth research is proposed on the best investment scale for industrial pollution control, construction of a big-data platform for industrial environmental protection, and a big-data dynamic simulation of environmental pollution governance.

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