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Empirical Analysis on the Relationship between Environmental Regulation and Environmental Level Based on Provincial Panel Data

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Abstract**—** *At present, it is an important period for China to build a modern and well-off society in an all-round way. In order to achieve sustainable development and contribute to the improvement of the global climate, the China government has formulated a series of energy-saving and emission-reduction policies and regulations to improve and improve the environmental level. So, can these policies achieve the expected goals? What are the similarities and differences in the impact on the provinces of China? Many problems remain unresolved. Therefore, it is urgent to clarify the relationship between environmental regulation and environmental level and put forward effective countermeasures. By analyzing the direct and indirect effects of environmental regulation on environmental level, this paper establishes the evaluation index system and measurement model of environmental level and environmental regulation. According to the different regression results of the eastern, central and western regions of China, the corresponding suggestions and measures are put forward to promote the development of energy conservation and emission reduction in China.*

Keywords**—** *Environmental regulation; environmental level; Industrial structure; Energy consumption structure.*

I. INTRODUCTION

Since the 20th century, the speed of world economic development has been increasing day by day. At the same time, various ecological and environmental problems have followed one after another. The sudden change of climate, ecological deterioration, lack of resources and other problems have made all countries in the world realize the threat of environmental pollution to the development of human society. All countries have also begun to work together to find solutions and countermeasures. In June 1992, at the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, representatives of various countries signed the United Nations Framework Convention on Climate Change (hereinafter referred to as the "Convention"). In December 1997, the third meeting of the participating countries of the Convention was held in Kyoto, Japan. At the meeting, the Kyoto Protocol to the United Nations Framework Convention on Climate Change (the "Kyoto Protocol") was adopted. As a supplementary provision of the Convention, the Kyoto Protocol, whose main purpose is to limit the global carbon emissions and mitigate the greenhouse effect, and to make the climate and environment relatively stable, entered into force on February 16, 2005.

Since the reform and opening up, China has taken the economic construction as the center and embarked on the road of rapid development. It has created a miracle of rapid economic development and a miracle of long-term social stability rarely seen in the world, but at the same time it has also paid a huge environmental price. In the face of increasingly severe ecological and environmental problems, the China government has attached great importance to it. Since 2009, it has issued the annual report on China's policies and actions to combat climate change every year. In the 2019 Annual Report on China's Policies and Actions to Address Climate Change, released on November 27, 2019, China's progress in addressing and resolving ecological and environmental issues was summarized, and China's willingness to actively assume international responsibilities and contribute to global ecological and environmental protection was also demonstrated.

In order to assist in energy conservation and emission reduction efforts, scholars have incorporated factors such as natural resources and environmental levels into theoretical models to discuss their impact on long-term economic growth. Although many scholars have tried to establish energy conservation and emission reduction evaluation systems from different perspectives and using different methods, there are relatively few studies on government environmental regulation, and few empirical analysis based on provincial panel data. Therefore, based on the study, analysis, and verification of the research achievements of many domestic and foreign scholars, this article applies various knowledge such as energy conservation and emission reduction and econometric analysis, combined with the current status of China's energy conservation and emission reduction policies, to comprehensively establish an environmental regulation evaluation index system, attempting to propose scientific and feasible suggestions for promoting China's low-carbon development.

II. THEORETICAL ANALYSIS

Environmental regulation refers to the negative externalities caused by environmental pollution. The government decides to regulate social production activities by formulating and implementing relevant energy-saving and emission-reduction policies, so as to achieve the sustainable development goals of environmental protection and economic development. The effect of environmental regulation on carbon emissions can be divided into direct effect and indirect effect.

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A. Direct Impact Effects

The government's environmental regulation policy can directly affect the environmental level, and generally has a positive impact, that is, the greater the effort, the corresponding optimization of the environmental level. The government can stipulate the emission reduction standard of enterprises through mandatory policies or directly shut down the enterprises exceeding the standard in order to achieve the effect of energy conservation and emission reduction; Or through market-oriented policies such as taxation and subsidies, enterprises with excessive pollutant emissions can be taxed, and enterprises with pollutant emissions up to standard can be subsidized, thus promoting enterprises to reduce emissions in two ways; At the same time, the government can also make enterprises consciously carry out energy conservation and emission reduction through voluntary policies such as raising public awareness of environmental protection and strengthening environmental protection supervision over enterprises.

However, environmental regulation will also have a negative impact on the environmental level to a certain extent. The higher the degree of environmental regulation by the government, the more stringent the environmental regulation policies the fossil energy suppliers expect in the future, thus increasing the current mining intensity, increasing the energy supply, lowering the energy price and increasing the energy demand, which will lead to an increase in pollutant emissions.

B. Indirect Effects

From the perspective of environmental regulation, industrial structure and environmental level, the more stringent the government's energy-saving and emission-reduction policies are, the higher the cost of high-energy-consuming and high-pollution enterprises will be. In order to reduce costs, pollution-intensive industries will be transferred to regions with more relaxed emission reduction policies or undergo industrial transformation. Clean-intensive industries, such as services, have been hit less and may even receive subsidies. Therefore, the government's environmental regulations can effectively limit the expansion of pollution-intensive industries, promote the development of modern service industry, promote the upgrading of industrial structure, and realize energy conservation and emission reduction.

Analyzing from the path of environmental regulation-energy consumption structure-environmental level, there may be two distinct effects. On the one hand, the government has adopted energy-saving and emission-reduction policies to increase the cost of fossil fuels used by enterprises, thus prompting enterprises to reduce the demand for fossil fuels and increase the demand for clean energy, thus optimizing the energy consumption structure. On the other hand, strict emission reduction policies will lead to more and more stringent expectations from energy suppliers, which will increase energy exploitation efforts to expand the supply, which is not conducive to optimizing the energy consumption structure, and thus lead to an increase in pollutant emissions.

III. Models and Variables

A. Model Settings

This paper uses the provincial panel data of China from 2011 to 2020, taking environmental level as the explanatory variable, environmental regulation as the core explanatory variable, and economic level and population size as the control variables to verify the direct impact of environmental regulation on carbon emissions, and constructs the following measurement model, as in

$$EL_{it} = \alpha_0 + \alpha_1 ETRE_{it} + \alpha_2 GDP_{it} + \alpha_3 POP_{it} + \varepsilon_{it} \quad (1)$$

Among them, Eit represents the environmental level of Province i in Year t, ETRE represents the degree of environmental regulation, GDP represents the economic level of each province, POP represents the population size of each province, and ε is a random interference term.

Industrial structure, energy consumption structure and technological progress are introduced as intermediate variables to investigate the indirect impact of environmental regulation on carbon emissions. Based on the intermediate effect theory, the following measurement model is constructed:

$$Y_{it} = \beta_0 + \beta_1 ETRE_{it} + \beta_2 GDP_{it} + \beta_3 POP_{it} + \varepsilon_{it} \quad (2)$$

Among them, Y IS the intermediate variable, namely industrial structure (IS), energy consumption structure (ECS) and technological innovation (TI). Model (2) reflects the impact of environmental regulation on the intermediate variables.

Introducing an intermediate variable into model (1) yields the following measurement model:

$$EL_{it} = \gamma_0 + \gamma_1 ETRE_{it} + \gamma_2 Y_{it} + \gamma_3 GDP_{it} + \gamma_4 POP_{it} + \varepsilon_{it} \quad (3)$$

Model (3) reflects the impact of the core explanatory variable—environmental regulation—on the environmental level after considering the intermediate variable.

B. Interpreted variable

In this paper, a multi-index environmental level evaluation index system is adopted, and the model is constructed as follows:

$$EL_i = 10.17X_1 - 54.52X_2 + 62.05X_3 + 7.5X_4 - 28.97X_5 + 44.01X_6 \quad (4)$$

Among them, ELi represents the comprehensive evaluation score of the environmental level in Province i, i = 1,2,3,4,5, ... 27 (except for Hebei, Anhui and Ningxia in Tibet), and the meanings of X1 to X6 are as follows:

TABLE 1. Comprehensive Index System of Environmental Level.

Symbol	Meaning
X1	Wastewater discharge
X2	Chemical oxygen demand
X3	Sulphur dioxide emissions
X4	Smoke and dust emissions
X5	Solid waste emissions
X6	Carbon dioxide per capita

C. Core Explanatory Variable

Considering that the impact path of environmental regulation on environmental level is relatively complex, the evaluation system of environmental regulation also contains many indicators. This paper mainly starts with mandatory,

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market-based and voluntary environmental regulation measures, and constructs the following comprehensive evaluation index system of environmental regulation that contains multiple indicators.

TABLE 2. Comprehensive Index System of Environmental Regulation.

Indicator classification	Indicator selection
Mandatory Environmental Regulation Indicators	Wastewater discharge compliance rate Removal rate of sulfur dioxide Smoke (powder) dust removal rate Comprehensive utilization rate of solid waste
Market-based Environmental Regulation Indicators	Total sewage charges levied resource tax consumption tax operation tax of vehicle and ship
Voluntary Environmental Regulation Indicators	Voluntary public participation environmental mark Environmental quality disclosure

In order to make each index can be measured in a standard and scientific way, the following treatment methods are adopted in this paper.

First, in order to ensure the comparability of each index and facilitate the subsequent calculation and analysis, each single index is normalized here, and each single index is linearly normalized according to the value range of 0-1. The formula is as follows:

$$E_{ij}^{s} = \frac{E_{ij} - Min(E_j)}{Max(E_j) - Min(E_j)} \quad (5)$$

Where Eij is the original value of indicator j, Esij is the standardized value of indicator j, and Max(Ej) and Min(Ej) are the maximum and minimum values of indicator j in all provinces in each year.

Then, due to the large gap between the various indicators in each province and the certain difference between different indicators in the same province, different indicators in different provinces are given different weights by calculating the adjustment coefficient between the various indicators. The formula is as follows:

$$W_j = \frac{I_{ij}/\sum_i I_{ij}}{O_i/\sum O_i} \quad (6)$$

Where Wj is the adjustment coefficient of the index J; For the mandatory environmental regulation index, I represents the pollutant emissions and O represents the gross industrial output value; For the market-based environmental regulation index, I represents the total industrial output value and O represents the number of industrial enterprises; For voluntary environmental regulation indicators, I represents the population with high school education or above, and O represents the total population.

Finally, according to the standardized value of each index and its average weight, the environmental regulation and total environmental regulation (ETRE) of each evaluation index are calculated. The larger the ETRE, the greater the environmental regulation. The formula is as follows:

$$S_j = \frac{1}{n}\sum_{j=1}^{n} W_j^* E_{ij}^s \quad (7)$$

$$ETRE = \sum S_j \quad (8)$$

D. Control variables

The level of economic activity and population size are also important factors that affect the regional environmental level. This article takes the per capita GDP of each province as the proxy indicator for the regional economic activity level, and the total population POP of each province as the proxy indicator for the regional population size, and introduces them into the model separately.

E. intermediate variables

Industrial structure (IS): the ratio of the output value of the tertiary industry to the output value of the secondary industry in each province is taken as the proxy indicator of the industrial structure.

Energy consumption structure (ECS): The proxy index of energy consumption structure is the ratio of coal consumption and oil consumption to total energy consumption in each province.

IV. Empirical Analysis

A. Basic Regression Results

Considering the lagging effect of environmental regulations, this article includes early environmental regulations as the core variable in the model. According to the comprehensive test results of F-test and Hausman test, the fixed effect model is used for empirical analysis. The analysis results are as follows:

TABLE 3. Regression Results of Model (1).

Variable	Eastern China lnEL	Central China lnEL	western China lnEL
ETRE(-1)	0.4191*	0.3207**	0.0963***
	(0.162)	(0.061)	(0.009)
lnGDP	-0.6158***	-0.6592***	-0.3972***
	(0.043)	(0.069)	(0.029)
lnPOP	-0.7344**	-0.8318*	-0.3502***
	(0.286)	(0.215)	(0.041)
c	-7.8032***	5.1195*	-2.6430***
	(1.812)	(2.156)	(0.311)
R2	0.8706	0.8573	0.8499

From Table 3, the impact of environmental regulation on the environmental level in the eastern region (0,4191) is greater than that in the central region (0.3207), and the impact of environmental regulation on the environmental level in the central region is greater than that in the western region (0.0963). The eastern region has superior geographical conditions and a high level of economic development. The level of government governance and the development of production management capabilities of enterprises are relatively perfect. At the same time, the public has a higher level of education and a higher degree of enthusiasm and awareness of environmental protection. Therefore, the environmental regulation has the most significant impact on

the environmental level. The economic development of the central region lags behind that of the eastern region, and the central region has a large number of energy-intensive provinces. Therefore, the impact of environmental regulations on the environmental level in the central region is lower than that in the eastern region. Generally speaking, the environmental regulations in the eastern region and the central region have a significant impact on the environmental level, while the environmental regulations in the western region do not have a significant impact on the environmental level. This is due to the relatively backward economic development in the western region, the imperfect development of environmental protection mechanism and information system, and the low public participation in environmental protection, which makes it difficult for the government to effectively optimize the environmental level.

B. Regression Results of Intermediary Effect

TABLE 4. Regression Results in Eastern China.

Variable	Model (2)		Model (3)	
	IS	ECS	lnEL	lnEL
ETRE(-1)	0.8476*	-0.1285**	0.2657**	0.1496*
	(0.461)	(0.062)	(0.084)	(0.026)
lnGDP	2,4785*	-0.2143***	-0.6104*	-0.6063*
	(0.733)	(0.103)	(0.046)	(0.039)
lnPOP	3.2445***	4.3127***	-0.3896*	-0.4697*
	(1.088)	(0.559)	(0.181)	(0.172)
IS			0.0858**	
			(0.051)	
ECS				-0.1473***
				(0.033)
c	-8.4967*	0.4358*	-5.7204**	-1.5732*
	(2.261)	(0.410)	(1.973)	(1.121)
R2	0.6312	0.8977	0.7793	0.7890

The environmental regulation in the eastern region has an obvious promotion effect on the industrial upgrading (0.8476). After adding the intermediate variable of industrial structure into the model, the industrial structure has a positive impact on the environmental level. The environmental regulation still has a significant impact on the environmental level, but the impact level decreases, indicating that the eastern region indirectly optimizes the environmental level through the industrial junction path. The environmental regulation in the eastern region can optimize the energy consumption structure (-0.1285). After introducing the intermediate variable, the energy consumption structure has a significant impact on the environmental level, while the environmental regulation has no significant impact on the environmental level. The analysis may be due to the economic development in the eastern region, the higher awareness of national environmental protection, and the geographical advantage to facilitate the introduction of clean energy.

The environmental regulation in the central region also promoted the optimization of industrial structure (0.1594). After introducing the intermediate variable of industrial structure, it failed the significance test, indicating that the environmental regulation in the central region promoted the optimization of industrial structure, but had no significant effect on the environmental level. The impact of environmental regulation on the energy consumption structure in the central region (-0.3016) is greater than that in the eastern region. After the introduction of intermediate variables, the impact of energy consumption structure on the environmental level is significant, while the impact of environmental regulation on the environmental level is insignificant. This is due to the fact that the central region has a large number of energy provinces, and the public are increasingly tired of environmental pollution, and are eager to strengthen energy conservation and emission reduction to improve the environment. The government adopts environmental regulation measures to reduce the exploitation and utilization of fossil energy such as coal, so that the path of the impact of environmental regulation on the environmental level through the energy consumption structure is more obvious.

TABLE 5. Regression Results in Central China.

Variable	Model (2)		Model (3)	
	IS	ECS	lnEL	lnEL
ETRE(-1)	0.1594**	-0.3016***	0.0674*	0.667*
	(0.067)	(0.672)	(0.062)	(0.049)
lnGDP	1.2943*	1.0976*	-0.7002***	-0.6997**
	(0.739)	(0.391)	(0.069)	(0.069)
lnPOP	4.7305**	6.7522***	-0.4772**	-0.6012***
	(1.911)	(1.973)	(0.178)	(0.080)
IS			0.0982*	
			(0.078)	
ECS				-0.5893**
				(0.074)
c	-3.7492**	6.2113***	-0.6392*	-7.0493**
	(1.559)	(1.656)	(1.483)	(1.551)
R2	0.6217	0.7762	0.7394	0.8304

TABLE 6. Regression Results in Western China.

Variable	Model (2)		Model (3)	
	IS	ECS	lnEL	lnEL
ETRE(-1)	0.0162*	0.0734*	0.0406**	-0.0031**
	(0.068)	(0.121)	(0.027)	(0.051)
lnGDP	2.9035***	5.0338***	-0.4318***	-0.5930***
	(0.524)	(1.019)	(0.025)	(0.018)
lnPOP	0.3872*	1.1134***	-0.3414***	-0.9742***
	(0.173)	(0.158)	(0.036)	(0.246)
IS			0.0148***	
			(0.031)	
ECS				-0.0266***
				(0.001)
c	0.4487***	-0.7893***	2.3387***	0.6523***
	(0.072)	(0.123)	(0.283)	(1.791)
R2	0.7132	0.9034	0.8294	0.7998

The environmental regulation in the western region does not have a significant impact on the industrial structure. After introducing the intermediate variable, the industrial structure has a significant impact on the environmental level, while the environmental regulation does not have a significant impact on the environmental level. This indicates that the environmental regulation in the western region is not sufficient to promote the upgrading and optimization of the industrial structure. It may even cause the high-polluting enterprises in the eastern and central regions to move to the western region and further deteriorate the environmental level in the western region.

After the introduction of intermediate variables, environmental regulations and energy consumption structure

in the western region have a significant negative impact on the environmental level. The analysis reason is that people in the western region are relatively lack of environmental awareness and participation enthusiasm, which is not conducive to the optimization of the energy consumption structure, resulting in a "green paradox".

V. CONCLUSIONS

The eastern region should adopt stronger environmental regulation measures. On the one hand, through market-oriented tools, improve and develop resource tax, environmental tax, environmental protection subsidy mechanism, etc. On the other hand, we will improve the environmental protection information disclosure system, public supervision system, enterprise environmental sign application mechanism, etc., and improve the role and impact of voluntary environmental regulation tools. Through the comprehensive use of various environmental regulation tools, the impact of industrial structure, energy consumption structure and technological innovation on the environmental level can be fully exerted.

The central region can use mandatory tools to appropriately raise the emission standards of pollutants. At the same time, information disclosure and public participation should be strengthened to give full play to the indirect effects of energy consumption structure and technological innovation. In addition, considering the large number of energy-intensive provinces and agricultural provinces in the central region, attention should be paid to energy conservation and emission reduction in the energy-intensive provinces and efforts should be made to achieve the goal of sustainable development. For the agricultural provinces, while optimizing the secondary industry, they should also do a good job in environmental protection in the primary industry and promote the low-carbon development of agriculture.

The western region should give priority to mandatory tools, strengthen environmental protection standards and energy conservation and emission reduction requirements, improve government implementation, and look for suitable energy conservation and emission reduction methods based on the experience of the eastern and central regions and their own resources and economic characteristics.

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