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Analysis of the Impact of Environmental Regulation on Industrial Pollutants: A Case of the Yangtze River Delta Region, China

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Abstract— *Based on the panel data of 42 prefecture-level cities in the Yangtze River Delta region of China from 2003 to 2017, and based on STIRPAT model and Environment Kuznets Curve (EKC) theory, this paper conducts an empirical analysis on the impact of environmental regulation on industrial pollutants emissions in the Yangtze River Delta region. The results show that there is a nonlinear inverted U-shaped relationship between environmental regulation, industrial SO_2 and industrial soot. Population size, secondary industry structure and energy consumption have significant promoting effects on the discharge of the three industrial pollutants. Foreign Direct Investment (FDI) is beneficial to reduce industrial SO_2 and industrial soot discharge, but has no significant effect on industrial wastewater emission reduction. Technological innovation has a significant effect on the emission reduction of three industrial pollutants. Education level can significantly reduce the emission of SO_2 and industrial waste water, but it has no significant effect on the emission of industrial soot. Based on the research results, the government and enterprises should formulate reasonable environmental regulation intensity to promote the development of green and innovative technologies, increase investment in energy conservation and emission reduction technologies, and attract high-quality FDI, so as to reduce the emission of industrial pollutants.*

Keywords— *Industrial pollutants, Environmental regulation, Environmental pollution.*

I. INTRODUCTION

Since the reform and opening up, China's economy has developed rapidly. However, the rapid economic development is accompanied by large-scale consumption of energy resources and large-scale discharge of industrial pollutants, which eventually leads to serious loss of natural resources and environmental quality.

The Yangtze River Delta economic Zone, located in the lower reaches of The Yangtze River in China, is an important part of the Yangtze River basin, connecting four provinces of Shanghai, Zhejiang, Jiangsu and Anhui. The Yangtze River Economic Zone is one of the regions with the most active economy, the highest degree of openness and the strongest innovation ability in China. Its economic aggregate, international trade level and foreign direct investment rank among the top in China. However, environmental pollution in the Yangtze River Delta is also a serious problem. Fig.1. shows the annual emission of industrial pollutants in the region. How to coordinate economic and environmental development, promote ecological civilization construction, and strengthen energy conservation and emission reduction is a hot issue in current regional research.

Economic expansion has been accompanied by intensive use of fossil fuels, resulting in more pollution emissions and a serious impediment to sustainable development. Economic growth needs the support of natural resources. If we only focus on economic growth and ignore the consumption of natural resources and environmental conservation, it will not last long. (Foreign Direct Investment) FDI lead technology spillover, which can promote energy conservation and emission reduction, thus reducing pollution. In addition, government environmental regulation may also promote enterprises to research and develop green and innovative technologies, thus reducing emission costs. Here, this study takes the three industrial pollutants (industrial SO_2, industrial waste water, industrial soot) of 42 cities in the Yangtze River Delta as the research object to explore the influence of environmental regulation on the industrial pollutants in the region.

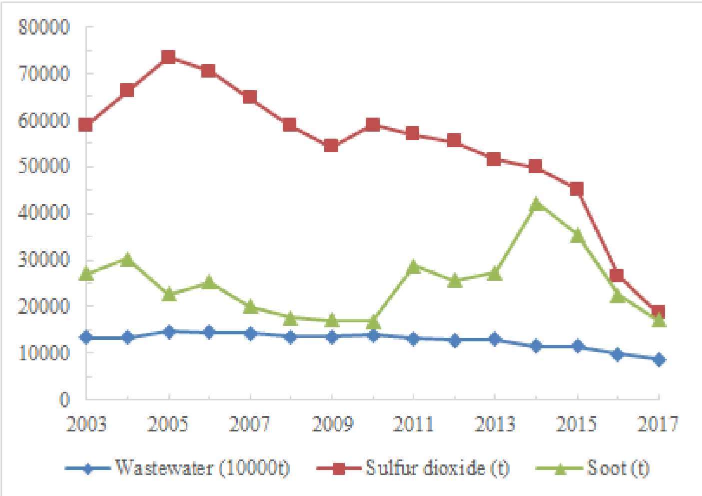

Fig. 1. The annual discharge of industrial pollutants.

II. LITERATURE REVIEW

There are abundant research results on the influencing factors of environmental pollution in the world. Academic researchers usually use a variety of environmental degradation indicators, such as CO_2, SO_2, or industrial wastewater, to represent environmental pollution levels.

Zhang and Zhao[1] evaluated the influencing factors of CO_2 emissions in 30 provinces of China from 1996 to 2015, and they believed that energy, industry and technology would become the main driving forces for environmental protection development in the future. Wasti and Zaidi[2] investigated the link among CO_2 emissions, energy consumption, gross domestic product, and trade liberalization in Kuwait from 1971 to 2017. They found that CO_2 emissions and energy consumption accelerate economic growth; CO_2 emission also plays a significant role in increasing energy consumption. Wang et al.,[3] used Logarithmic Mean Divisia Index (LMDI) method to analyze the driving factors of SO_2 emissions in 13cities in Jiangsu Province, China. They found that air pollution control is the main positive drive of SO_2 emission decrease, while energy intensity is the main negative factor. Hu et al.,[4] investigated long-run dynamics of sulphur dioxide emissions, economic growth, and energy efficiency during 2002 to 2015 in China. Their analysis found that GDP has a positive impact on SO_2 emissions in the short run and gained in energy efficiency have a significant negative effect on SO_2 emissions in the long run.

Environmental regulation is a means to prevent the negative externality of environmental pollution. The main arguments of environmental regulation on the relationship between environmental pollution are based on the "green paradox" and "Porter's hypothesis". "Green Paradox" shows that environmental regulation policies may have side effects when considering fossil fuel suppliers[5]. To maximize profits, suppliers will increase production and accelerate energy use, leading to environmental degradation. Porter hypothesis[6] indicates that appropriate environmental regulation intensity will force enterprises to make green technology innovation, reduce resource consumption and environmental pollution.

The competitive advantages of regions and enterprises cannot be separated from technological replacement and innovation. Technological innovation not only improves economic performance, but also helps to reduce pollution and promote environmental improvement[7]. More precisely, cleaner production technologies can help reduce resource consumption intensity and non-essential energy inputs, promote the reduction of pollution emissions in the entire production process, reduce non-essential energy inputs, and thus reduce unnecessary outputs[8]. Theoretically, FDI influences the environment of cities through "pollution paradise" effect or "pollution halo" effect. Due to weak environmental regulations, transnational corporations may transfer high-polluting enterprises to investment areas, causing "pollution paradise" effect and environmental degradation. However, multinational companies may also bring technological innovation and more environmental management practices, leading to the "pollution halo" effect that improves the energy efficiency of the investment areas and reduces the environmental pollution of the investment areas[9,10].

Combined with the actual situation of the development of the Yangtze River Delta region and the deficiencies of previous studies, this paper studies the impact of population, economic growth, industrial structure, energy consumption, FDI, technological innovation, education level and environmental regulations on industrial contamination.

III. METHODOLOGY

A. Model

Research on environmental pollution can be carried out through the classical IPAT model[11]. IPAT model is used to evaluate the main model of pollution of the environment pressure, the model that the environmental Impact (I) and Population (P), regional wealth level (Affluence, A) and Technology development level (T), show that a country or a region's environment by its Population, Affluence and Technology development level of mutual influence. Kuznets[12] developed the EKC model, which mainly means that in the early stage of development, countries pay more attention to industrialization and faster economic growth, but do not regulate and control environmental problems, leading to serious pollution. However, at a certain level of economic development, countries focus on controlling pollution emissions through the adoption of advanced technologies and strict environmental policies. In addition, with the improvement of development, the education level is also improving, and people's awareness of environmental pollution is also increasing, which may lead to the decline of environmental pollution.

This paper takes the random model of STIRPAT model as the framework[13] and combines EKC theory to construct the model equation as follows:

$$\begin{aligned} lnSO_2 = \alpha + \beta_1 \ln Pop_{it} + \beta_2 lnpGDP_{it} + \beta_2^{'} (lnpGDP_{it})^2 \\ + \beta_3 SI_{it} + \beta_4 \ln EC_{it} + \beta_5 \ln FDI_{it} + \beta_6 \ln TL_{it} \\ + \beta_7 lnEDU_{it} + \beta_8 ER_{it} + \beta_9 ER^2 + \varepsilon_{it} \end{aligned} \quad (1)$$

$$\begin{aligned} \ln WW = \alpha + \beta_1 \ln Pop_{it} + \beta_2 lnpGDP_{it} + \beta_2^{'} (lnpGDP_{it})^2 \\ + \beta_3 SI_{it} + \beta_4 \ln EC_{it} + \beta_5 \ln FDI_{it} + \beta_6 \ln TL_{it} \\ + \beta_7 lnEDU_{it} + \beta_8 ER_{it} + \beta_9 ER^2 + \varepsilon_{it} \end{aligned} \quad (2)$$

$$\begin{aligned} \ln WS = \alpha + \beta_1 \ln Pop_{it} + \beta_2 lnpGDP_{it} + \beta_2^{'} (lnpGDP_{it})^2 \\ + \beta_3 SI_{it} + \beta_4 \ln EC_{it} + \beta_5 \ln FDI_{it} + \beta_6 \ln TL_{it} \\ + \beta_7 lnEDU_{it} + \beta_8 ER_{it} + \beta_9 ER^2 + \varepsilon_{it} \end{aligned} \quad (3)$$

where, Model (1) takes volume of industrial SO_2 emissions (SO_2) as the dependent variable, Model (2) takes volume of industrial wastewater emissions (WW) as the dependent variable, and Model (3) takes volume of industrial solid waste emission (WS) as the dependent variable. *Pop* is population size; *pGDP* is per capita GDP, used to indicate economic growth; *SI* stands for industrial structure; EC stands for energy resources consumption; *FDI* is foreign direct investment; *TL* for technical innovation; *EDU* represents the level of education in a region, *ER* represents the intensity of environmental regulation.

This model will be used to study the impact of population, per capita GDP, industrial structure, energy resources consumption, foreign direct investment, technological innovation, regional education level, and environmental regulation on industrial contamination in the Yangtze River Delta region.

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B. Data

The sample selected in this paper is the panel data of prefecture-level cities of 42 cities in the Yangtze River Delta region from 2003 to 2017. The data are mainly from The Statistical Yearbook of Chinese Cities and the statistics bureau of various regions. The specific variables involved in the study are population size (*Pop*), economic growth (*pGDP*), industrial structure (*SI*), energy resources consumption (EC), foreign direct investment (*FDI*), technological innovation level (*TL*), education level (*EDU*), and environmental regulation (*ER*). The proxy variable of economic growth, per capita GDP, was reduced based on 2003. Environmental regulation is measured by the weighted synthesis of industrial SO_2 removal rate and industrial smoke (powder) dust removal rate[14]. The evolution trend of environmental regulation is shown in Fig. 2. The illustration of the dependent variables and the influence factors is presented in Table 1.

TABLE 1. The illustration of variables

Variables	Indicators
lnSO_2	the logarithmic volume of sulphur dioxide emission (ton)
*ln*WW	the logarithmic volume of industrial waste water discharged (10^4 tons)
*ln*WS	the volume of industrial soot(dust) emission (ton)
*ln*Pop	the logarithmic household Registered Population at Year-end (10^4 person)
*ln*pGDP	the logarithmic GRP per capita (Yuan)
*ln*FDI	the logarithmic actual foreign investment(Yuan)
*ln*EC	the logarithmic electricity Consumption for Industrial (10^4 kwh)
SI	the value of the second industry of GRP (%)
*ln*TL	the logarithmic local general public budget expenditure for science and technology (Yuan)
*ln*EDU	the logarithmic local general public budget expenditure for education (Yuan)
ER	environmental regulation composite index (/)

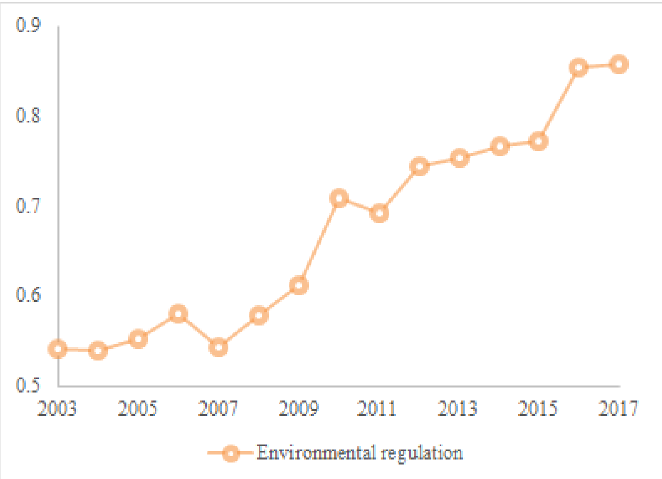

Fig. 2. Intensity of environmental regulation.

IV. Empirical Analysis

In this study, Generalized Least Squares (GLS) method was used to estimate the regression results, as shown in Table 2:

TABLE 2. Estimation regression

Variables	Model (1) SO_2	Model (2) WW	Model (3) WS
*ln*pGDP	1.763**	0.546	-1.223
	(0.689)	(0.650)	(0.978)
(*ln*pGDP)^2	-0.060*	0.007	0.077*
	(0.032)	(0.031)	(0.046)
*ln*Pop	0.858***	0.950***	0.536***
	(0.128)	(0.138)	(0.175)
SI	0.038***	0.026***	0.024***
	(0.005)	(0.004)	(0.007)
*ln*EC	0.209***	0.132***	0.130**
	(0.040)	(0.038)	(0.057)
*ln*FDI	-0.056*	-0.002	-0.109**
	(0.031)	(0.029)	(0.045)
*ln*TL	-0.077**	-0.100***	-0.117**
	(0.031)	(0.028)	(0.045)
*ln*EDU	-0.295***	-0.278***	0.188
	(0.095)	(0.090)	(0.136)
ER	5.331***	0.628	2.056*
	(0.854)	(0.775)	(1.237)
ER^2	-4.842***	-0.593	-2.039**
	(0.650)	(0.590)	(0.940)
Constant	-7.007**	-1.649	7.814
	(3.408)	(3.230)	(4.840)
Obs	615	615	615
Chi-square	545.746	199.801	89.126
Prob > chi2	0.000	0.000	0.000
R^2	0.784	0.816	0.486

Note: ***, ** and * indicates significance level at 1%, 5% and 10% respectively. St. dev are in parentheses.

Results from Table 2 indicates that increases in population (*ln*Pop) and energy consumption (*ln*EC) surges SO_2, WW, WS. An inverted U-shape relationship was established between economic growth (*ln*pGDP) and SO_2 and WS, however it has no significant effect on WW. A EKC U-shaped relationship was found between economic growth and partial pollutant discharge (SO_2 and WS). Industrial structure (*SI*) escalates industrial pollutants discharge, inferring that SO_2, WW and WS were affected significantly due to the secondary industry development. Energy consumption (EC) have significant promoting effects on the discharge of three pollutants. Energy consumption contributes significantly to environmental degradation. FDI (*ln*FDI) passed the negative significance test in Model (1) and Model (3), indicating that FDI in the Yangtze River Delta region has a "Pollution halo" effect, which indicates that SO_2 and WS decrease with the increase of foreign investment in the Yangtze River Delta region. According to our regression results, technological innovation (*ln*TL) contributes to environmental pollution reduction in the Yangtze River Delta. That's probably because green innovative technologies of energy conservation and emission reduction are effectively developed in this region. Education level (*ln*EDU) has had a significant impact on SO_2 and WW, however it has no significant effect on WS.

And most notably, the square term of environmental regulation (ER^2) in Model (1) and Model (3) is significantly negative, and there is a significant nonlinear inverted U-shaped relationship between environmental regulation and partial industrial pollutants discharge (SO_2, WS). It might mean that environmental regulatory policies supporting pollutant discharge reduction in the long-run. Because of the “Green paradox”, environmental regulation can cause more

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energy consumption at weak level. When environmental regulation intensity exceeds a threshold level, the effect is gradually becoming apparent. However the coefficients of ER^2 is insignificantly negative for WW emissions. This indicates that the effect of environmental regulation on emission reduction of different pollutants is heterogeneous.

V. POLICY IMPLICATIONS

In view of the above empirical results, this study proposes the following suggestions:

First, local governments can moderately increase the intensity of environmental regulations to "force" enterprises to transform to green enterprises. It should be noted that the government should set different environmental regulation intensity based on the heterogeneity of regional economic development level and so on. And it is necessary to develop different regulatory measures according to different pollutant conditions.

Second, the government needs to strictly control the quality of foreign direct investment and introduce investments that help promote green innovation. And, technological innovation is still the fundamental means to promote industrial optimization and enterprise transformation. In terms of improving the level of technological innovation, while increasing funding for environmental technology research and development, we should ensure that research and development expenditures can effectively develop energy-saving and emission-reduction technologies.

Third, the government needs to continue spending more on education. Developing education can improve human capital, and high-quality innovation always depends on high-quality human capital. Human capital can mitigate environmental degradation and improve environmental quality. Education can build capacity and acquire green innovation skills, improve energy efficiency and reduce pollution emissions.

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