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Original Research

Environmental Decentralization, Environmental Regulation and Environmental Pollution: Evidence from China

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Abstract

Environmental decentralization is an institutional factor that influences the effect of ecological environment governance. Based on panel data of provinces in China from 2008 to 2015, this paper evaluates the indicators of environmental decentralization, and uses a fixed-effect model and a threshold model to test the influence of environmental decentralization and environmental regulation on environmental pollution. The results indicate that China's environmental decentralization can significantly curb environmental pollution in general. There is a U-shaped relationship between environmental decentralization and environmental pollution. Reasonable environmental decentralization can restrain environmental pollution, while excessive environmental decentralization aggravates environmental pollution. There is an inverted U-shaped relationship between environmental regulation and environmental pollution. If the intensity of environmental regulation is too low, it cannot inhibit environmental pollution, while if the intensity of environmental regulation is increased to a certain level, it can help to inhibit environmental pollution. The joint impact of environmental decentralization and environmental regulation cannot reduce environmental pollution. That is, with the enlargement of environmental decentralization, environmental regulation fails to reduce environmental pollution. The effect of environmental decentralization has significant regional heterogeneity in economic development level and emission intensity. The above conclusions have important reference value for optimizing the environmental decentralization system and formulating scientific environmental decentralization policies.

Keywords: environmental decentralization, environmental regulation, environmental pollution, threshold model, China

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Introduction

China’s industry and economy have achieved rapid development, but they are characterized by high energy consumption and high emissions, resulting in a large amount of pollution emissions [1, 2]. In response to severe environmental pollution problems, the Chinese government has revised and promulgated a series of environmental protection laws [3], such as the Environmental Protection Law of PRC, the Law of PRC on the Prevention and Control of Atmospheric Pollution, and the Law of PRC on the Prevention and Control of Environmental Pollution by Solid Waste, the Law of PRC on Prevention and Control of Water Pollution and the Law of PRC on environmental Impact Assessment. The implementation of these laws has curbed the trend of environmental degradation, but the damage to the environmental system by economic activities continues [4]. The Chinese government has also continued to reform the environmental management system. In 1988, the Environmental Protection Agency became an independent department. As an agency directly under the State Council, it supervises and manages environmental protection affairs across the country. Local governments have also set up independent environmental management agencies. In 1998, the Environmental Protection Agency was reorganized into the State Environmental Protection Administration. With the enhancement of the financial strength of the central government, the environmental management capacity of the central government has been continuously improved. In 2008, the State Environmental Protection Administration was reformed into the Ministry of Environmental Protection, which is an important functional department of the State Council [5, 6]. The central government has continuously strengthened the degree of intervention and regulation of local government environmental governance, increased financial transfer payments for environmental protection, and increased incentives and constraints on local environmental governance. The central government regards ecological protection as the content of local government performance assessment, and implements an accountability system for the environmental protection affairs of local governments and officials [7].

After a series of reforms, the functions of environmental protection departments at all levels have been continuously expanded and strengthened. In addition, the distribution of environmental management powers between the central and local governments has also undergone a dynamic process. China’s environmental decentralization can be divided into three stages [7]. In the first stage, from 1973 to 1993, the decentralized environmental management and administrative system was established. In the second stage from 1994 to 2007, environmental management showed a trend of centralization under the framework of decentralized system. The third stage is from 2008 to the present, under the decentralized system, the central regulation and local environmental governance incentives have been continuously strengthened. The key to environmental management is to rationally distribute the environmental management power among governments [8]. The rational distribution of environmental management powers among governments and the improvement of the environmental decentralization system are the prerequisites for solving China’s environmental problems [9]. In this context, what is the level of environmental decentralization in China? Does it have the function of environmental governance? Does environmental regulation restrained pollution emissions? Will environmental decentralization weaken the environmental governance effect of environmental regulation? Based on these problems, this paper studies the third stage of environmental decentralization, analyzes the relationship between environmental decentralization, environmental regulation and environmental pollution, and provides a reference for improving China's environmental protection system and improving the effect of environmental governance.

The marginal contributions of this study are as follows. First, the environmental decentralization, environmental regulation and environmental pollution are included in the same analysis framework to study, not only to study the impact of environmental decentralization and environmental regulation on pollution emissions, but also to study the relationship between environmental regulation and pollution emissions under different degrees of environmental decentralization. Second, different econometric estimation methods such as fixed effect model, system GMM and panel threshold model are used to cross check the relationship of the above variables. Third, the rational level of environmental decentralization is determined, and the threshold effect of environmental decentralization is discussed. Fourth, we consider regional heterogeneity and conduct further research from the aspects of economic development level and pollutant emission intensity, so as to better grasp the internal mechanism of the impact of environmental decentralization and environmental regulation on pollutant emissions.

This paper is structured as follows. Section 2 reviews the relevant literature. Section 3 introduces the estimation methods and data. Section 4 presents the empirical results and discussion. Section 5 gives conclusions and policy recommendations.

Literature Review

Environmental decentralization refers to how to allocate the responsibilities of environmental management between the central government and local governments [10, 11]. Endow different levels of government with corresponding management rights over environmental affairs, and establish a cooperative mechanism for environmental governance among local governments [12]. Reasonable distribution of environmental management power is a good way to solve the problem of insufficient supply of environmental public goods [8, 13]. However, the debate between centralization and decentralization of environmental governance and how to decide the optimal level of environmental decentralization remain unresolved. There are different views on the relationship between environmental decentralization and environmental pollution.

Some scholars support the view of environmental centralization, and they explain it from the perspective of “race to the bottom” and the efficiency of public goods supply. Environmental pollution has the characteristics of negative externalities [14], and environmental protection is centrally managed by the central government, which can effectively avoid the tragedy of the commons and make up for the shortcomings of government failure [15, 16]. However, environmental decentralization may induce "Race to the Bottom". In order to attract investment and boost local economic development, local governments may relax environmental supervision by taking advantage of their greater autonomy in local affairs, thereby aggravating environmental pollution [17-19]. The environmental centralization system can promote the government to provide environmental public services more efficiently [20]. However, under the decentralization system, with the increase of administrative levels, there will be significant differences in the principal-agent costs between governments at all levels [21]. This leads to the “free-rider” behavior of governments at all levels in providing ecological environment public goods, thus weakening the implementation effect of ecological environment pollution control [22, 23].

Other scholars support the view of environmental decentralization and believe that improving the level of environmental decentralization can effectively control environmental pollution [24-27]. Because local governments can better grasp the preferences and needs of residents in their jurisdictions for public goods [28], local governments have information advantages, which promote the effective allocation of local resources and human capital, and can efficiently provide public goods preferred by residents [29, 30]. Local governments under the decentralization system can provide better environmental public services according to the actual conditions within their jurisdictions, while the centralization tends to ignore regional heterogeneity, making it difficult to meet the differentiated needs of residents in each region [31]. Under the decentralization system, if enterprises bring excessive pollution costs and few benefits to the jurisdiction, local governments may strengthen ecological environment supervision and force polluting enterprises to move out of the jurisdiction, resulting in benign competition of “Race to the Top” [32], so as to improve the ecological environment.

Regarding the research on environmental regulation and pollution emission, there is a debate on whether environmental regulation promotes pollution reduction. Whether the “compliance costs effect” of environmental regulation is dominant or the “innovation offsets effect” is dominant. From a static perspective, the “compliance cost effect” points out that environmental regulation will raise the “compliance cost” of producers, and to a certain extent limit the improvement of production technology and innovation of production processes [33, 34]. In this way, it is unfavorable for producers to promote pollution reduction through production technology improvement, but will increase production and pollution emission under the goal of profit maximization [35]. The increase in the cost of pollution abatement by companies may have a crowding-out effect, inhibiting the motivation of companies to control pollution and reducing R&D investment [36, 37]. Sinn (2008) called this phenomenon of environmental regulatory policy failure the "green paradox", and discussed the reasons for it: due to the increasing intensity of environmental regulations, energy owners will accelerate energy extraction to avoid future higher environmental tax rates, thereby accelerating energy consumption, which in turn lead to a rapid expansion of greenhouse gas emissions [38]. Some scholars have verified the existence of the green paradox through empirical research [39, 40].

The “Innovation offsets effect” dynamically examines the pollution reduction effect of environmental regulation. Porter and Linde (1995) believe that proper environmental regulation standards can motivate producers to innovate green technologies, which may offset the cost of complying with these standards, resulting in an "innovation offsets effect" and ultimately achieve the goal of reducing pollution [41], which is also known as "Porter Hypothesis". Many scholars support the “Porter Hypothesis” based on empirical tests [42-44]. Moreover, some scholars point out that there is an obvious nonlinear relationship between environmental regulation and environmental pollution [45-47]. Due to the influence of technical conditions, industrial environment and FDI and other factors, the relationship between the above two variables presents different nonlinear threshold characteristics [48-50].

The existing literature mainly studies the impact of environmental decentralization on pollution discharge or the impact of environmental regulation on pollution discharge. However, few literatures have integrated environmental decentralization, environmental regulation and environmental pollution into the same analytical framework. Previous sources studies on the relationship between the above variables mostly used linear models, and the empirical conclusions were inconsistent. The study on the effect and internal mechanism of environmental decentralization and environmental regulation on pollutant emission will provide theoretical reference for improving the decentralized environmental management system.

Material and Methods

Variable Selection

Explained Variable

This paper takes environmental pollution (pol) as the explained variable. Since industrial pollution is the main source of pollution in China's ecological environment [51], this paper uses industrial pollutant emissions to measure the degree of pollution. Since a single pollutant cannot comprehensively measure regional pollution emissions, this paper adopts five indicators, including industrial wastewater discharge, industrial solid waste produced, industrial waste gas emission, industrial sulfur dioxide emission and industrial smoke and dust emission, by referring to the methods of Li (2018) [32] and Lu and Yang (2019) [52]. The environmental pollution index is constructed by using the entropy method to comprehensively evaluate the pollution emission in different regions. The smaller the index value, the lighter the ecological environment pollution. The following are the basic steps of the entropy method.

First, standardize the original data. Suppose there are n indicators of m provinces, and X_{ij} is the jth indicator of province i. The normalized value of each indicator data is:

$$X'_{ij} = \frac{X_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)} \quad (1)$$

When calculating the entropy value, it is necessary to take the logarithm calculation. In order to avoid the situation that X_{ij}' is 0 after normalization, and at the same time try to keep the original information of the data, we slightly shift the normalized value by A (A = 10^{-3}) units, namely:

$$X''_{ij} = X'_{ij} + A \quad (2)$$

Second, compute the information entropy of each indicator:

$$E_j = -\ln(m)^{-1} \sum_{i=1}^{m} p_{ij} \ln p_{ij},$$

$$\text{where } p_{ij} = X''_{ij} / \sum_{i=1}^{m} X''_{ij} \quad (3)$$

Third, Calculate the weight of each indicator:

$$W_i = \frac{1 - E_j}{\sum_{j=1}^{n} (1 - E_j)} \quad (4)$$

Finally, calculate the comprehensive environmental pollution index:

$$Pol_i = \sum_{j=1}^{n} X''_{ij} \cdot W_i \quad (5)$$

Core Explanatory Variables

A core explanatory variable of this paper is environmental decentralization (ed). Environmental decentralization mainly refers to granting local governments certain authority in environmental management, allowing local governments to choose the type of environmental management policy according to the specific conditions within their jurisdiction [27]. Its purpose is to rationally distribute intergovernmental environmental management powers according to the characteristics of environmental protection, and to give different degrees of environmental decentralization to different areas of affairs, so as to offer high-quality environmental public services [20].

However, the environmental management systems of different countries or regions are very different, and it is not easy to find a unified indicator to evaluate the environmental decentralization of different countries [21]. Some studies judge the decentralization and centralization of government by the evidence and factual characteristics of the legal system [30, 53, 54]. However, the decentralization defined by law is far less complex than the actual local environmental decentralization system, and these measurement indicators may not be able to measure environmental decentralization comprehensively and accurately. Qi et al. (2014) [7] suggested using the staff distribution characteristics of environmental management departments to denote the degree of environmental decentralization, and some scholars also adopted this method to measure environmental decentralization [11, 12, 27]. The distribution ratio and changes of employees in different levels of government environmental management departments can effectively express the division of environmental management rights. The main reasons are as follows.

First, the government needs to have corresponding institutions and employees to perform public services and functions. The deployment of government environmental management departments and employees at all levels can ensure that the government exercises its environmental management rights [7, 12]. Secondly, environmental decentralization is essentially the decentralized management of ecological and environmental governance affairs. The variation of environmental management authority is reflected in the establishment of environmental management departments and employees, and the distribution of employees in environmental management departments can represent the substance of environmental management authority allocation. Therefore, it is reasonable to adopt the distribution characteristics of employees in environmental management departments to represent the level of environmental decentralization [7]. The specific measurement formula is as follows:

$$ed_{it} = \frac{LE_{it} / LP_{it}}{NE_t / NP_t}\left[1-\left(GDP_{it} / GDP_t\right)\right] \tag{6}$$

where ed_{it} denotes environmental decentralization of province i in year t, LE_{it} denotes the number of employees of the local environmental management department in province i in year t, LP_{it} denotes the local population in province i in year t, NE_t denotes the total number of employees in the national environmental management department in year t, NO_t is the total population of the country in year t, GDP_{it} denotes the gross domestic product of province i in year t, GDP_t is the gross domestic product in year t, $[1 - (GDP_{it}/GDP_t)]$ denotes the economic scale scaling factor. Considering that environmental decentralization may be affected to a certain extent by the scale of the regional economy (e.g., the more developed the region is, the more employees in the environmental management department will be), which will cause measurement errors and endogenous problems. In order to reduce endogenous problems, the environmental decentralization indicator is deflated with the economic scale scaling factor [7]. In addition, this paper refers to Zhang et al. (2017) [11] and uses the environmental decentralization not adjusted by the economic scale factor as an alternative indicator to conduct a robustness test. The allocation of employees in environmental management departments can effectively reflect the participation of local governments in environmental management. The higher the index, that is, the higher the involvement of local governments in environmental management and the higher the level of environmental decentralization.

Another core explanatory variable is environmental regulation (er). This variable cannot be directly measured, and the previous literature adopts alternative indicators, which mainly include input indicators and performance indicators. Input indicators measure the direct cost of compliance with regulations and the cost paid by the government and environmental protection agencies to implement regulations and ensure the effects of regulations. Input indicators include pollution abatement costs [43, 44] and environmental protection investment [55, 56]. Performance indicators reflect the level of pollution produced by enterprises under the restriction of environmental regulations, that is, the performance of environmental regulations [57]. Performance indicators include emissions tax [58, 59], pollutant emissions [19], and Urban green coverage rate [60]. This paper refers to Pan et al. [55] and You et al. [56], the proportion of each province's environmental protection investment in each province's GDP is used to represent environmental regulation, so as to eliminate the influence of regional industrial scale and economic scale. This indicator reflects the government's endeavor and determination in environmental management, thus representing the actual strictness of environmental regulations in the province. This indicator can usually represent the intensity of environmental regulation at the industrial and regional levels [57].

Other Explanatory Variables

According to the selection criteria of Bai and Nie (2017) [27] and Ran et al. (2020) [9], this paper selects the following control variables. (1) Industrial structure (ind), expressed by the proportion of the added value of the secondary industry in the region to the regional GDP. (2) Foreign direct investment (FDI), expressed by the amount of FDI actually used by each region converted into RMB. At present, the view of the relationship between FDI and pollution emissions is still controversial. There are two main viewpoints, the "pollution haven" hypothesis and the "pollution halo" hypothesis. (3) Technical factor (tec), represented by the number of patents granted in each region. (4) Urbanization (urb), denoted by the proportion of urban population to regional population.

This paper uses panel data from 2008 to 2015 in 31 provincial administrative regions in China (excluding Hong Kong, Macao and Taiwan in China). The data are acquired from China Environment Yearbook, China Environmental Statistics Yearbook, and EPS database. Since the statistics department no longer publishes the staff data of the provincial environmental management agencies from 2016, the environmental decentralization indicator ends in 2015. Borrowing from the method of Wu et al. (2020) [12], this paper performs natural

Table 1. Descriptive statistics.

Variable	Definition	Obs	Mean	Std.Dev.	Min	Max
lnpol	Environmental pollution	248	-1.700	1.116	-6.529	-0.217
lned	Environmental decentralization	248	-0.070	0.336	-0.677	0.829
lner	Environmental regulation	248	0.233	0.544	-2.996	1.539
lnind	Industrial structure	248	3.836	0.210	2.983	4.119
lnfdi	FDI	248	7.842	1.509	3.588	10.79
lntec	Number of patents granted	248	9.216	1.686	4.533	12.51
lnurb	Urbanization	248	3.927	0.271	3.087	4.495

logarithm processing on all variables to eliminate possible heteroskedasticity in the model. Table 1 displays descriptive statistics of the variables.

Method and Model

Benchmark Regression Model

In order to empirically test the impact of environmental decentralization and environmental regulation on environmental pollution, this paper establishes a panel data regression model.

$$\ln pol_{it} = \beta_0 + \beta_1 \ln ed_{it} + \beta_2 \ln er_{it} + \beta_3 \ln ind_{it} + \beta_4 \ln fdi_{it} + \beta_5 \ln tec_{it} + \beta_6 \ln urb_{it} + \alpha_i + \varepsilon_{it} \quad (7)$$

where pol represents environmental pollution index, ed represents environmental decentralization, er represents environmental regulation, ind represents industrial structure, fdi represents foreign direct investment, tec represents technological factors, urb represents urbanization, α_i denotes individual fixed effect, and ε_{it} denotes random error.

In order to test the joint effect of environmental decentralization and environmental regulation on environmental pollution, this paper adds the interaction term of the core explanatory variables to the benchmark model. In order to make the original core explanatory variable still have economic significance, we center the interaction term, and the specific model is as follows:

$$\ln pol_{it} = \beta_0 + \beta_1 \ln ed_{it} + \beta_2 \ln er_{it} + \beta_3 \overline{\overline{\ln ed_{it}}}\,\overline{\overline{\ln er_{it}}} + \beta_4 \ln ind_{it} + \beta_5 \ln fdi_{it} + \beta_6 \ln tec_{it} + \beta_7 \ln urb_{it} + \alpha_i + \varepsilon_{it} \quad (8)$$

where $\overline{\overline{\ln ed_{it}}} = \left(\ln ed_{it} - \overline{\ln ed_{it}}\right)$, $\overline{\overline{\ln er_{it}}} = \left(\ln er_{it} - \overline{\ln er_{it}}\right)$. $\overline{\ln ed_{it}}$ and $\overline{\ln er_{it}}$ represent the mean values of variables ed and er in year t, respectively.

Considering that the views of environmental decentralization and environmental pollution are still controversial, namely positive, negative and uncertain, this paper argues that there may be a nonlinear relationship between them. Similarly, some sources consider that environmental regulation and environmental pollution also have a nonlinear relationship [48, 50]. Therefore, this paper adds the quadratic term of environmental decentralization and the quadratic term of environmental regulation to the benchmark model.

$$\ln pol_{it} = \beta_0 + \beta_1 \ln ed_{it} + \beta_2 \ln ed_{it}^2 + \beta_3 \ln er_{it} + \beta_4 \ln ind_{it} + \beta_5 \ln fdi_{it} + \beta_6 \ln tec_{it} + \beta_7 \ln urb_{it} + \alpha_i + \varepsilon_{it} \quad (9)$$

$$\ln pol_{it} = \beta_0 + \beta_1 \ln ed_{it} + \beta_2 \ln er_{it} + \beta_3 \ln er_{it}^2 + \beta_4 \ln ind_{it} + \beta_5 \ln fdi_{it} + \beta_6 \ln tec_{it} + \beta_7 \ln urb_{it} + \alpha_i + \varepsilon_{it} \quad (10)$$

Panel Threshold Model

In this paper, the panel threshold model is adopted to further analyze the nonlinear relationship between environmental decentralization and environmental pollution, and the inflection point of change can be obtained. We adopt the model proposed by Hansen [61] and select environmental decentralization as the threshold variable to establish a threshold model:

$$\ln pol_{it} = \mu_{it} + \beta_1 \ln ed_{it} \mathrm{I}\left(\ln ed_{it} \le \gamma\right) + \beta_2 \ln ed_{it} \mathrm{I}\left(\ln ed_{it} > \gamma\right) + \theta z_{it} + \varepsilon_{it} \quad (11)$$

where i denotes provinces; t denotes the year; pol_{it} is the dependent variable, which denotes the environmental pollution of the province; ed_{it} is the independent variable, and ed_{it} also belongs to the threshold variable; γ represents the threshold value; ε_{it} is the random error; β_1, β_2, and θ denote the coefficients; z_{it} stands for a set of control variables; and I(.) denotes an indicator function, which takes 1 when the condition in parentheses is satisfied, and 0 otherwise.

Results and Discussion

Evolution Characteristics of Environmental Decentralization and Environmental Pollution

Fig. 1 depicts the changing trend of China's environmental pollution index from 2008 to 2015. In general, China's environmental pollution index shows a clear upward trend, especially since 2011, China's industrial pollutant emissions have risen to a higher level. During this period, China's industry developed rapidly, with the industrial added value from 2008 to

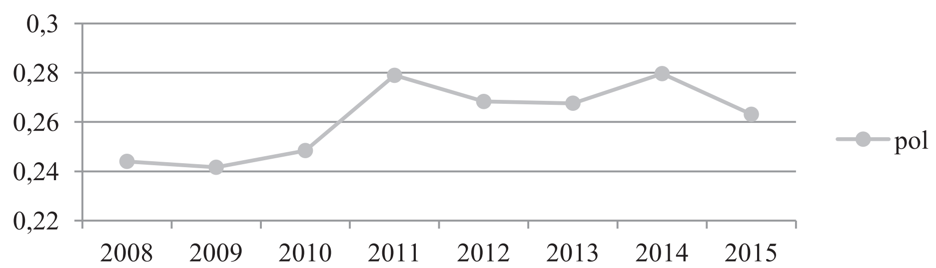

Fig. 1. Change trend of industrial pollution level in China from 2008 to 2015.

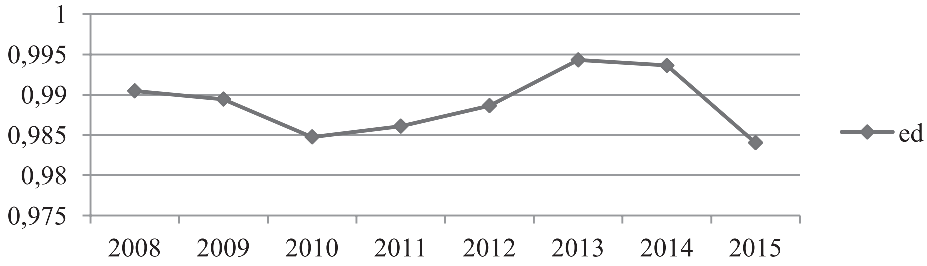

Fig. 2. Change trend of environmental decentralization in China from 2008 to 2015.

2015 increasing from CNY 13,172.4 billion to CNY 23,496.89 billion. Some major industrial pollutants have also increased substantially. From 2008 to 2015, China's industrial waste gas emissions increased from 40,386.6 billion standard cubic meters to 68,519 billion standard cubic meters, and the production of industrial solid waste increased from 1901.25 million tons to 3,270.79 million tons.

Fig. 2 depicts the trend of environmental decentralization in China from 2008 to 2015. The degree of environmental decentralization shows the characteristics of wave changes. Specifically, the degree of environmental decentralization decreased in 2010 and 2011. This is due to the increasing degree of central intervention and regulation in the environmental governance of local governments since the establishment of the Ministry of Environmental Protection of the People's Republic of China, increased financial transfer payments for ecological and environmental protection by the central government, enhanced cross-regional coordination in pollution control, and the use of environmental protection as a criterion for evaluating local governments. However, the degree of environmental decentralization increased significantly in 2013 and 2014, mainly due to the gradual extension of environmental management affairs to local governance, which led to the continuous expansion of the staff size of local environmental protection agencies.

Benchmark Regression

Before regression estimation, all variables should be tested for stationarity. In this paper, LLC test and Fisher test are used for testing. The test results show that all variables reject the null hypothesis and pass the stationarity test.

In terms of specific model selection, the Hausman test results reject the null hypothesis at the 1% significance level, that is, the random effects model. Therefore, we should choose the fixed effects model. Next, this paper mainly uses the fixed effect model for estimation. Table 2 reports the estimation results, and Model 1 is the regression result of Equation (7). In the model, the estimated coefficient of environmental decentralization on environmental pollution is significantly negative. It shows that the increased degree of environmental decentralization is beneficial to reduce environmental pollution, which is the same as the conclusions of Li et al. [26], Lu and Yang [52] and Bai and Nie [27]. Since 2008, the central government has begun to take ecological and environmental protection indicators as the content of the performance evaluation of local governments, and has implemented an accountability and one-vote veto system for local governments and officials [7]. Environmental pollution control is gradually becoming a significant standard to measure the performance of local officials, which to some extent arouses the enthusiasm of local officials in environmental protection. Therefore, granting certain environmental governance powers to local governments will help them formulate environmental regulations more accurately according to local conditions, reasonably allocate environmental protection agencies and personnel, and carry out environmental management activities, thereby reducing environmental pollution [27].

The estimated coefficient of environmental regulation on environmental pollution is significantly positive, that is, the current environmental regulation has no restrain effect on environmental pollution as a whole. Due to the relatively low intensity of environmental regulation and the relatively small proportion of investment in environmental pollution control, environmental pollution cannot be effectively controlled. When the proportion of environmental protection expenditure increases a certain proportion, environmental pollution can be controlled, and the higher the proportion of environmental protection investment can better improve the environment [62].

Model 2 is the estimation result of Equation (8). The estimated coefficient of the interaction term of environmental decentralization and environmental regulation is significantly positive, indicating that the interaction effect of the two is not beneficial to reduce environmental pollution. The decentralization of environmental management authority will worsen the effect of environmental regulation on suppressing pollution discharge.

In model 3 and Model 4, the quadratic terms of environmental decentralization and environmental regulation are added respectively. Model 3 shows that the coefficient of the primary term of environmental decentralization is negative, and the coefficient of the quadratic term is significantly positive, indicating

Table 2. Benchmark regression results.

	(1)	(2)	(3)	(4)
	FE1	FE2	FE3	FE4
lned	-0.2108*	-0.2246**	-0.0259	-0.2499**
	(0.108)	(0.107)	(0.115)	(0.109)
lner	0.1332***	0.1021***	0.1129***	0.1156***
	(0.025)	(0.028)	(0.025)	(0.026)
c_lned*c_lner		0.1727**		
		(0.069)		
$(\text{lned})^2$			0.7843***	
			(0.203)	
$(\text{lner})^2$				-0.0307**
				(0.015)
lnind	0.0014	0.0319	-0.0090	-0.0108
	(0.157)	(0.156)	(0.152)	(0.156)
lnfdi	-0.0555	-0.0556	-0.0739	-0.0679
	(0.047)	(0.046)	(0.046)	(0.047)
lntec	-0.1475***	-0.1472***	-0.1385***	-0.1427***
	(0.037)	(0.037)	(0.036)	(0.037)
lnurb	2.1085***	2.1692***	2.2423***	2.1293***
	(0.324)	(0.321)	(0.315)	(0.321)
_cons	-8.2366***	-8.5920***	-8.7345***	-8.2069***
	(1.124)	(1.120)	(1.096)	(1.116)
N	248	248	248	248
R^2	0.326	0.345	0.371	0.339

Standard errors in parentheses * $p<0.1$, ** $p<0.05$, *** $p<0.01$

that there is a U-shaped relationship between environmental decentralization and environmental pollution. Appropriate environmental decentralization is beneficial to restrain environmental pollution, while excessive environmental decentralization aggravates environmental pollution. Peng (2016) also made similar findings [20]. A moderate level of environmental decentralization may motivate local governments to take effective environmental regulation measures and conduct environmental governance more effectively. However, excessive environmental decentralization can easily lead to conspiracy between local governments and polluting companies to conceal the real situation of pollution discharge, thus aggravating local environmental pollution [63]. Local governments have excessive environmental management power, which may make local governments focus on developing local economy so as to win the promotion championship, tend to allocate resources to regional economic construction, ignore environmental protection, aggravate industrial pollution emissions, and form “race to the bottom” effect [12].

Model 4 shows that the coefficient of the primary term of environmental regulation is significantly positive, and the coefficient of the quadratic term is significantly negative, which reveals that the relationship between environmental regulation and environmental pollution is an inverted-U shape. That is, if the environmental regulation intensity is too low, it is impossible to restrain pollution discharge. When the environmental regulation intensity is high enough, it is beneficial to restrain environmental pollution. Because environmental regulation need time to become effective, the investment period for environmental protection is long, and the effect of environmental pollution control in the short term is limited. With the improvement of environmental regulation and the increasing intensity of regulation, the proportion of investment in environmental protection will increase, and the effect of pollution control will be better [64, 65]. Due to the time-lag effect, the pollution control effect of environmental regulation is more obvious in the long run [66].

Heterogeneity Analysis

Due to the great differences in natural environment conditions and economic development levels in various regions of China, the effect of environmental decentralization may also vary greatly in different regions [7]. This paper divides the samples into developed and developing regions, as well as high-emission and low-emission regions, and the method of exogenous grouping is used to further study the relationship between these variables from the perspective of regional heterogeneity.

Developed and Developing Regions

We refer to the method of Li and Zhang (2019) [66], divide the samples into developed regions and developing regions according to per capita GDP, and compare the impact of environmental decentralization on environmental pollution. That is to say, the regional GDP per capita higher than the national average belongs to the developed region, lower than the national average belongs to the developing region. Table 3 indicates that environmental decentralization is more beneficial to the control of environmental pollution in economically developed regions. In economically developed regions, the estimated coefficient of the two is significantly negative; in economically developing regions, the coefficient is negative, but not statistically significant. In developed regions, environmental decentralization can effectively decrease pollution emissions, and the effect is significantly better than that in developing regions (0.4859>0.1619). The main reason is that economically developed regions have higher requirements for environmental quality, and environmental decentralization can motivate local governments to exercise their autonomy and provide better ecological and environmental public services according to the actual conditions within their jurisdictions.

Table 3 also indicates that regional environmental regulation has not inhibited regional environmental pollution, especially in economically underdeveloped regions, the regression coefficient value and significance level of variables are higher, and the effect of aggravating pollution is more significant. The main reason is that in order to promote local economic development, developing regions may relax environmental regulations and attract high-polluting

Table 3. Sample regression results under different economic development.

	Developed regions		Developing regions	
	(1)	(2)	(1)	(2)
lned	-0.4859***	-0.4871***	-0.1619	-0.1365
	(0.141)	(0.139)	(0.253)	(0.255)
lner	0.0343	0.0575**	0.1681***	0.1354**
	(0.023)	(0.027)	(0.035)	(0.052)
c_lned*c_lner		0.1369		0.1026
		(0.083)		(0.119)
lnind	-0.2221	-0.2580	0.0294	0.0467
	(0.234)	(0.231)	(0.217)	(0.218)
lnfdi	-0.2314***	-0.2240***	-0.0932	-0.0863
	(0.074)	(0.073)	(0.069)	(0.069)
lntec	-0.1272***	-0.1424***	-0.1764***	-0.1678***
	(0.041)	(0.041)	(0.056)	(0.057)
lnurb	1.8776***	1.8761***	2.3956***	2.3892***
	(0.356)	(0.351)	(0.484)	(0.485)
_cons	-5.2266**	-5.0056**	-8.8205***	-8.9783***
	(2.017)	(1.995)	(1.632)	(1.644)
N	91	91	157	157
R^2	0.439	0.463	0.370	0.374

Standard errors in parentheses * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Table 4. Sample regression results under different pollutant emission.

	High-emission regions		Low-emission regions	
	(1)	(2)	(1)	(2)
lned	-0.4110	-0.2551	-0.2026*	-0.2398**
	(0.255)	(0.252)	(0.116)	(0.114)
lner	0.0868**	0.1210***	0.1277***	0.0588
	(0.039)	(0.040)	(0.029)	(0.038)
c_lned*c_lner		0.2796***		0.2523***
		(0.101)		(0.094)
lnind	-0.0748	-0.1855	0.0467	0.1376
	(0.235)	(0.230)	(0.201)	(0.199)
lnfdi	0.0535	0.0815	-0.1022**	-0.0969*
	(0.108)	(0.105)	(0.050)	(0.049)
lntec	-0.0291	-0.0572	-0.1386***	-0.1288***
	(0.064)	(0.062)	(0.046)	(0.045)
lnurb	0.4508	0.4382	2.6831***	2.7879***
	(0.593)	(0.570)	(0.385)	(0.378)
_cons	-2.5935	-2.0911	-11.0673***	-11.9320***
	(2.049)	(1.977)	(1.293)	(1.300)
N	105	105	143	143
R^2	0.177	0.250	0.479	0.510

Standard errors in parentheses * p<0.1, ** p<0.05, *** p<0.01

industries to invest in the region, thereby aggravating environmental pollution [52]. All in all, economically developed regions have higher requirements for environmental quality, the industrial structure is greener and more environmentally friendly, and the regional environmental decentralization and environmental regulation have a better effect on the governance of regional environmental pollution.

High-Emission and Low-Emission Regions

The divergence in pollution emission intensity means that the industrial structure and production technology of each region are diverse, and the environmental management of local governments will also be different. The influence of environmental decentralization on pollution discharge presents significant regional heterogeneity. According to the average value of the environmental pollution index, this paper separates the samples into high-emission areas and low-emission regions.

Table 4 shows that in low-emission regions, environmental decentralization is significantly negatively correlated with environmental pollution. In high-emission regions, environmental decentralization is negatively related to environmental pollution, but it is not statistically significant. In low-pollution areas, because the government pays attention to improving environmental quality and implements strict environmental policies, enterprises are forced to innovate in technology, and technological innovation has significantly suppressed environmental pollution. FDI has inhibited environmental pollution, resulting in a "pollution halo" effect. In high-emission regions, technological innovation restrains environmental pollution, but it is not significant, and FDI aggravates environmental pollution, resulting in a "pollution paradise" effect.

Robustness Test

Index Replacement

To examine the robustness of the above conclusions, we use the unadjusted environmental decentralization indicator as an alternative indicator. Drawing on the method of Lu and Zhang [67] to construct environmental decentralization indicators, without considering the reduction factor of economic scale, the calculation formula is $ed_{it} = \frac{LE_{it} / LP_{it}}{NE_t / NP_t}$, and the meanings of relevant indicators are consistent with the above.

Table 5. Index replacement.

	(1)	(2)	(3)	(4)
	FE1	FE2	FE3	FE4
lned	-0.2135**	-0.2255**	-0.0623	-0.2518**
	(0.108)	(0.107)	(0.112)	(0.109)
lner	0.1333***	0.1039***	0.1133***	0.1157***
	(0.025)	(0.028)	(0.025)	(0.026)
c_lned*c_lner		0.1753**		
		(0.074)		
$(lned)^2$			0.7860***	
			(0.206)	
$(lner)^2$				-0.0307**
				(0.015)
lnind	0.0047	0.0376	-0.0076	-0.0071
	(0.158)	(0.156)	(0.153)	(0.156)
lnfdi	-0.0555	-0.0544	-0.0719	-0.0679
	(0.047)	(0.047)	(0.046)	(0.047)
lntec	-0.1476***	-0.1472***	-0.1394***	-0.1427***
	(0.037)	(0.037)	(0.036)	(0.037)
lnurb	2.1124***	2.1703***	2.2544***	2.1328***
	(0.324)	(0.321)	(0.316)	(0.322)
_cons	-8.2560***	-8.6208***	-8.7898***	-8.2254***
	(1.125)	(1.124)	(1.100)	(1.117)
N	248	248	248	248
R^2	0.326	0.344	0.370	0.339
adj. R^2	0.211	0.228	0.259	0.223

Standard errors in parentheses * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Table 5 provides the estimated results. The variable coefficient of environmental decentralization is significantly negative, which indicates that environmental decentralization is beneficial to restrain environmental pollution. The coefficient of environmental regulation variable is significantly positive, that is, environmental regulation cannot restrain environmental pollution. The coefficient of interaction term is significantly positive, and the regression results of other variables are basically similar to those in Table 2. Therefore, the conclusions of the preceding analysis are robust.

Endogeneity Test

In order to solve the problem of estimation error caused by potential missing variables, and to consider the endogeneity of environmental decentralization and the path-dependent characteristics of environmental pollution, we uses the SYS-GMM approach to further examine the robustness of the conclusions.

It can be seen from Table 6 that AR(1), AR(2) and Sargan test are all satisfactory. The results of AR(1) and AR(2) indicate that the random erro term has only first-order autocorrelation but no second-order autocorrelation. Sargan test results indicate that there is no over-identification problem for instrumental variables. Therefore, the choice of instrumental variables is rational, and the setting of the model is correct. The estimation results prove that environmental decentralization significantly inhibits environmental pollution, and environmental regulation does not inhibit environmental pollution. The estimated results of the endogeneity test are very close to those of the benchmark regression, which shows that the conclusion is still robust after considering endogeneity.

Table 6. Regression results of system GMM.

	(1)	(2)
	SYSGMM1	SYSGMM2
L.lnpol	0.7431***	0.7212***
	(0.075)	(0.074)
lned	-0.1833*	-0.1748*
	(0.105)	(0.103)
lner	0.1336***	0.0961***
	(0.028)	(0.033)
c_lned*c_lner		0.1628**
		(0.081)
lnind	0.6074***	0.6313***
	(0.160)	(0.158)
lnfdi	0.1119**	0.1061**
	(0.049)	(0.048)
lntec	-0.0659	-0.0649
	(0.045)	(0.044)
lnurb	0.3645	0.4380
	(0.358)	(0.353)
_cons	-4.4979***	-4.8752***
	(1.644)	(1.624)
N	217	217
AR(1)	-2.5433	-2.7761
	[0.011]	[0.006]
AR(2)	-1.4769	-1.4874
	[0.140]	[0.137]
Sargan test	23.26534	22.57446
	[0.117]	[0.126]

Note: The standard errors are in parentheses and the p-values are in square brackets. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Further Analysis of Threshold Models

In this paper, the panel threshold model is adopted to further analyze the nonlinear relationship between environmental decentralization and environmental pollution, and the inflection point of change can be obtained. In this paper, the bootstrap method is used to repeat the sampling 300 times for simulation to obtain the P value, and the significance of the threshold effect is tested according to the corresponding P value. Table 7 reports the environmental decentralization threshold effect and significance test. There is a significant single-threshold effect in this model, but the double-threshold is not significant. Therefore, the research model of environmental decentralization and environmental pollution should be set as a single threshold model. Table 8 reports the estimated results of the threshold and its 95% confidence interval, with a threshold of 0.3227.

Table 9 reports the model estimation results. In different threshold areas, the impact of environmental decentralization on environmental pollution will vary. When the environmental decentralization is less than 0.3227, the environmental decentralization has a significant negative impact on environmental pollution, and the marginal effect coefficient is -0.324. When the environmental decentralization is greater than 0.3227, the environmental decentralization has a significant positive impact on environmental pollution, and the marginal effect coefficient is 0.738. In the above discussion, we find a U-shaped relationship between environmental decentralization and environmental pollution. When the degree of environmental decentralization is less than the threshold, it means that the environmental protection management authority is largely exercised by the central government, which can effectively prevent the tragedy of the Commons, improve the efficiency of public service supply of environmental management [21, 12], and thus reduce environmental pollution. However, when the degree of environmental decentralization is higher than the threshold value, the local government may make use of the autonomy of environmental affairs management to attract investment by relaxing environmental regulation so as to boost the regional economic development, thus leading to

Table 7. Threshold effect test.

Threshold	f Value	p Value	10%	5%	1%
Single	28.60	0.0500	23.3436	27.6885	37.5709
Double	16.50	0.2067	21.5995	26.8340	40.6697

Table 8. Threshold value estimates.

Variables	Threshold Value	Lower	Upper
Lned	0.3227	0.3011	0.3411

Table 9. Threshold model regression results.

TE	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Lned (Lned≤0.3227)	-0.324***	0.105	-3.080	0.002	-0.531	-0.116
Lned (Lned>0.3227)	0.738***	0.216	3.420	0.001	0.313	1.163
lner	0.0725***	0.0267	2.710	0.007	0.0198	0.125
lnind	-0.0893	0.150	-0.590	0.553	-0.385	0.207
lnfdi	-0.103**	0.0455	-2.250	0.025	-0.192	-0.0128
lntec	-0.114***	0.0360	-3.180	0.002	-0.185	-0.0435
lnurb	2.026***	0.307	6.600	0.000	1.421	2.632
_cons	-7.573***	1.073	-7.060	0.000	-9.689	-5.457
obs	248					
R-sq	0.3978					
f test	19.82					
Prob > f	0.0000					

Note: *, **, and *** denote significance within the levels of 10%, 5%, and 1%, respectively

environmental deterioration. Therefore, environmental decentralization first restrains environmental pollution and then aggravates it. This verifies the necessity of promoting the centralization reform of environmental management in China. The task of environmental pollution control in China is increasingly arduous. Since 2016, the Chinese government has strengthened centralized management of environmental protection, with the purpose of appropriately increasing environmental centralization and reinforcing environmental governance [11].

Conclusions

Conclusions and Recommendations

Environmental decentralization is an institutional factor that affects the effect of ecological environment governance. This paper selects the panel data of China's provinces from 2008 to 2015, evaluates the indicators of environmental decentralization, and uses the fixed effect model and the threshold effect model to empirically analyze the impact of environmental decentralization and environmental regulation on environmental pollution. The study first shows that the relationship between environmental decentralization and environmental pollution is U-shaped. Reasonable environmental decentralization can restrain environmental pollution, while excessive environmental decentralization aggravates environmental pollution. Secondly, environmental regulation and environmental pollution have an inverted U-shaped relationship. If the intensity of environmental regulation is too low, it cannot restrain environmental pollution. When the intensity of environmental regulation exceeds the critical point, it is beneficial to restrain environmental pollution. Thirdly, the interaction effect of the both is not beneficial to reduce environmental pollution. That is, excessive decentralization will worsen the inhibitory effect of environmental regulation on pollution discharge. Fourth, the effect of environmental decentralization has significant regional heterogeneity. In economically developed regions, environmental decentralization and environmental regulation are more effective in controlling regional environmental pollution. In low-emission regions, environmental decentralization is significantly negatively correlated with environmental pollution. In high-emission regions, environmental decentralization is negatively related to environmental pollution, but it is not statistically significant.

According to the above research and the actual situation of environmental protection in China, the following suggestions are put forward:

First, the allocation of environmental management authority among governments at all levels. Environmental management authority can be divided into environmental administrative management, environmental supervision and environmental monitoring [7]. Local governments should be given full environmental administrative authority, mainly in environmental planning, environmental investment and environmental law enforcement, which will help local environmental protection departments give full play to their information advantages, manage the ecological environment according to local conditions, and reduce environmental pollution in their jurisdictions. The central government should maintain centralized authority in environmental supervision and environmental monitoring, supervise the environmental management performance of local governments, and urge local governments to attach importance to environmental protection. Improve environmental regulation standards, increase investment in environmental protection, and reduce pollution emissions.

Second, it is necessary for the central government to implement differentiated decentralization policies by region. The above research shows that in economically developed regions and low-pollution regions, environmental decentralization has a better governance effect on regional environmental pollution. The local government pays attention to improving environmental quality and implements strict environmental policies. Therefore, it is necessary to moderately improve the level of environmental decentralization in economically developed and low-emission regions according to local conditions, and use their economic and technological advantages to reduce pollution emissions. For underdeveloped regions and high-pollution regions, the local government may relax environmental regulation in order to promote local economic development. Therefore, while giving the local government the corresponding environmental administrative authority, the central government should strengthen environmental supervision, set ecological environment standards and bottom lines, and provide financial support and pollution prevention and control technology to comprehensively reduce pollutant emissions.

Third, the intensity of environmental regulation should be increased. It is necessary to improve environmental regulation standards, increase environmental protection expenditures, and improve environmental protection infrastructure. The government should support the development of green and low-carbon industries, limit the scale of pollution-intensive industries and the adoption of cleaner production technologies. Environmental protection agencies should strictly implement environmental protection laws and systems, and supervise enterprises to carry out industrial pollution control.

Limitations and Future Research

Although this paper for the first time conducted an empirical study on the relationship between environmental decentralization, environmental regulation and environmental pollution, there are still some shortcomings. First, limited by the availability of data, this paper adopts provincial data to conduct research. The future research should be based on urban data, because the urban government is the concrete executor of environmental management. Second, since China's statistical department has no longer published personnel data of provincial environmental protection departments since 2016, the data of environmental decentralization indicators are up to 2015. Therefore, the method in this paper cannot measure the data of environmental decentralization degree after 2015. In the future, more scientific and reasonable alternative indicators should be explored to more accurately measure environmental decentralization and make the research data available, so that the research time can be extended to the recent period.

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Conflict of Interest

The authors declare no conflict of interest.

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