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Do Environmental Regulation and Foreign Direct Investment Drive Regional Air Pollution in China?

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Abstract: With economic development, air pollution is becoming increasingly serious, which affects the sustainable development of the global economy. In order to explore policy measures to curb air pollution, this paper selects data from 30 regions in China and explores their impact studies on air pollution from the perspectives of environmental regulation and foreign direct investment using a systematic GMM model. Then, the threshold effect model is selected to verify their nonlinear relationship. The conclusions are as follows: (1) Environmental regulation does not pass the significance test. There is no significant "U-shaped" or "inverted U-shaped" relationship between environmental regulation and air pollution. In the eastern region, there is an inverted U-shaped relationship, which is consistent with the environmental Kuznets curve (EKC) hypothesis, and the effect in the central and western regions is higher than in the eastern region of China. (2) The entry of foreign direct investment (FDI) aggravates the environmental pollution problem in China, and the overall status quo is consistent with the pollution haven hypothesis, which shows an inverted U-shaped curve between FDI and air pollution. The eastern region does not have any U-shaped relationships. The other two regions show an inverted U-shaped curve between foreign direct investment and air pollution; these two regions are still in the left half of the curve, and the increase in foreign capital will lead to aggravation of the pollution status quo. (3) The industrial structure will aggravate air pollution in the whole country and the central and western regions; the eastern region shows a suppression effect, but this is not significant. Urbanization exacerbates air pollution in the central and western regions but has an insignificant effect in the eastern region. The level of economic development increases air pollution in all regions. The expansion of the population size brings a large amount of production and living pollution, which aggravates environmental pollution. The research in this paper can provide theoretical references for regional policies to control air pollution.

Keywords: environmental regulation; foreign direct investment; air pollution; sustainable development; green economy

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1. Introduction

Along with the deepening of economic globalization, sustainable development has become the focus of attention of most countries around the world. Among them, the global effect of air pollution, represented by haze pollution, is more obvious; air pollution poses a threat to sustainable development because it simultaneously affects various social, environmental and economic criteria related to equitable human development, such as health, food security, gender equality, climate stability and poverty reduction. The link between air pollution and development, the economy and the environment implies that reducing air pollution is relevant to achieving the Sustainable Development Goals. In some developing countries, air pollution is the biggest environmental threat to human health, which not only seriously affects people's normal life and physical health but also becomes an important obstacle to enhancing people's happiness and sense of access [1]. Solving the problem of air pollution has become an urgent task in achieving ecological development.

With the continuous deepening of reform, the Chinese government has also gradually relaxed. This has increased the amount and scale of FDI year by year. The Commerce Data Center of the Ministry of Commerce of China provides data showing that, in 2021, the actual amount of foreign investment used nationwide was CNY 114.96 billion, an increase of 14.9% year-on-year, achieving double-digit growth. With the increasing level of opening up and deepening openness, China has become a major inflow of FDI. The influx of FDI provides capital, technology and management experience, and promotes the economic growth of China [2]. At the same time, the environmental effects brought by the expansion of FDI have also received increasing attention [3], especially the hazy weather that has often occurred in recent years, affecting a wide range of areas, such as public health. Therefore, as a complex covering capital, technology and management, what is FDI's impact on air pollution in various regions? Does this impact show a linear relationship? Answering the above questions has important theoretical value and practical significance for formulating interlinked policies for attracting investment and environmental policies, enhancing the environmental friendliness of foreign investment and achieving sustainable development.

Most cities and provinces in China have faced different degrees of haze in recent years, which not only seriously endangers people's daily life and health but also causes huge economic losses directly and indirectly [4]. In response to the increasingly severe haze situation, the state has introduced many laws, regulations and policies on air pollution control and increased the supervision and punishment of industrial enterprises for violations. As a typical representative of public goods, it is difficult to identify the root cause of air pollution by relying solely on the role of the market, and its prevention and control process cannot be separated from the centralized control and collaborative management of the government. As a pollution management tool widely used by the government, exploring the effectiveness of environmental regulation on air pollution has guiding significance and practical value for the future air pollution prevention and control work of the Chinese government. As a traditional form of governmental environmental improvement, environmental regulation has been gradually applied by the government in the field of air pollution management in recent years and has become an important tool for improving urban environmental quality [5]. However, with the increasing enrichment of policy contents, the scientific evaluation of environmental regulation in a reasonable and effective way has become a trending topic and a frontier of research in the environmental field. What is the impact of environmental regulations on air pollution? Does it show a linear relationship? Further investigation is required to obtain valuable policy advice. Based on this background, this study uses a systematic GMM model to verify the impact of FDI and environmental regulation on air pollution, verifies the nonlinear relationship using the threshold model and, finally, proposes countermeasures to improve air pollution in order to provide a scientific reference for regional sustainable development.

The main contributions of this paper are as follows: (1) this study starts with regional heterogeneity and explores the heterogeneity of the impact of foreign direct investment and environmental regulation at the national level and different regional levels, which can provide a theoretical reference for the regional formulation of pollution control policies and is an extension of and supplement to existing studies; (2) the nonlinear relationship between the impact of business direct investment and environmental regulation on air pollution is verified, and the inflection point of the impact is measured, providing a reference for policy; (3) based on the results of the empirical analysis, corresponding policy recommendations are derived, which can provide a reference for regional policy-making departments and can have important practical value for controlling air pollution and achieving the goal of sustainable development.

2. Literature Review

2.1. FDI and Environmental Pollution

With regard to the relationship between FDI and environmental pollution, existing studies have not reached consistent conclusions, and there is a big controversy about the functional direction of FDI in pollution. In general, there are two camps, namely, those supporting the "pollution haven" hypothesis and those supporting the "pollution halo" hypothesis. The "pollution haven" hypothesis suggests that host countries provide less stringent environmental protection rules in order to attract FDI [6,7]. For example, Copeland and Taylor [8] found that countries with a lower income have a relative competitive advantage in pollution-intensive products, which theoretically validates the "pollution sanctuary" hypothesis. Javorcik [9] analyzed the data of 534 multinational enterprises in 24 countries and concluded that countries with higher environmental standards have lower FDI inflows, which provides evidence for the "pollution sanctuary" hypothesis. Existing domestic studies on FDI and haze air pollution mainly support the "pollution sanctuary" hypothesis [10]. Liu and Zhao [11] used data from 285 cities in China from 2003 to 2013 and also found that the "pollution sanctuary" hypothesis is true in some areas. The "pollution refuge" hypothesis is valid in other areas.

Although the "pollution haven" hypothesis has been confirmed by many scholars, some scholars still agree with the "pollution halo" hypothesis. The "pollution halo" hypothesis refers to the improvement of the host country's environment through the growth effect, the spillover effect of advanced clean technology, and scientific and perfect management systems [12,13]. The "pollution halo" hypothesis suggests that FDI can improve the environmental quality [14]. Foreign scholar Dean [15] found that, with the development of trade liberalization and the increase in income, people's demand for environmental quality also increased. Domestic scholars Huang and Zhou [16] showed that foreign direct investment can effectively suppress wastewater emissions and improve environmental quality, thus verifying the "pollution halo" hypothesis. Qin and Yu [17] also constructed a spatial regression model from a spatial perspective and showed that the "pollution sanctuary" hypothesis was not valid in China.

2.2. Environmental Regulation and Environmental Pollution

This relationship study includes the following two main areas: First, environmental regulation inhibits air pollution. Wang and Xu [18] took the investment preference of industrial enterprises as the entry point and found that environmental administrative control and environmental pollution regulation have a strong inhibitory effect on haze, while environmental economic regulation weakens the effect. Xu and Cheng [19] found that the industrial structure effect and the technical efficiency effect of environmental regulation can inhibit air pollution. Liu and Jiang [20] analyzed the haze levels after grading and concluded that the containment of national haze by environmental regulation is achieved through the role of medium- and light-pollution provinces. Laplante and Rilstone et al. [21] showed that environmental regulation can reduce pollution emissions. Hettige et al. [22] found that environmental regulations can also reduce industrial pollution emissions. Cole et al. [23] showed that environmental regulations were effective in reducing air pollution based on pollution data from industrial enterprises in the U.K. Marconi [24] studied China and 14 countries in the European Union, comparing and analyzing the impact of environmental regulations on exhaust- and wastewater-intensive enterprises. Second, some studies concluded that the impact of environmental regulation on air pollution cannot be verified, maybe because environmental decentralization intensifies competition among local governments, which ultimately makes environmental regulation less effective [25]; in addition, the high costs associated with environmental regulations may be the reason for the failure of environmental regulations [26–29]. For example, Gao et al. [30] argued that environmental regulations can only improve industrial pollution in the eastern provinces, and the effect was not good at the national level. Xu [31] found that environmental regulations aggravated pollution emissions, i.e., the "compliance cost" effect of environmental regulations dominated. Greenstone [32] showed that strict environmental regulations cannot reduce pollution. Blackman et al. [33] concluded that environmental regulations did not play a significant role in promoting "green" technological innovation but rather increased pollution emissions.

In summary, air pollution is closely related to natural and human activity factors. Research on air pollution from the aspects of environmental regulation and foreign direct investment is less abundant. There are fewer studies on the regional heterogeneity of air pollution and on interprovincial heterogeneity, and the existing studies mainly focus on cross-country or cross-regional heterogeneity. In view of the current research status and methodology, this paper presents the impact on air pollution in two dimensions: environmental regulation and foreign direct investment, and studies the regional heterogeneity of the impact of environmental regulation and foreign direct investment on air pollution.

3. Methodology

3.1. Systematic GMM Model

Panel data are data that track the same individual over time, and they consist of two dimensions, i.e., cross-sectional individual sample data (N samples) and temporal data (T periods) and a "dynamic panel" in a panel model if the explanatory variables contain explanatory lags. Panel data can facilitate the observation of individual time-series characteristics. Panel data contain two dimensions of information, usually with a larger sample size, which can improve the accuracy of estimation. Fixed effects and random effects models are the general models for the regression analysis of panel data, but these two models also have certain shortcomings; they cannot investigate the dynamic relationships between variables, tend to ignore the effects of the inertia of individual behaviors and cannot solve the resulting endogeneity problem, and the existence of endogeneity can make the parameters in the estimation results inaccurate [34]. However, generalized moment estimation (GMM) is a robust estimator, and the parameter estimates obtained from it are more realistic than those obtained from other methods [35]. Systematic GMM estimation is the combination of difference and level equations to form a system of equations for estimation, which can improve the efficiency of estimation. The use of systematic GMM estimation requires certain conditions to be met, and two tests [36], namely, the autocorrelation test and the overidentification test, are required for empirical testing as a way to prove that the differenced series of the perturbation terms of these panel data are not autocorrelated and that the model is applicable only if these two conditions are met [37]. In general, dynamic panel models have the following form:

$$y_{i,t} = \alpha_0 + \alpha_i y_{i,t-1} + \beta_j \sum_j X_{j,i,t} + \eta_i + v_{it} \tag{1}$$

$$\mathrm{i} = 1, 2, \cdots, \mathrm{N}; \mathrm{j} = 1, 2, \cdots, \mathrm{M}; \mathrm{t} = 1, 2, \cdots, \mathrm{T}$$

where X denotes control variables, $y_{i,t}$ is the explanatory variable, η_i denotes an unobservable and time-invariant individual effect and v_{it} denotes a heterogeneous error term. In this paper, air pollution is the explained variable, and environmental regulation and foreign direct investment are the main explanatory variables. Since the explanatory variables are usually serially correlated over time, we include the lagged terms of the explanatory variables in the regression equation. In addition, according to the literature, there may be a nonlinear relationship between them, so we also introduce their squared terms in the equation and use a dynamic panel data model to estimate the relationship between the variables after controlling for some other relevant variables.

3.2. Variable Selection

(1) Explained variable

Air pollution (AQ): The explained variable is measured by the PM2.5 air pollution index. Environmental pollution is divided into atmospheric pollution, water pollution and soil pollution. In terms of spatial mobility, the flow rate of the atmosphere is much higher than that of water and soil, and its diffusion degree and diffusion range are also the largest [38,39]. In terms of its harm degree, fresh air is essential for human survival, and once air pollution is serious, it will greatly threaten people's health. Additionally, haze is an important manifestation of air pollution. Haze refers to particles such as PM2.5, dust and aerosols floating in the atmosphere, and the haze disaster affects human breathing and daily life. The PM2.5 index is easy to detect and obtain and can more accurately measure the environmental quality of a region [40]. The larger the value of PM2.5, the more serious the air pollution. In order to mitigate the effects of area or population heterogeneity across provinces, this paper uses geographically area-weighted interprovincial PM2.5 data for China for the explained variable, obtained from global PM2.5 concentration data published by the Center for Socioeconomic Data and Applications at Columbia University.

(2) Explanatory variables

Environmental regulation (ER): There are many ways to measure environmental regulation. Referring to Zhang et al. [41] and Yu and Gao [42], this study uses the ratio of industrial pollution control investment to industrial value added in each region as a metric. The relevant data are obtained from the China Environment Statistical Yearbook, CEIC database and China Statistical Yearbook for the relevant years.

Foreign direct investment (FDI): Some scholars believe that FDI has a deteriorating effect on the environment and support the pollution haven hypothesis, while other scholars believe that FDI has an improving effect on the environment and support the pollution halo hypothesis. In view of the fact that FDI stock can more accurately reflect the impact of FDI on environmental pollution, this paper selects the proportion of FDI stock to regional GDP for research [43].

(3) Control variables

Population density (PS): In the relationship between humans and the environment, humans are both the source of environmental damage and the main force in protecting the environment. As the population of an area continues to grow and the total demand for that area increases, people expand the scale of resource exploitation, and the environment becomes worse as a result [44]. Air pollution, as a part of environmental pollution and human activities, is also one of the important reasons for the deteriorating air quality. On the other hand, as urbanization accelerates, the population tends to flow to the economically developed eastern coastal areas, and in the process of labor migration, they usually choose areas with a higher environmental quality; therefore, population density can also be seen as a variable of environmental awareness. In this paper, the population density variable is chosen to investigate the effect of environmental awareness on air quality [45]. Since there are 2 possible effects, the expected judgment on the sign of the coefficient is therefore not made.

Economic development level (GDP): In this paper, we use the GDP per capita of each province calculated in 2008 as the base period to express the level of economic development.

Urbanization (UR): Urbanization is a process of transformation from rural to urban, which includes both the transformation of the population quantity and spatial scale and the transformation of production and lifestyle. One of the main measures of the urbanization level is the population share method, which is widely used by domestic and foreign scholars for its simple calculation and clear definition. In this paper, the population share method will be used to measure urbanization. The data of the urban population and total population in the past years are obtained from the National Bureau of Statistics.

Industrial structure (IS): The industrial structure of a country or region has an impact on the environment. The secondary industry, mainly manufacturing, tends to be more pollution-intensive, while the tertiary industry, mainly high-tech and service industries, tends to be cleaner. This paper draws on most of the research methods and adopts the proportion of secondary industry value added to GDP to reflect the industrial structure of each province, where an increase in this ratio indicates more serious pollution and vice versa. The specific variables selected are shown below in Table 1.

Table 1. Variable selection.

Variable Type	Variable	Symbol	Definition
Explained variable	Air pollution	AQ	PM2.5 air pollution index
Explanatory variables	Environmental regulation	ER	The ratio of industrial pollution control investment to industrial value added in each region
	Foreign direct investment	FDI	The proportion of FDI stock to regional GDP
Control variables	Population density	PS	Population (people)/area (km^2)
	Economic development level	GDP	The GDP per capita of each province
	Urbanization	UR	The population share method
	Industrial structure	IS	The proportion of secondary industry value added to GDP

Therefore, the basic model is as follows:

$$\text{lnAQ}_{i,t} = \alpha_0 + \alpha_1 lnAQ_{i,t-1} + \alpha_2 lnER_{i,t} + \alpha_3 ln(ER)^2{}_{i,t} + \alpha_4 lnFDI_{i,t} + \alpha_5 ln(FDI_{i,t})^2 + \beta_j \textstyle\sum_j lnX_{j,i,t} + \eta_i + \upsilon_{it} \quad (2)$$

where i represents regions ($i = 1, 2, \cdots, 30$); t is time ($t = 2008, 2009, \cdots, 2021$); AQ represents air pollution; ER is environmental regulation; FDI represents foreign direct investment; X represents other control variables, i.e., economic development level (GDP), population size (PS), industrial structure (IS) and urbanization (UR); η_i denotes provincial fixed effects; υ represents the error term; and β_j represents the estimated coefficient of the control variables. In order to reduce the estimation error caused by heteroskedasticity without changing the nature of the panel data and the interrelationships of the variables, this paper adopts a log-transformation treatment for the variables.

In addition, before establishing the dynamic panel model, this paper divides the national data used in this paper into three large regional subsamples, i.e., the eastern, central and western regions, according to the relevant criteria in the National Development and Reform Commission Document No. 33 of 2000 and then analyzes whether there are differences in the impact trend characteristics of different regions later in the paper. The descriptive statistics results are shown in Table 2.

Table 2. Descriptive statistics results.

Variable	Observed Value	Mean	Standard Deviation	Minimum	Maximum
AQ	420	45.565	22.123	4.678	99.053
ER	420	0.662	0.335	0.208	0.935
GDP	420	3.67	4.55	2.12	6.47
FDI	420	0.063	0.113	0.043	0.145
UR	420	0.323	0.018	0.235	0.376
IS	420	0.213	0.312	0.143	0.449
PS	420	0.025	0.032	0.012	0.067

3.3. Nonlinear Analysis Method

The threshold panel model, a spatialization of the threshold regression model, is transformed into a threshold panel model when the research object is extended to multiple individuals and multiple years, and the model focuses on the judgment of the threshold value, which can be understood as the threshold value of the sudden structural change. The idea of the model is to transform the nonlinear model into a segmented linear model by determining the threshold value, segmenting the stage and constructing different models for different cases. The estimation principle is mainly based on the principle of the least sum of squares of residuals (SSR) [46,47]. In ordinary models, exploring nonlinear relationships is generally carried out by adding the square or the higher order of the study variables directly on the basis of trend plots or by manually selecting the grouping basis through images to segment the model, while the threshold panel regression model can effectively solve the human errors brought by the above methods. First, the threshold regression model does not need to determine the form of nonlinearity in advance; the number of thresholds and the corresponding threshold values are calculated by multiple iterations, which are completely determined by the endogeneity of the sample itself, excluding the human interference factors. Second, the confidence interval of the threshold values is supported by the theory of asymptotic distribution, and it is estimated whether the threshold value is significant by using the "bootstrap" method and an iterative self-test.

Its basic form is

$$y_{it} = \mu_i + \beta_1' x_{it} + \varepsilon_{it}, q_{it} \le \gamma \tag{3}$$

$$y_{it} = \mu_i + \beta_2' x_{it} + \varepsilon_{it}, q_{it} > \gamma \tag{4}$$

where q_{it} represents the threshold variable, γ is the threshold value and ε_{it} obeys the independent identical distribution. To make the equation simpler, the above equation is simplified by introducing the indicator function I (*).

$$y_{it} = \mu_i + \beta_1' x_{it} I(q_{it} \le \gamma) + \beta_2' x_{it} I(q_{it} > \gamma) + \varepsilon_{it} \tag{5}$$

Special Definition: $\beta = \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix}$, $x_{it}(\gamma) = \begin{cases} x_{it} I(q_{it} \le \gamma) \\ x_{it} I(q_{it} > \gamma) \end{cases}$. It can be simplified again:

$$y_{it} = \mu_i + \beta_1' x_{it} I(\gamma) + \varepsilon_{it} \tag{6}$$

Then, the time series for individual *i* is averaged:

$$\overline{y_i} = \mu_i + \beta' \overline{x_i}(\gamma) + \overline{\varepsilon_i} \tag{7}$$

where $\overline{y_i} = T^{-1} \sum_{i=1}^{T} y_{it}, \overline{x_i}(\gamma) = T^{-1} \sum_{i=1}^{T} x_{it} I(\gamma), \overline{\varepsilon_i} = T^{-1} \sum_{i=1}^{T} \varepsilon_{it}$.

Differentiating Equations (6) and (7) yields

$$y_{it}{}^{*} = \beta' x_{it}{}^{*} I(\gamma) + \varepsilon_{it}{}^{*} \tag{8}$$

where $y_{it}{}^{*} = y_{it} - \overline{y_i},\ x_{it}{}^{*} I(\gamma) = x_{it} I(\gamma) - \overline{x_i}(\gamma), \varepsilon_{it}{}^{*} = \varepsilon_{it} - \overline{\varepsilon_i}$.

Finally, the model is estimated using a two-step approach. First, for a given value of γ, a consistent estimation of Equation (8) with OLS yields the correlation estimator $\hat{\beta}(\gamma)$ and the residual sum of squares SSR(γ). Second, among all the values of γ, the $\hat{\gamma}$ that minimizes SSR($\hat{\gamma}$) is selected, and, finally, $\hat{\beta}(\gamma)$ can be obtained.

4. Results

4.1. Multicollinearity Test

Before carrying out the empirical test, in order to ensure the accuracy and applicability of the data, the data need to be tested for multicollinearity. Multicollinearity means that there is a linear correlation between the independent variables, i.e., one independent variable can be a linear combination of one or more other independent variables. This study uses the variance inflation factor (VIF) to test multicollinearity. The results of the VIF test are shown in Table 3 below, showing that the maximum VIF value of all variables is 2.11 and the minimum value is 0.98, which are far below the critical value of 10, indicating that there is no multicollinearity.

Table 3. Multicollinearity test results.

	AQ	ER	GDP	FDI	UR	IS	PS
VIF	1.03	2.11	1.89	1.42	2.04	1.77	0.98

4.2. Testing for Data Stationarity

To avoid the problem of "pseudo-regression" and "spurious regression" caused by the unstable panel data, the panel data were first tested for smoothness by using the LLC (Levin–Lin–Chu) test to test the explained and explanatory variables. The original hypothesis of unstable data was strongly rejected with $p < 0.01$, indicating that the data are stable (see Table 4).

Table 4. Stability test results.

Variables	Levin-Lin-Chu Test		Stability
	t-Statistic	*p*-Value	
AQ	−9.092	0.000	Stable
ER	−7.234	0.001	Stable
GDP	−10.273	0.002	Stable
FDI	−5.334	0.003	Stable
UR	−3.984	0.000	Stable
IS	−9.993	0.000	Stable
PS	−8.374	0.000	Stable

4.3. Random Effects and Fixed Effects Model Selection

First, we performed a Hausman test on the data to determine whether to use fixed effects or random effects. According to the Hausman test results (Table 5), the value of the statistic is 9.68 and the *p*-value is 0.0000, which indicates that the results of using fixed effects are better, and thus the systematic GMM model with panel fixed effects was chosen for the next regression estimation in this paper.

Table 5. Hausman test results.

Test Method	LLC Statistic	*p*-Value	Result
Hausman test	9.68	0.0000	Reject the original hypothesis

Table 6 presents the results of the econometric tests using systematic GMM estimation for the sample. In order to test whether there is a nonlinear correlation between them, we include the squared terms of both in the model. Meanwhile, to test whether the systematic GMM is reasonable, this study tested the following: first, whether the random disturbance terms of the difference equations are serially correlated, and second, whether the instrumental variables are selected effectively. The results show that AR (1) is significant but AR (2) is not significant at least at the 5% significance level, indicating that the model has a first-order autocorrelation but not a second-order autocorrelation. The Sargan test cannot reject the original hypothesis, indicating that the selected instrumental variables are also valid. Therefore, the model is reasonable and valid.

Table 6. Systematic GMM regression results.

Variable	National	East	Central	West
lnFDI	0.1123 ***	−0.2099 ***	0.1455 ***	0.0933 ***
	(3.56)	(−4.39)	(5.34)	(5.18)
$(\text{lnFDI})^2$	−0.0954 ***	−0.0321 ***	−0.1994 ***	−0.1167 ***
	(−6.29)	(−4.44)	(−5.17)	(−5.91)
lnER	0.112	0.0567 ***	0.1219 ***	0.1684 ***
	(1.01)	(4.79)	(3.12)	(4.34)
$(\text{lnER})^2$	−0.1098	−0.0353 ***	−0.1564 ***	−0.2342 ***
	(−0.44)	(−2.98)	(−4.23)	(−4.14)
lnGDP	0.0544 ***	0.0267	0.0568 ***	0.1354 ***
	(3.67)	(0.67)	(4.28)	(4.88)
lnIS	−0.0776 ***	−0.0032	−0.1435 ***	−0.2564 ***
	(−4.78)	(−0.67)	(−5.45)	(−5.26)
lnUR	−0.0980	−0.0302	0.1167 ***	0.1009 ***
	(−0.86)	(0.37)	(6.39)	(3.11)
lnPS	0.1509 **	0.0933 *	0.1894 ***	0.2349 ***
	(2.15)	(1.83)	(4.23)	(7.38)
-cons	0.1008 ***	0.2156 ***	−0.3455 ***	0.2444 ***
	(4.51)	(3.63)	(−4.67)	(3.55)
AR(1)	−3.2231 ***	−3.1235 ***	−3.9055 ***	−2.6753 ***
AR(1)	1.4533	1.5155	1.4573	1.1466
Sargan test	0.9833	0.9732	0.9873	0.9651

Note: *, **, *** denote $p < 0.1$, $p < 0.05$, $p < 0.01$, respectively.

(1) Analysis of the impact of environmental regulation on regional air pollution in China

The primary and secondary coefficients are not significant, and there is no significant "U-shaped" or "inverted U-shaped" relationship between environmental regulation and air pollution for the national sample. In recent years, although the central government has been increasing its attention to environmental pollution and its control efforts, in the context of the incentive structure of the central government and the decentralization of local governments, the implementation of environmental regulations by cities to maximize their interests has been inadequate, making the pollution control effectiveness of environmental regulations from the central government unsatisfactory on a national scale.

The elasticity coefficient of environmental regulations in the eastern, central and western regions is positive, and its quadratic term is significantly negative, indicating that the impact of environmental regulations on air pollution has an inverted "U" shape, which verifies that there is a nonlinear relationship between the two, i.e., a short-term increase in environmental regulations will inhibit the efficiency of the green economy, but a long-term increase in its intensity will promote the local economy. This is consistent with the EKC hypothesis stating that an increase in environmental regulations will suppress the efficiency of the green economy in the short term but promote a decrease in the local air pollution level in the long term with the increase in its intensity. The reasons for this are as follows: on the one hand, there are externalities, such as information asymmetry, in short-term environmental regulation policy making, which leads to the inefficiency of environmental regulation; on the other hand, enterprises are driven by profit to engage in the underground economy and to avoid paying emission fees, and the cost of producing unit products in the underground economy is lower than in the formal sector, so enterprises will increase the scale of the underground economy, which leads to an increase in total pollution emissions. In the long term, with the improvement in environmental regulation and supervision policies and related supporting facilities, environmental regulation can help to gradually guide capital out of the "two high and one leftover" industries with serious pollution towards high-tech and green environmental protection industries, thus effectively reducing resource consumption and environmental pollution emissions, forming new economic growth points and eventually promoting a decline in regional air pollution levels. The elasticity of the central and western regions is higher than that of the east as the central region is gradually becoming the backbone of ecological civilization construction, accelerating the transformation of the economic development mode, actively exploring the development mode of "two types of society" and striving to build the central city cluster into a national "two types of society" construction to promote the effective implementation of pollution prevention and control work by driving the whole situation locally. For the western region, the "inverted U-shaped" relationship may be related to the "Belt and Road Initiative". Since 2013, the Belt and Road Initiative has provided a new opportunity for economic transformation in the western region. As the land-based starting point of the Belt and Road cooperation, the western region has been strengthening ecological protection, developing a green economy and accelerating air pollution control. Currently, the intensity of environmental regulations in the western region is on the right side of the inflection point, and it is expected that with the change of development mode and the improvement of environmental regulation tools, air pollution is expected to be improved.

(2) Analysis of the impact of foreign direct investment on regional air pollution in China

First, the primary term of FDI is significantly positive, indicating that the growth of FDI leads to an increase in air pollution in China, and the entry of foreign capital aggravates the environmental pollution problem, meaning that the pollution haven hypothesis exists in China. The squared term coefficients are all negative and pass the significance test, meaning that FDI and air pollution show an inverted U-shaped curve, indicating that, in the long run, the relationship between the two is not always positive, and when FDI exceeds a certain threshold, it will have an improving effect on the environment.

In the eastern region, the regression results with the primary term pass the test at the 1% significance level, and the regression coefficient is negative, indicating that there is a negative relationship between FDI and air pollution in the eastern region, i.e., the growth of FDI in the eastern region leads to the weakening of air pollution, and the entry of foreign capital leads to a reduction in environmental pollution in the eastern region, which is consistent with the pollution halo hypothesis. From the viewpoint of the coefficient of the secondary term, it passes the significance test, and the regression coefficient is negative, which indicates that there is a significant negative correlation between the secondary term and air pollution, there is no U-shaped relationship in the eastern region and the increase in foreign capital plays an improving role concerning the environment.

Central region: There is a positive correlation between the FDI primary term and air pollution, that is, the growth of foreign investment in the central region leads to pollution verification, and the entry of foreign investment aggravates air pollution in the central region, consistent with the pollution haven hypothesis, which refers to the tendency of companies in pollution-intensive industries to be established in countries or regions with relatively low environmental standards. The negative value of the regression coefficient of the secondary term indicates that there is a significant negative correlation between the secondary term and air pollution. lnFDI and environmental pollution show an inverted U-shaped curve, and the central region is still in the left half of the curve; therefore, an increase in foreign capital will lead to aggravation of the pollution status in the central region.

Western region: First, the primary terms of lnFDI pass the significance test, and the regression coefficients are all positive, indicating that there is a positive correlation between FDI and air pollution, i.e., the growth of foreign investment in the western region leads to an increase in air pollution, and the entry of foreign investment aggravates the environmental pollution in the western region of China, which is consistent with the pollution haven hypothesis. Second, the secondary terms pass the significance test, and the regression coefficients are all negative, indicating that there is a significant negative correlation between the secondary terms and air pollution, and an inverted U-shaped relationship between foreign investment and the environment, with the western region still in the left half of the curve. Therefore, an increase in foreign investment will lead to aggravation of the pollution status in the western region.

The coefficients of the industrial structure are positive both nationally and in the central and western regions, and they pass the significance test. In the model setting, this indicates that, as the proportion of secondary industry is increasing, the use of natural resources and damage to the ecological environment are also gradually increasing, as well as the level of air pollution, which has a significant effect on the generation of air pollution. The difference is that the eastern region has the smallest elasticity coefficient, although the elasticity coefficient is negative, but it does not pass the significance test, indicating that the industrial structure of the eastern region has been continuously optimized. The ratio of secondary industry is decreasing, and the negative impact on air pollution is smaller.

The coefficient of the urbanization level in the central and western regions is significantly positive, indicating that the urbanization level is positively related to air pollution, probably because as urbanization progresses, a large number of people remain in cities, which puts high demands on urban transportation, housing and infrastructure. In order to meet these demands, urban road areas and motor vehicles start to increase, and tailpipe emissions lead to increased concentrations of air pollutants; the increased demand for housing and infrastructure increases the use of building materials such as steel and cement, which increases the concentration of sooty exhaust gases in the air. However, it is insignificant at the national level and in the eastern region, where the elasticity coefficient is negative, indicating that urbanization in the eastern region is progressing faster, promoting the concentration of talent and technology and making a greater contribution to regional innovation, and thus its negative impact on air pollution is insignificant.

The coefficient of the impact of the economic development level on air pollution in the country and all regions is positive, indicating that air quality will deteriorate with economic growth, which may be due to the fact that economic growth is accompanied by high-intensity energy requirements; the pollution emissions of enterprises exceed the environmental carrying capacity; the speed of pollution treatment has been unable to keep up with rapid industrialization and large-scale emissions; and economic growth at this time will aggravate air pollution. However, the eastern region does not pass the significance test, which indicates that the eastern region is more economically developed with sufficient capacity in addition to environmental pollution problems, and thus, the positive effect of economic growth on environmental pollution is not significant.

There is a positive relationship between population density and air pollution. With the increase in population, a "congestion effect" is introduced. Moreover, with the rapid expansion of the urban population, the demand for and consumption of housing, household appliances and motor vehicles increase, bringing about the emission of domestic waste and incineration, as well as the burning of energy for heating in winter.

4.4. Threshold Regression Results

The results of the systematic GMM estimation show that the impact of environmental regulations and FDI on air pollution varies among regions. Why does this difference occur? The empirical analysis of this paper finds that there is a nonlinear relationship between the variables, so there may be a threshold effect, and only when this "threshold" is crossed can the mitigation effect on air pollution be fully exploited. Therefore, the next step in this paper is to investigate the threshold values and the coefficients of the different intervals that affect air pollution. Since this paper focuses on the effects of FDI and environmental regulation on air pollution, only the threshold effects of these two variables are discussed.

Before using the panel threshold model, a threshold effect test is first required in order to determine whether a threshold exists, as well as the number of thresholds that exist, and, finally, to choose the corresponding model form. In order to ensure the smoothness of the data, all variables are logarithmically treated. The corresponding *p*-value and F-value were obtained after 1000 bootstrap repetitions of the simulated likelihood ratio test for single and double thresholds, and the final results are shown in Table 7.

Table 7. Threshold effect test results.

Threshold Variables	Region	Single-Threshold Model		Double-Threshold Model		Threshold Estimates	95% Confidence Interval
		F-Value	*p*-Value	F-Value	*p*-Value		
ER	National	9.883	0.001	11.34	0.45	9.498	[8.023, 9.557]
	East	4.223	0.002	5.33	0.13	4.567	[3.112, 4.678]
	Central	2.093	0.012	14.24	0.25	3.189	[2.981, 3.442]
	West	1.284	0.002	4.09	0.14	3.213	[3.945, 3.778]
FDI	National	15.093	0.001	7.333	0.23	11.671	[10.601, 13.778]
	East	8.884	0.002	6.354	0.18	5.678	[5.643, 5.765]
	Central	3.023	0.012	3.442	0.22	7.623	[7.524, 7.731]
	West	4.183	0.002	11.556	0.48	7.713	[7.545, 7.908]

Specific F-values and *p*-values were obtained after 1000 bootstrap repetitions (see Table 7). The results show that only the single-threshold model is significant at the 1% level for all threshold variables, while the dichotomous threshold effects are not significant at the 1%, 5% and 10% significance levels, and the smaller confidence intervals indicate that the estimated thresholds are largely accurate.

The results of Table 7 show that the threshold variable of environmental regulation for the whole country and the three regions passes the single-threshold test at the 5% significance level, while it fails the double-threshold test. The threshold variable of foreign direct investment for the whole country and the three regions passes the single-threshold test at the 5% significance level, while it fails the double-threshold test. The threshold test also gives the threshold value. The threshold values of environmental regulation are 9.498, 4.567, 3.189 and 3.213 for the whole country and the eastern, central and western regions, respectively. The threshold values of foreign direct investment are 11.671, 5.678, 7.623 and 7.713 for the whole country and the eastern, central and western regions, respectively, further confirming the conclusion of the nonlinear relationship drawn in this paper. These inflection point data can provide a theoretical reference for policy management of environmental pollution and can have important practical significance for achieving high-quality economic development.

5. Conclusions and Recommendations

5.1. Conclusions

(1) There is no significant "U-shaped" or "inverted U-shaped" relationship between environmental regulation and air pollution in the national sample, and there is strong regional heterogeneity in different regions.

The primary term of environmental regulation in the eastern region is significantly positive, but the quadratic term is significantly negative, indicating that the impact of environmental regulation on air pollution shows an inverted U-shaped relationship, which verifies the nonlinear relationship. Environmental regulation will inhibit the improvement of air pollution in the short term, but in the long term, it will decrease air pollution. This is consistent with the EKC hypothesis. The elasticity of the eastern region is the lowest, mainly because the central and western regions are gradually playing the role of the backbone of ecological civilization construction, accelerating the transformation of the economic development mode, actively exploring the development model of "two types of society", strengthening ecological environmental protection, and developing the green economy and accelerating air pollution control.

(2) The entry of FDI has aggravated the air pollution problem in China, and the overall situation in China is consistent with the pollution haven hypothesis. FDI and air pollution show an inverted U-shaped curve, indicating that, in the long run, the relationship between the two is not always positive, and when FDI exceeds a certain critical value, FDI will decrease air pollution. There is a negative correlation between FDI and air pollution in the eastern region, and the entry of FDI leads to a reduction in air pollution in the eastern region, which is consistent with the pollution halo hypothesis, but no U-shaped relationship in the eastern region is found; therefore, FDI will have an improving effect on the environment. The entry of FDI aggravates air pollution in the central and western regions, which is consistent with the pollution haven hypothesis. The central and western regions are still in the left half of the curve, and the increase in foreign capital will lead to aggravation of air pollution.

(3) The coefficients of the industrial structure are positive and pass the significance test both nationally and in the central and western regions, indicating that an increasing proportion of the secondary industry will aggravate air pollution. In the eastern region, there is a negative elasticity coefficient, but it is not significant, indicating that the industrial structure in the eastern region has been continuously optimized and has a less negative impact on air pollution. Urbanization has a positive relationship with air pollution in the central and western regions, and the urbanization process increases the concentration of smoke and dust exhaust in the air. However, it is insignificant at the national level and in the eastern region. Economic development has a positive effect on air pollution nationally and in all regions, indicating that air pollution deteriorates with economic growth, but the eastern region is not significant, indicating that the eastern region is more economically developed and has sufficient capacity to deal with air pollution; thus, the positive effect of economic growth on air pollution is insignificant. There is a positive correlation between population density and air pollution in all regions, and the expansion of the population size brings a lot of production and living pollution, which increases the burden on the environment.

5.2. Suggestions

Synthesizing the above research findings, this study believes that the effect of environmental regulation on environmental pollution is not a simple linear relationship but a nonlinear relationship governed by a variety of factors and conditions. The strength of environmental regulation does not always pull down or promote the rate of environmental pollution reduction; when environmental regulation is within a certain reasonable range, the strength of environmental regulation can suppress the level of air pollution. Additionally, the empirical results show that factors such as foreign direct investment play a very important role in influencing air pollution. Therefore, the following countermeasures are proposed:

(1) The different levels of economic development and industrial structure contributing to urban air pollution mean that environmental regulation policies should be tailored to local conditions, combined with the characteristics of urban economic development, and used to explore various ways to effectively manage air pollution while promoting the continuous optimization of the industrial structure and economic development, breaking regional "barriers" by strengthening the rational planning and layout of urban transportation and other infrastructure, making full use of the spillover effects of inter-city environmental regulation policies and promoting inter-city cooperation and sharing of information technology and resources.

(2) From the perspective of attracting foreign capital, we should not blindly use foreign capital but focus on eliminating the technological gap between domestic and foreign enterprises and guide domestic enterprises to innovate on the basis of fully absorbing the technology brought by FDI so as to improve the overall technological level of the host country and improve environmental protection technology. The local government should increase investment in scientific research and high-tech labor to strengthen the region's ability to absorb FDI technology spillover as well as strengthen the cultivation of high-quality human resources, promoting the "quality" of the population size.
(3) Differentiated environmental regulation policies should be formulated and implemented in different regions. The environmental problems show a pattern of "low in the east and high in the west" as opposed to the "high in the east and low in the west" level of economic development. The current situation of environmental issues determines the necessity of implementing regionally differentiated environmental regulatory instruments. The future development of the eastern region, where economic development is fast, should attach importance to the development of reasonable environmental regulation measures, focus on the implementation of market-based environmental regulation tools and improve the environmental regulatory system.
(4) The government should continuously raise people's awareness of environmental protection, strengthen the prediction and early warning mechanism for heavily polluted weather and enhance the response to heavily polluted weather. Local governments should mobilize spontaneously to achieve "blue water and blue sky" instead of creating a "political blue sky" through political mobilization. Local governments should pay long-term attention to environmental pollution problems, as opposed to short periods of "leadership attention", to achieve environmental management. Only by enhancing people's awareness, strengthening government control and improving emission reduction technology can we truly achieve harmonious development of people and nature and sustainable economic development.
(5) The urban structure should be optimized; the population scale, population aggregation and urban layout of cities should be scientifically determined; and the intensive utilization rate of land should be improved. Since the population scale affects the effect of economic growth on environmental pollution, we should coordinate the economic and population development of large, medium and small cities, reasonably control the population scale of cities, strictly control the population of megacities and disperse some of the political, economic and cultural functions of megacities while improving the efficiency of resource utilization, eliminating those backward production capacities and preventing the backward production capacities from being transferred to other cities. We should also actively promote the development of small and medium-sized cities, and in the process of taking over the industrial transfer of big cities, we should screen and transform the industries imported in, not to receive them all or to take the old road of development first and governance later, but to promote the comprehensive development of cities.

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