RESEARCH ARTICLE

Strategic interactions in environmental regulation enforcement: evidence from Chinese cities

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Abstract

Environmental regulation policy is the main means of pollution control and emission reduction and plays an irreplaceable role in environmental governance. However, due to the competitive behavior of economic development, the local government cannot effectively use the efficiency of environmental regulation to reduce the emission of environmental pollution. Taking 284 prefecture-level cities in China from 2005 to 2016 as samples, this paper studies the strategic interaction of environmental regulation enforcement by local governments under different circumstances and its impact on environmental pollution, so as to provide reference for national overall environmental governance planning. Through the research, it is found that the strategic interaction of environmental regulation enforcement among Chinese cities is characterized by the race-to-the-top. And the strategic interaction of environmental regulation enforcement among cities of the same economic level has the strongest impact. Besides, the impact of environmental regulation on environmental pollution has different intensity in different scenarios, showing a non-positive correlation. Most importantly, the Pollution Paradise exists in some cities under special circumstances.

Keywords Environmental regulation · Environmental pollution · Enforcement interaction · Spatial econometric model

Introduction

With the increasingly serious degree of environmental pollution (Moutinho et al. 2018), human health and the living environment are greatly threatened (Dogan et al. 2019; Tingru and Wenling 2018), and environmental pollution has been one of the biggest challenges faced by human beings (Wang et al. 2019a). The issue of environmental governance has been concerned all over the world (Dogan and Inglesi-Lotz 2020; Dogan and Turkekul 2016); from the *Kyoto Protocol* to the *Paris Agreement*, China has gradually become a leader in international climate governance. As the largest developing country, since the reform and opening-up, China's economy has developed rapidly and its GDP growth rate ranks among the highest in the world. But with China's rapid economic growth, environmental pollution has grown up to be a serious problem. According to the *2016 Environmental Performance Index Report* released by Yale University, China's environmental performance index (EPI) ranks second from the bottom, making it a *major disaster area* for excessive $PM_{2.5}$. Serious environmental pollution will affect the health and quality of life of residents, which has caused the public and all levels of government to attach great importance to. To control environmental pollution, the central government and provincial and municipal governments have comprehensively implemented the ecological governance concept of the *green mountains and clear water are golden mountains and silver mountains* continuously strengthened environmental governance, and many effective environmental governance policies have been formulated, such as environmental regulation (Zhang et al. 2018b; Zhang et al. 2019a), household fuel policy (Meng et al. 2019), and carbon trading scheme (Chang and Zhang 2018; Rosendahl 2019; Song et al. 2018; Zhang et al. 2019b). However, since the reform of the tax-sharing system in China, under the dual role of decentralized governance structure and performance evaluation system, local governments compete with other regions to improve their economic level, resulting in strategic behaviors in the implementation of environmental policies. The scientific and reasonable

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establishment of environmental regulations in various regions is conducive to the accurate and efficient control of environmental regulation and the overall reduction of regional pollutant emission intensity. The reasonable degree of environmental regulation not only improves the health and quality of life of Chinese residents but also provides references for other countries or regions in the world to deal with pollution.

In the policies and regulations of environmental governance, environmental regulation can effectively control environmental pollution, significantly improve regional ecological efficiency, and promote the efficiency of the green economy (Hu et al. 2018; Qu 2018), which plays a positive role in protecting the environment and promoting high-quality economic development (He and An 2019; Tao and Hu 2019). As a means of government intervention in resource and environmental problems, environmental regulation plays an irreplaceable role in solving the externality of environmental pollution and correcting market failure. Most scholars believe that China's environmental regulation policies have a positive effect on environmental pollution control to some extent, and environmental regulation can significantly reduce environmental pollution (Chen et al. 2018; Hui and Zhao 2017; Wang and Liu 2019; Zhang et al. 2018a). The effectiveness of environmental regulation has been recognized and put into practice by environmental authorities and many scholars. However, Yu et al. (Yu et al. 2018) used municipal panel data to estimate the results and found that the current environmental regulation does not reach the expected goal of controlling and reducing pollution. The Green Paradox exists in environmental regulation intensity, which hinders the improvement of environmental quality (Li and Ma 2018; Ren et al. 2018; Xu and Zuo 2013).

As an important part of local government governance, the relationship between local government environmental regulation and enterprise decision-making has been widely concerned in academic research (Milani 2017). Environmental regulation affects the profit margin mechanism of enterprises and promotes the industrial transformation and development of cities, which is an important factor influencing the layout of pollution-intensive industries. (Li and Zou 2018; Liu et al. 2019; Long and Wan 2017; Tian et al. 2018; Wang et al. 2019b). Zhao et al. (Zhao et al. 2019) believed that the implementation of environmental regulation had a significant impact on improving the technological innovation capacity of pollution-intensive manufacturing. The existing literature discusses the relationship between local government environmental regulation and enterprise decision-making behavior, mainly from the two aspects of enterprise innovation behavior and relocation behavior, and puts forward two interesting theories: The *Porter Hypothesis* and the *Pollution Paradise Hypothesis*. The *Porter Hypothesis* holds that enterprises' innovation activities are largely influenced by strict and appropriate environmental regulations, because enterprises can

reduce their environmental governance costs by improving their technological innovation level (Porter and Claas 1995). The *Pollution Paradise Hypothesis* holds that after a country strengthens environmental regulation, to reduce pollution control costs, polluting enterprises will move to countries with a low degree of environmental regulation, which provides a haven for polluting enterprises (Copeland and Taylor 2004; Solarin et al. 2017; Walter and Ugelow 1979).

Environmental regulation has a high spatial spillover effect, and there is a phenomenon that environmental regulation causes pollution to be transferred nearby. Regions with a high degree of environmental regulation are likely to cause polluting industries to be transferred to neighboring areas, which may lead to inter-regional environmental competition (Dong and Wang 2019; Shen et al. 2017; Wang 2013). Therefore, most scholars support the existence of the pollution shelter hypothesis and believe that the pollution shelter hypothesis is established in China (Cohen et al. 2018; Jing et al. 2017; Sun et al. 2017). As the spatial spillover effect of environmental pollution and the effect of pollution shelter on environmental governance is gradually recognized, the call for joint governance also starts to increase. No matter in developed or developing countries, local governments are not independent individuals. They tend to form strategic behaviors in policy formulation or implementation, with obvious mutual imitation behaviors (Li et al. 2014). There are abundant literature on the study of forms of intergovernmental interaction (Besley and Case 1995; Brueckner and Saavedra 2001; Case et al. 1993; Fredriksson and Millimet 2002). However, because of the differences in research objects and research periods, there are different views on this issue in the academic circle. First, some literature believe that to compete for liquidity factors, local governments will be scrambling to lower their environmental regulation level (Woods 2006). These literature summarize the interactive behaviors of local governments competing to lower the level of environmental regulation as the *race-to-the-bottom*. Second, contrary to the view of the first type of literature, some literature hold that environmental regulation interaction of local governments is shown as the *race-to-the-top*, that is, local governments strive to improve their environmental regulation level (Fredriksson and Millimet 2002). The underlying mechanism lies in the nimbyism of local governments and the pursuit of elements that prefer a high-quality environment. Third, some other literature hold that heterogeneity exists between regions, so the interaction of environmental regulation between local governments cannot be completely summarized whether it is the *race-to-the-bottom* or the *race-to-the-top*. These literature tend to believe that both of them exist (Jin and Shen 2018; Konisky 2007).

Due to the transnational nature of regional environmental pollution, there is a game relationship between local governments in the implementation of environmental regulation. Chinese-decentralized environmental regulation is regarded

as a game tool for local governments to compete for mobile resources, which lead to the strategic interaction of environmental regulation between regions, thus giving birth to the general phenomenon of incomplete implementation of environmental regulation (Zhang 2016). Some studies believe that to compete for liquidity factors and solidify local resources, the environmental regulation behaviors of local governments are characterized by the *race-to-the-bottom* (Li and Shen 2008; Liu and Peng 2019). For those regions that are in the process of industrial structure transformation, to attract mobility factors that prefer a high-quality environment (such as superior talents), it is more likely to form a competition of environmental regulation (Konisky 2007; Zhang and Zhu 2010). The establishment of a joint governance organization has a significant impact on the deepening of regional unity. It can not only effectively enhance the communication and exchange of regional action on air pollution control, but also strengthen the coordination of related matters between governments and departments (Hu et al. 2019).

Through sorting out the existing literature, it is found that although the literature on the interactive forms of the implementation of local government environmental regulation and the impact of local government environmental regulation on environmental pollution have been abundant, but only part of the literature study, the interaction form of the implementation degree of local government environmental regulation and its impact on environmental pollution under different environmental regulation scenarios. Environmental regulation can significantly restrain the increase of environmental pollution and play an important role in environmental governance, while the difference in the degree of environmental regulation between regions is affected by the interactive form of environmental regulation between local governments. Then, is there any heterogeneity in the forms of enforcement interaction between local governments? If so, what is the form of heterogeneity in the form of interaction between the enforcement of environmental regulation and the impact of regional environmental pollution? How to develop a reasonable degree of implementation of environmental regulation and give full play to the role of environmental regulation ineffective pollution control and emission reduction at the national level? Aiming at the problems above, first of all, based on the geographic neighboring matrix, economic near-adjacent matrix and distance matrix adjacent matrix, three types of space from the executive level in the face of China's local government environmental regulation to perform interactive form, the inspection focused on environmental regulation of heterogeneity between the local government, deepen the literature study of China's local government environmental regulation. Secondly, this paper further investigates the heterogeneous impact of local government environmental regulation implementation interaction on environmental pollution, analyzes the relationship between environmental regulation and environmental

pollution, and tests the existence of the environmental sanctuary hypothesis. Finally, the multi-scale influence mechanism of environmental regulation on environmental pollution is discussed in detail in the context of environmental pollution, providing references for the Chinese government to rationally adjust the implementation degree of regional environmental regulation to achieve the optimal effect of environmental governance.

There are two innovative points in this paper: First, this paper constructs a spatial econometric model of the two-zone system (i.e., the strong degree of environmental regulation enforcement and the weak degree of environmental regulation enforcement) to explore the interactive effect of different levels of environmental regulation enforcement, and makes a more comprehensive study of the interactive mechanism of environmental regulation enforcement, thus filling in the gaps in existing studies. Second, in this paper, the degree of environmental regulation to build the system of a three-zone system (that is, the stronger environmental regulation execution degree, moderate degree, and weak environmental regulation execution environment regulation execution degree) spatial econometric model not only discusses the environmental regulation under different degrees of pollution of the environment pollution to the environment, but also studies the degree of pollution of the environment under the influence of different environmental regulations of environmental pollution. The results of this paper provide reference for the government departments to actively carry out effective joint prevention and control and to curb environmental pollution.

Models and data

Model selection and construction

Spatial correlation test

To test whether the research data in this paper have spatial relevance, this paper refers to the existing literature (Lesage 2014; Li and Wu 2017) and uses Moran index to test the spatial correlation between environmental pollution and environmental regulation indicators. The test results are shown in Table 1.

According to Table 1, Moran's I of the spatial correlation test results of environmental pollution and environmental regulation are both positive, indicating that environmental pollution and environmental regulation show a positive correlation between space units. According to the Z test results, the above spatial correlation results are all significant. It shows that the environmental pollution and environmental regulation of cities in China have obvious spatial agglomeration effect, so the spatial econometric model should be adopted for demonstration.

Table 1 The results of spatial correlation test

Moran's I	EP	ER	Moran's I	EP	ER
2005	0.11***	0.04*	2011	0.05*	0.04*
	(3.17)	(1.91)		(1.76)	(1.80)
2006	0.14***	0.07*	2012	0.04*	0.08**
	(3.88)	(1.94)		(1.96)	(2.18)
2007	0.11***	0.05*	2013	0.14***	0.09**
	(3.15)	(1.98)		(3.82)	(2.62)
2008	0.11***	0.12***	2014	0.20***	0.14***
	(3.11)	(3.30)		(5.52)	(3.83)
2009	0.10***	0.11***	2015	0.11***	0.15***
	(2.67)	(3.01)		(2.93)	(4.18)
2010	0.14***	0.13***	2016	0.21***	0.22***
	(3.91)	(3.57)		(5.88)	(6.13)

The Z value is in parentheses

*Indicates significant at the 10% level

**Indicates significant at the 5% level

***Indicates significant at the 1% level

Spatial model selection

To select the spatial econometric model suitable for the data in this paper, the spatial autoregressive (SAR) model, the spatial error model (SEM), the spatial Durbin model (SDM), and the spatial Dubin error model (SDEM) were compared according to the model selection criteria, and finally, the most suitable model for the data in this study was selected. The test results are shown in Table 2.

By comparing the model fitting effect indexes R^2, log-likelihood and sigma^2 of the regression results of four spatial econometric models, it can be found that the R^2 of the SDM is 0.5063, with the maximum value. At the same time, the Log-likelihood of the SDM is -60946.2450, and its value is also the largest among the four models. And the sigma^2 value of the SDM is the smallest among the four models. According to the judgment of the fitting effect of the model based on the fitting effect index, the SDM is the most suitable model among the four models for the data in this study. Therefore, this paper chooses the SDM as the basic model to study the emission reduction effect of the interactive mechanism of environmental regulation in China. The structure of the SDM is shown in Eq (1).

$$Y = \rho WY + X\beta + WX\delta + \varepsilon \quad (1)$$

Among them, Y represents the dependent variable, WY represents the lagged term of the dependent variable, X represents the independent variable, WX represents the lagged term of the independent variable, W represents the spatial weight matrix, and ε represents the error term, which is subject to independent identical distribution ($i.i.d$).

Empirical model

This paper firstly refers to the research of Jin and Shen (2018) to construct a two-zone system SDM to test the interactive form of urban environmental regulation implementation. The structure of the interactive model of environmental regulation implementation is shown in Eq (2).

$$ER_{it} = \alpha_1 D_{it} I_{it} \sum_{j\neq i} \omega_{ij} ER_{jt} + \alpha_2 D_{it}(1-I_{it}) \sum_{j\neq i} \omega_{ij} ER_{jt}$$

$$+ \alpha_3(1-D_{it})I_{it} \sum_{j\neq i} \omega_{ij} ER_{jt}$$

$$+ \alpha_4(1-D_{it})(1-I_{it}) \sum_{j\neq i} \omega_{ij} ER_{jt} \quad + \beta_1 X_{it}$$

$$+ \beta_2 \sum_{j\neq i} \omega_{ij} X_{jt} + \mu_i + \upsilon_t + \varepsilon_{it} \quad (2)$$

Among them, $D_{it} = \begin{cases} 1, & ER_{it} > \sum_{j\neq i} \omega_{ij} ER_{jt} \\ 0, & \text{Others}, \end{cases}$ $I_{it} = \begin{cases} 1, & \sum_{j\neq i} \omega_{ij} ER_{jt} > \sum_{j\neq i} \omega_{ij} ER_{jt-1} \\ 0, & \text{Others}, \end{cases}$ i represents the ith city, t represents the year, ER_{it} represents the degree of environmental regulation of the city i in the year t, $\sum_{j\neq i} \omega_{ij} ER_{jt}$ represents the weighted average sum of the degree of environmental regulations of all cities except city i in year t. ω_{ij} is a member of the spatial weight matrix. X_{ij} represents the control variables at the city level, while μ_i and υ_t respectively represent the fixed effect of the city and the fixed effect of the year.

According to the differences in the degree of environmental regulation implementation in the region and surrounding areas, referring to the relevant literature (Jin and Shen 2018; Liu and Peng 2019), the possible results of the interaction mechanism for environmental regulation implementation between cities are shown in Table 3.where (1) When the coefficients $\alpha_1 > 0$, $\alpha_3 > 0$ and $\alpha_2 > 0$, $\alpha_4 > 0$ in Eq. (3) indicate that the strategic interaction in the implementation of environmental regulation among regions is characterized by the race-to-

Table 2 Test results of spatial econometric model

Index	SAR	SEM	SDM	SDEM
R^2	0.5061	0.5037	0.5063	0.5056
Log-likelihood	-57775.5840	-2408.0033	-60946.2450	-2378.9036
Sigma^2	0.1943	0.1952	0.1942	0.1945

Table 3 Classification of the results of the interaction mechanism of environmental regulation implementation

Coefficient	$\alpha_2 > 0, \alpha_4 > 0$	$\alpha_2 > 0, \alpha_4 < 0$	$\alpha_2 < 0, \alpha_4 > 0$	$\alpha_2 < 0, \alpha_4 < 0$
$\alpha_1 > 0, \alpha_3 > 0$	Race-to-the-top			Strategic-interaction
$\alpha_1 > 0, \alpha_3 < 0$		Extreme-difference		
$\alpha_1 < 0, \alpha_3 > 0$			Seek-indifference	
$\alpha_1 < 0, \alpha_3 < 0$	Strategic-interaction			Race-to-the-bottom

the-top, and local governments compete to improve their level of environmental regulation. (2) When $\alpha_1 > 0$, $\alpha_3 > 0$ and $\alpha_2 < 0$, $\alpha_4 < 0$, or $\alpha_1 < 0$, $\alpha_3 < 0$ and $\alpha_2 > 0$, $\alpha_4 > 0$, it indicates that the strategic interaction in the implementation of environmental regulation between regions is characterized by the strategic- interaction. The environmental regulation degree of local governments increases with the increase of environmental regulation degree of neighboring cities, and decreases with the decrease of environmental regulation degree of neighboring cities. (3) When $\alpha_1 > 0$, $\alpha_3 < 0$ and $\alpha_2 > 0$, $\alpha_4 < 0$, the form of strategic interaction in the implementation of environmental regulations among regions is extreme- difference. It indicates that when the environmental regulation degree of the neighboring city is enhanced, if the environmental regulation degree of the neighboring city is strong, the environmental regulation degree of the neighboring city is significantly enhanced. If the degree of environmental regulation in this city is weak, the degree of environmental regulation in neighboring cities will be significantly weakened. As a result, the degree of environmental regulation in this city is becoming stronger or weaker, gradually presenting extreme differentiation characteristics. (4) When $\alpha_1 < 0$, $\alpha_3 > 0$ and $\alpha_2 < 0$, $\alpha_4 > 0$, the strategic interaction in the regional environment regulation implementation is seek-indifference. If the environmental regulation of the city is stronger, the neighboring cities significantly reduce the environmental regulation of the city. If the environmental regulation of the city is weak, the neighboring city has significantly enhanced the environmental regulation of the city. The environmental regulation of cities with strong environmental regulation is getting weaker and weaker, and the environmental regulation of cities with weak environmental regulation is getting stronger and stronger. (5) When $\alpha_1 < 0$, $\alpha_3 < 0$ and $\alpha_2 < 0$, $\alpha_4 < 0$, it indicates that the strategic interaction in the implementation of environmental regulations among regions is characterized by the race-to-the-bottom. In order to compete for liquidity factors, local governments will compete to reduce the degree of environmental regulations. (6) In another case, the form of strategic interaction of environmental regulation enforcement between cities is irregular.

There are differences in the performance forms of the interactive mechanism of environmental regulation enforcement between regions, so are the results of the interaction between different degrees of environmental regulation consistent? In order to analyze the interactive effect of environmental

regulation execution with different degrees of environmental regulation, this paper constructs a spatial econometric model containing three degrees of environmental regulation with reference to the spatial econometric model (Vega and Elhorst 2015). As shown in Eq. (3).

$$EP_{it} = \alpha_1 DL_{it} ER_{it} + \alpha_2 DM_{it} ER_{it} + \alpha_3 DX_{it} ER_{it} + \alpha_4 DL_{it} \sum_{j \neq i} \omega_{ij} ER_{jt} + \alpha_5 DM_{it} \sum_{j \neq i} \omega_{ij} ER_{jt} + \alpha_6 DX_{it} \sum_{j \neq i} \omega_{ij} ER_{jt} \quad (3)$$

$$+ \beta_1 X_{it} + \beta_2 \sum_{j \neq i} \omega_{ij} X_{jt} + \mu_i + \upsilon_t + \varepsilon_{it}$$

Among them, $DX_{it} = \left\{ 1, \quad ER_{it} > \forall \left(ER_{jt}\right) \quad 0, \text{Others},\right.$ $DM_{it} = \left\{ 1, \quad \min\left(ER_{jt}\right) < ER_{it} < \max\left(ER_{jt}\right) \quad 0, \text{Others},\right.$ $DL_{it} = \left\{ 1, \quad ER_{it} < \forall \left(ER_{jt}\right) \quad 0, \text{Others}.\right.$ i represents the ith city, t represents the year. ER_{it} represents the degree of environmental pollution of the city i in the year t. EP_{it} represents the degree of environmental regulation of the city i in the year t, $\sum_{j \neq i} \omega_{ij} ER_{jt}$ represents the weighted average sum of the degree of environmental regulations of all cities except city i in year t. ω_{ij} is a member of the spatial weight matrix. X_{it} represents the control variables at the city level, while μ_i and υ_t respectively represent the fixed effect of the city and the fixed effect of the year.

Variables and data

Referring to the measurement method of environmental regulation implementation by Shen et al. (2017), the weighted linear sum method was adopted to construct the comprehensive index of environmental regulation based on two single indexes, sulfur dioxide removal rate and industrial smoke (powder) dust removal rate. The calculation formula is shown in Formula (4).

$$ER_{it} = \sum_{j=1}^{2} \left(\frac{p_{ijt}}{\sum_i p_{ijt}} \middle/ \frac{gdp_{it}}{\sum_i gdp_{it}} \right) \left[\left(p_{ijt} - \min\left(p_{jt}\right)\right) \middle/ \left(\max\left(p_{jt}\right) - \min\left(p_{jt}\right)\right) \right] / 2$$

$$(4)$$

where p_{ijt} represents the value of the jth pollutant in the ith city in year t, and $\max(p_{jt})$ and $\min(p_{jt})$ represent the maximum and minimum values of the jth pollutant in all cities in year t respectively.

Industrial pollution emission indicator

In this paper, the total pollution emission index is used as the proxy variable of industrial pollution emission. According to the calculation method of environmental pollution by Zhu et al. (2011), the pollutants in this paper include the emission of industrial wastewater, industrial smoke (powder) dust, and industrial sulfur dioxide.

Control variables

Referring to the existing literature (Jin and Shen 2018; Shen et al. 2017), we also added other control variables in the regression.

1) The level of economic development: expressed by GDP per capita.
2) Industrial structure: the proportion of secondary industry in GDP.
3) Trade openness: concerning Shen and Zhang (2015), the ratio of foreign direct investment utilized in a city to GDP indicates the degree of opening to the outside world, and the ratio of retail sales of social consumer goods to GDP indicates the degree of opening to the outside world.
4) Fiscal decentralization degree: expressed by the proportion of fiscal revenue in the budget of the city to the total fiscal expenditure in the budget of the city.
5) Population density: expressed by the ratio of the total population to the administrative area at the end of the year.
6) Urban registered unemployment rate: expressed by the proportion of urban registered unemployed persons in the total of employees of units, private, and self-employed employees and urban registered unemployed persons.
7) The average salary of employees.

Space weight matrix

According to the selection criteria of the weight matrix of Jin and Shen (2018) and Zhang et al. (2019a), three kinds of space weight matrices were selected to depict neighboring cities: (1) First-order Queen adjacency matrix ($W1$). When the boundary between the city i and the city j is adjacent, ω_{ij} is equal to 1; when the city i is not adjacent to city j, ω_{ij} is equal to 0. (2) Economic distance weight matrix ($W2$). $\omega_{ij} = 1/ \mid pgdp_i - pgdp_j + 1 \mid$, where pgdp represents GDP per capita. Different from the above two matrices' idea of constructing the spatial weight matrix from the perspective of geographic distance, this matrix measures the proximity between cities by economic distance (the difference in per capita GDP). (3) Geographical distance weight matrix ($W3$). ω_{ij} is the inverse of the distance between the city i and city j as the crow flies. Compared with the 0–1 matrix, this matrix assumes that any city may have interaction behavior, but the closer city has more obvious interaction behavior. To make the spatial hysteresis term have the meaning of weighted average, the above three matrixes were processed with row standardization, and the diagonal element was set as 0.

Since the diagonal position in the economic weight matrix and the distance weight matrix is 0, all other positions are non-0 values. Therefore, it is impossible to compare the degree of environmental regulation and environmental pollution between this city and neighboring cities according to the method of classification in this paper. To study the impact of different degrees of environmental regulation on environmental pollution, and the impact of environmental regulation on environmental pollution under different degree scenarios of environmental pollution, in this paper, the upper and lower 10% fractions of the weight matrix of economic and distant space are taken as the dividing line between the strong and weak environmental regulation degrees, the severe environmental pollution intensity, and the mild environmental pollution degree. When the degree of environmental regulation is lower than the 10% quantile of the degree of environmental regulation of the neighboring city, the degree of environmental regulation is relatively weak. When the degree of environmental regulation in this city is within the 10–90% quantile range of the degree of environmental regulation in the neighboring city, it is greater than the 10% quantile value of the degree of environmental regulation in the neighboring city, and less than the 90% quantile value of the degree of environmental regulation in the neighboring city; the city's degree of environmental regulation is a moderate degree of environmental regulation. When the degree of environmental regulation in this city is higher than the 90% quantile value of the degree of environmental regulation in neighboring cities, the degree of environmental regulation in this city is a stronger degree of environmental regulation. The classification of environmental pollution processes is consistent with the classification of environmental regulations.

The data samples in this paper are composed of panel data of 284 prefecture-level cities in China from 2005 to 2016. Chaohu, Bijie, Tongren, Sansha, Haidong, and Lasa were excluded due to the adjustment of administrative divisions and lack of data in the sample period. All price-type variables are current prices. To eliminate the impact of inflation, we use the prefecture-level city-level GDP index for leveling, and the base period is 2005. All variable data were derived from *China statistical yearbook*, *EPS data platform*, *China environmental statistical yearbook*, and provincial statistical yearbook. To avoid heteroscedasticity and other problems in the data, this paper carried out logarithmic processing on all the data. After testing, the logarithmic data were stable. The explained variables, explanatory variables, and control variables in this paper are shown in Table 4.

Table 4 Descriptive statistics of major variables

Variable	Explain	Obs	Mean	Std. dev.	Min	Max
ER	Degree of environmental regulation	3408	0.06	0.03	0.00	0.20
EP	The index of environmental pollution	3408	1.00	1.19	0.00	35.74
pgdp	Economic development level	3408	21926.93	16226.20	70.00	257570.00
struc	Industrial structure (%)	3408	49.02	10.91	14.95	90.97
opene	Degree of opening to the outside world	3408	7.63	19.15	0.00	336.74
openi	Degree of internal openness	3408	0.07	0.11	0.00	1.20
fiscal	Fiscal decentralization	3408	0.49	0.23	0.05	1.54
pdensity	Density of population	3408	426.40	327.33	4.70	2648.30
unemp	Urban registered unemployment rate	3408	0.03	0.02	0.00	0.41
pwage	Average wages of staff and workers	3408	21331.35	6860.52	2530.00	120990.00

Empirical results and analysis

Firstly, this paper studies the forms of environmental regulation enforcement interaction. On this basis, the paper further examines the influence of environmental regulation on environmental pollution, and discusses the influence of environmental regulation on environmental pollution under different circumstances.

Interactive mechanism of environmental regulation enforcement

To investigate the forms of execution interaction of environmental regulations, this paper analyzes the forms of execution interaction between different environmental regulations based on three spatial weight matrices. Columns (1)–(3) in Table 5 and Fig. 1 report the results of Eq. (2).

Table 5 Interactive forms of environmental regulation implementation

Variable	W1 (1)	W2 (2)	W3 (3)
$W \times ER$ ($D_{it} = 1, I_{it} = 1$)	0.82*** (36.61)	0.92*** (33.82)	0.63*** (11.21)
$W \times ER$ ($D_{it} = 1, I_{it} = 0$)	0.84*** (40.11)	0.94*** (36.12)	0.65*** (11.43)
$W \times ER$ ($D_{it} = 0, I_{it} = 1$)	0.96*** (41.55)	1.11*** (40.52)	0.85*** (15.10)
$W \times ER$ ($D_{it} = 0, I_{it} = 0$)	0.96*** (42.89)	1.08*** (39.82)	0.78*** (13.70)
Control variable	Yes	Yes	Yes
Regional fixed effect	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes
R^2	0.660	0.658	0.620
Log-L	− 1779.40	− 1605.14	− 1659.63

*Indicates significant at the 10% level

**Indicates significant at the 5% level

***Indicates significant at the 1% level

The interactive form of environmental regulation between Chinese cities is *race-to-the-top*. Equation (3) considers the change of the degree of environmental regulation of neighboring cities and the relationship between the degree of environmental regulation of the central city and neighboring cities. The results in Table 5 are relatively accurate to obtain the interactive mechanism of environmental regulation among Chinese cities. According to the results in Table 5, the impact of environmental regulations in neighboring cities on environmental regulations in central cities is significantly positive under different scenarios and different spatial weight matrices. No matter how the degree of environmental regulation of the neighboring cities changes, the degree of environmental regulation of the central cities is significantly enhanced. According to the existing literature's definition of the interactive mechanism of environmental regulation enforcement, this result supports the interactive form of environmental regulation enforcement of *race-to-the-top*, which is consistent with the conclusion of the existing literature (Jin and Shen 2018). When Chinese cities formulate or implement environmental regulation policies, they will continue to enhance the degree of environmental regulation of their own region despite the influence of neighboring cities, which indicates that the environmental regulation of Chinese cities will be gradually strengthened and the pollution control and emission reduction effect will be significant. According to the district classification in Fig. 1, when the three spatial relationships are used as the spatial weight matrix, most cities belong to their own cities with a strong degree of environmental regulation enforcement, and the degree of environmental regulation enforcement in neighboring cities is lower year by year. That is, $D_{it} = 1, I_{it} = 0$.

The interaction of environmental regulation execution is the strongest among cities of the same economic level. According to the results in Table 5, through the comparative analysis of the same degree of environmental regulation scenario, it is found that when the spatial weight matrix is the economic weight (W2), the degree of environmental regulation is most strongly affected by the degree of environmental
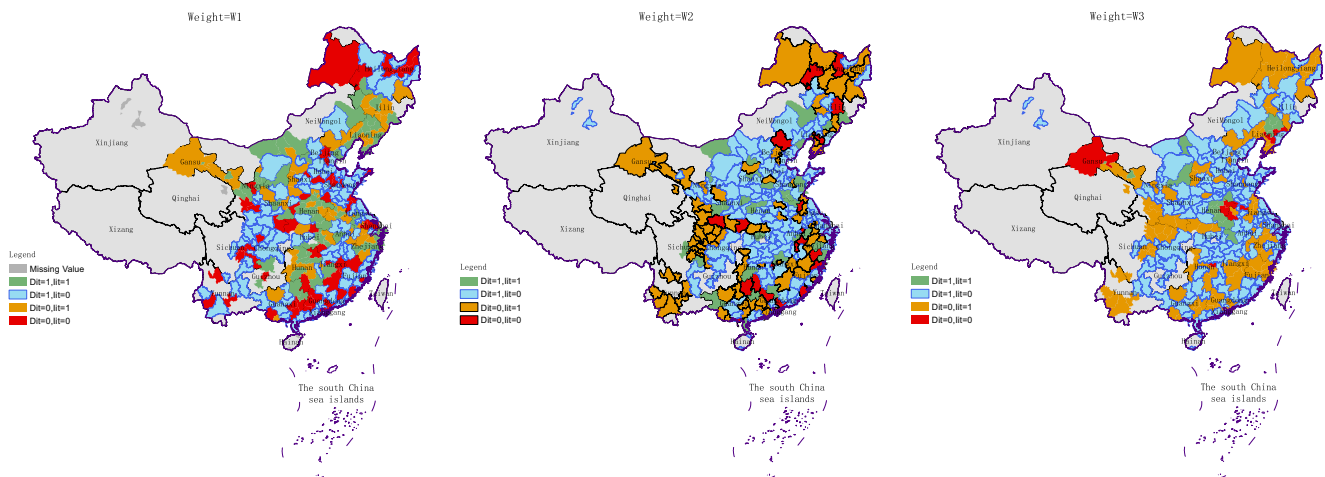
Fig. 1 The implementation degree of environmental regulation in two districts is described

regulation of neighboring cities. For example, when the degree of environmental regulation of the central city is stronger than that of the neighboring city and the degree of environmental regulation of the neighboring city increases year by year ($D_{it} = 1$, $I_{it} = 1$), the response coefficient α_1 of the model with geographical proximity as the spatial weight matrix is 0.82, the response coefficient α_1 of the model with the economic level relation as the spatial weight matrix is 0.92, and the response coefficient α_1 of the model with distance as the spatial weight matrix is 0.63. Among them, α_1 ($W2$) > α_1 ($W1$) > α_1 ($W3$). It shows that the city with the adjacent economic development level can have stronger interactive impact on the implementation of environmental regulations, which is consistent with the actual situation.

The impact of environmental regulation on environmental pollution

This paper further investigates the heterogeneity of the interaction between local governments' environmental regulation implementation and its impact on environmental pollution. Columns (1)–(6) in Table 6 and Fig. 2 report the regression results of Eq. (3).

Environmental regulation suppresses environmental pollution, and when the degree of environmental regulation is the weakest, the impact of environmental regulation on environmental pollution is the weakest. As can be show in Table 6, the estimated coefficients of the degree of environmental regulation in this city are all significantly negative, and the influence intensity is greater than 0.1. When the degree of environmental regulation of the city is enhanced, the pollution emission of the city is significantly inhibited, which indicates that improving the degree of environmental regulation of the city can reduce the pollution emission of the city, and verifies the effectiveness of environmental regulation on environmental pollution control. By observing the results in Fig. 2, it is found

that when the degree of environmental regulation is the weakest, the inhibitory effect of environmental regulation on environmental pollution is the weakest. For example, when the spatial weight matrix is the geographical proximity matrix ($W1$), the reaction coefficient α_1 is -0.11, α_2 is -0.14, and α_3 is -0.11, and they are all significant at the significance level of 1%, which is obvious $|\alpha_1| \leq \min(|\alpha_2|, |\alpha_3|)$. The environmental regulations with other levels of enforcement have a much stronger impact on environmental pollution than those with the weakest levels of enforcement.

The degree of environmental regulation has a significant spillover effect, and the main spillover paths are different due to the different degrees of environmental regulation. By observing the impact of the spatial lag item of the interaction of environmental regulation implementation in Table 6 and Fig. 2 on environmental pollution, it is found that the coefficient of $W \times ER$ is significantly negative. It indicates that environmental regulation cannot only inhibit the deterioration of environmental pollution in the city, but also significantly inhibit the deterioration of environmental pollution in the neighboring cities. It further verifies that the degree of environmental regulation has the spatial interactive form of *race-to-the-top*. By comparing the spillover effect of environmental regulation degree under different environmental regulation degree, it is found that when the environmental regulation degree is at its weakest, the main spillover path of environmental regulation degree is based on the proximity of geographical location. When the degree of environmental regulation is relatively strong, the main spilt path of the degree of environmental regulation is based on the distance-space weight matrix, which is consistent with the overall effect in column 3 of Table 6.

The joint control effect among Chinese cities is remarkable, and the environmental regulation of neighboring cities has a significant restraining effect on the environmental pollution of the city. When the environmental regulation degree of neighboring cities is enhanced, the environmental regulation degree

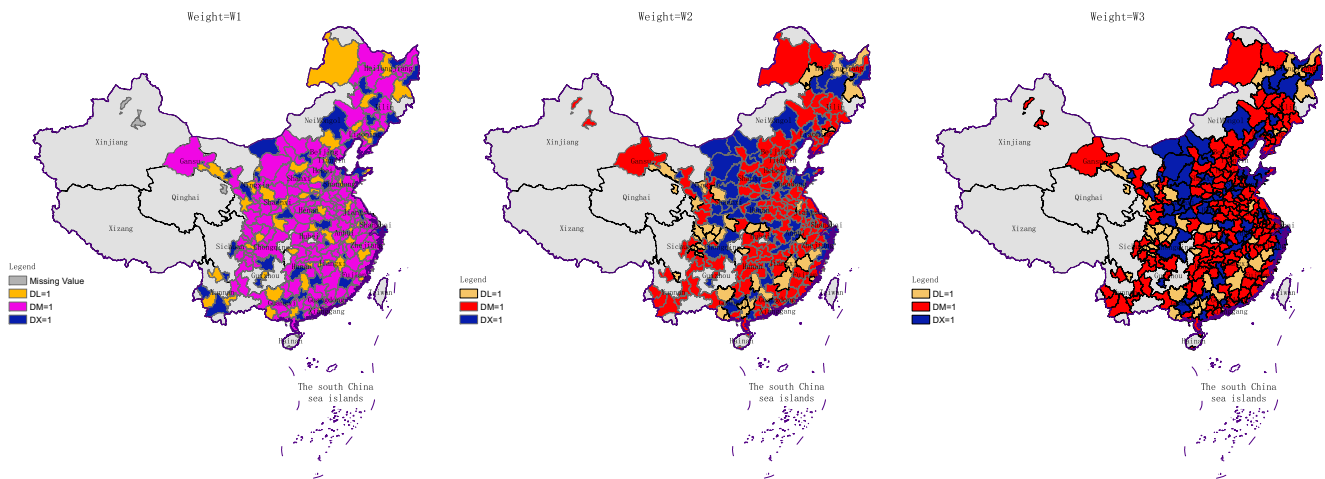**Table 6** The impact of environmental regulation on environmental pollution

Variable	W1 (1)	W2 (2)	W3 (3)	W1 (4)	W2 (5)	W3 (6)
ER	− 0.12***	− 0.13***	− 0.11***			
	(− 8.58)	(− 9.51)	(− 8.33)			
ER (DL = 1)				− 0.11***	− 0.12***	− 0.11***
				(− 4.99)	(− 5.90)	(− 5.58)
ER (DM = 1)				− 0.14***	− 0.12***	− 0.10***
				(− 8.20)	(− 6.53)	(− 5.64)
ER (DX = 1)				− 0.11***	− 0.16***	− 0.14***
				(− 4.46)	(− 7.20)	(− 6.07)
W × ER	− 0.18***	− 0.09**	− 0.33***			
	(− 6.78)	(− 2.34)	(− 3.20)			
W × ER (DL = 1)				− 0.18***	0.06	− 0.02
				(− 4.20)	(0.88)	(− 0.09)
W × ER (DM = 1)				− 0.18***	− 0.21***	− 0.34**
				(− 5.32)	(− 3.72)	(− 2.19)
W × ER (DX = 1)				− 0.11*	− 0.07	− 0.56***
				(− 1.80)	(− 1.12)	(− 2.82)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Regional fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.86	0.85	0.86	0.86	0.85	0.86
Log-L	− 1724.67	− 1785.79	− 1752.35	− 1719.43	− 1778.90	− 1749.34

*Indicates significant at the 10% level

**Indicates significant at the 5% level

***Indicates significant at the 1% level

of the city will also be enhanced, thus restraining the deterioration of the environmental pollution in the city. When the local government improves the environmental regulation level of the city, due to the significant imitative strategy features of the environmental regulation level among Chinese cities, the governments of neighboring cities will correspondingly improve the environmental regulation level, and finally restrain the environmental pollution of neighboring cities.

The impact of environmental regulations on environmental pollution based on different scenarios

The above part mainly analyzes the impact of different degrees of environmental regulations on environmental pollution. To avoid the interference of environmental pollution degrees, this part examines the impact of environmental regulation on environmental pollution under different pollution

Fig. 2 Description of the degree of environmental regulations in the three-district system

degrees. By comparing the pollution situation with the pollution situation of neighboring cities, this paper studies the interaction of environmental regulation enforcement under the conditions of better, medium, and poor pollution. The results are shown in Table 7 and Fig. 3.

The more serious the environmental pollution is, the stronger the inhibition effect of environmental regulation on environmental pollution is. By comparing the results in Table 7 and Fig. 3, it is found that the more serious the environmental pollution is, the stronger impact of the implementation degree of environmental pollution on environmental pollution is. For example, when the executive degree of environmental pollution is the weakest, the impact intensity of environmental pollution executive degree based on the weight matrix of geographical proximity on environmental pollution is 0.13, 0.16, and 0.24, respectively. It is obvious that $\alpha_1 (EP = L) < \alpha_1 (EP = M) < \alpha_1 (EP = X)$. The degree of environmental regulation has a significant inhibitory effect on environmental pollution and has become one of the important policies for pollution control and emission reduction. However, due to the differences between cities in China, their economic development level and environmental pollution degree are different, so there will be differences in the degree of environmental pollution caused by environmental regulations. The weaker the degree of environmental pollution is, the pollution control and

emission reduction effect of environmental regulations have reached a certain degree, and the impact intensity on environmental pollution is gradually weakened. Therefore, with the improvement of environmental regulations, the impact intensity on environmental pollution is far less than that in regions with serious environmental pollution. For example, in Beijing and Tianjin, although the air quality is low, the treatment of industrial pollution has reached a certain degree, such as the relocation of industrial enterprises, etc., even if the degree of environmental regulation changes, it is difficult to reduce the pollution from the industrial side, so the impact of the degree of environmental regulation on environmental pollution is weak.

The degree of environmental regulation has different effects on environmental pollution in different situations. When the environmental pollution is weak or serious, the weak implementation degree of environmental pollution has the strongest impact on the environmental pollution. When the environmental pollution is medium, the strong environmental pollution executive degree has the strongest influence on the environmental pollution. When the environmental pollution is weak, the environmental treatment has achieved a certain effect, so it is difficult to play a greater effect of pollution control and emission reduction. However, when environmental pollution is serious, environmental pollution has been finalized,

Table 7　The impact of environmental regulations on environmental pollution based on different pollution scenarios

Variable	EP = L			EP = M			EP = X		
	W1 (1)	W2 (2)	W3 (3)	W1 (4)	W2 (5)	W3 (6)	W1 (7)	W2 (8)	W3 (9)
ER (DL = 1)	− 0.13*** (3.53)	− 0.11*** (− 5.06)	− 0.09*** (− 4.29)	− 0.16*** (− 6.51)	− 0.11 (− 0.49)	− 0.10 (− 0.54)	− 0.24*** (− 2.95)	− 0.05 (− 0.79)	− 0.10 (− 1.63)
ER (DM = 1)	− 0.07** (− 2.52)	− 0.02 (− 1.05)	0.00 (− 0.01)	− 0.11*** (− 5.49)	− 0.12*** (− 2.58)	− 0.07* (− 1.75)	− 0.20*** (− 5.33)	− 0.19*** (− 6.48)	− 0.19*** (− 6.28)
ER (DX = 1)	− 0.04 (− 1.39)	− 0.10*** (− 4.00)	− 0.09*** (− 3.65)	− 0.18*** (− 4.38)	− 0.25*** (− 3.56)	− 0.17** (− 2.45)	0.00 (0.04)	− 0.21*** (− 3.58)	− 0.15*** (− 2.62)
W × ER (DL = 1)	− 0.09 (− 1.02)	0.09 (1.37)	− 0.01 (− 0.05)	− 0.24*** (− 5.28)	− 2.31 (− 0.94)	19.31*** (4.17)	− 0.01 (− 0.07)	0.02 (0.12)	− 0.88 (− 0.96)
W × ER (DM = 1)	− 0.08 (− 1.20)	− 0.05 (− 0.72)	0.37 (1.61)	− 0.20*** (− 5.02)	− 0.12 (− 0.74)	− 0.54 (− 1.18)	− 0.28*** (− 3.15)	− 0.39*** (− 4.29)	− 0.75*** (− 2.88)
W × ER (DX = 1)	− 0.09 (− 1.07)	− 0.01 (− 0.11)	− 0.38 (− 1.60)	− 0.27*** (− 3.11)	− 0.02 (− 0.11)	− 3.95*** (− 2.69)	0.32** (2.10)	− 0.39 (− 1.50)	− 1.40* (− 1.69)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.85	0.85	0.86	0.86	0.85	0.85	0.85	0.85	0.85
Log-L	− 1771.16	− 1814.62	− 1773.15	− 1725.27	− 1824.03	− 1772.89	− 1762.53	− 1795.33	− 1761.16

*Indicates significant at the 10% level

**Indicates significant at the 5% level

***Indicates significant at the 1% level
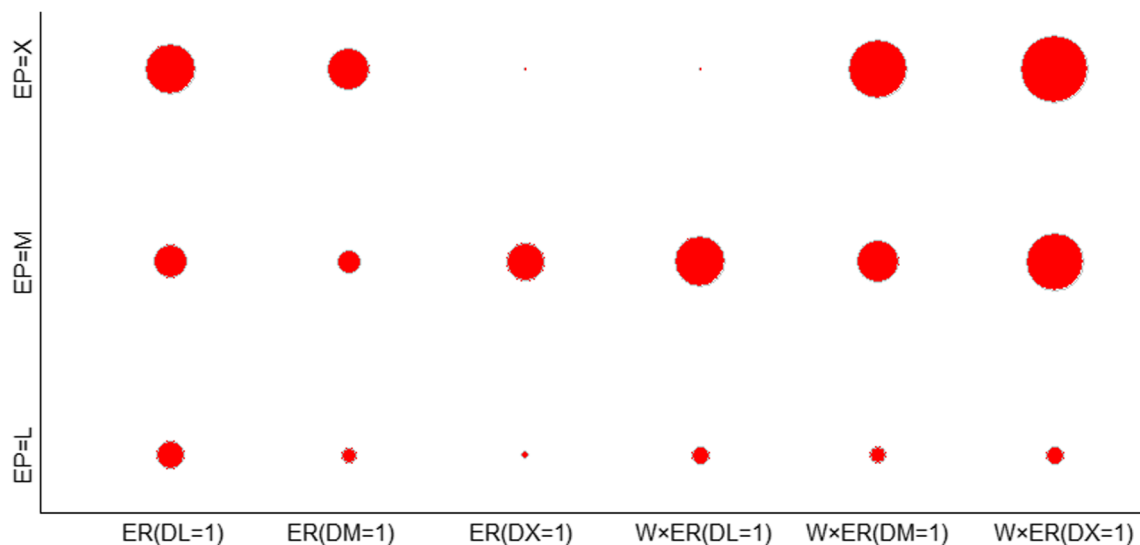
Fig. 3 The impact of environmental regulations on environmental pollution based on different pollution scenarios. The circumference of the circle represents the intensity of environmental regulation's impact on environmental pollution

and environmental regulation policies cannot achieve good results. On the contrary, weak environmental regulation can effectively control pollution and reduce emissions, and gradually alleviate environmental pollution. At the same time, this conclusion can prove that Pollution Paradise exists in cities with severe environmental pollution, since the environmental pollution degree is compared with that of neighboring cities.

The pollution paradise exists under special circumstances. Some scholars found the existence of the Pollution Paradise by studying various regions, while this paper found the existence of the Pollution Paradise in some situations by studying the spatial relations of different scenarios. The existence judgment of environmental refugees is mainly based on the impact of environmental regulations on the environmental pollution of neighboring cities. If the impact intensity is positive, it indicates that the environmental regulation of neighboring cities enhances the environmental pollution degree of the city, leading to the city becoming the pollution shelter of neighboring cities. According to the results in Table 7, five Pollution Paradises are identified in this part, namely, when the environmental pollution degree is weak, the area with the weak degree of environmental regulation becomes the environmental refugees in the area with a close economic level ($EP = L$, $ER = DL$, $W2$). The area with a medium degree of environmental regulation becomes the environmental refuge of the nearby area ($EP = L$, $ER = DM$, $W3$). When the degree of environmental pollution is moderate, the area with a weak degree of environmental regulation becomes the environmental refuge of the nearby area ($EP = M$, $ER = DL$, $W3$). When the degree of environmental pollution is serious, the area with a weak degree of environmental regulation becomes the environmental refuge of the area with a close economic level ($EP = X$, $ER = DL$, $W2$). Areas with a strong degree of

environmental regulation become environmental refugees in neighboring areas ($EP = X$, $ER = DX$, $W1$).

Robustness test

To increase the robustness of the conclusion, the conclusion excluding the interactive mechanism of environmental regulation implementation is affected by the artificial setting or omission of variables. We refer to Zhang and Zhao 2012 and Shen et al. (2017), industrial sulfur dioxide removal rate (rpercent_s) and industrial smoke (powder) dust removal rate (rpercent_d) were used to represent the degree of environmental regulation for the robustness test. The spatial weight matrix adopts the commonly used geographic proximity matrix. If the interactive mechanism of environmental regulation implementation is not disturbed by the missing variables, the estimated coefficient of environmental regulation in adjacent cities should also be significantly positive when the explained variables are industrial sulfur dioxide removal rate and industrial smoke (powder) dust removal rate.

Table 8 reports the results of the robustness test. Where column (1) is the estimation result with the removal rate of industrial sulfur dioxide as the explained variable, and column (2) is the estimation result with the removal rate of industrial smoke (powder) as the explained variable. It can be found that the results in Table 8 are consistent with those in Table 5. Regardless of the situation of environmental regulation in neighboring cities, the environmental regulation in neighboring cities has a significant positive impact on the environmental regulation in the central region, which effectively supports the interactive mechanism of environmental regulation implementation in the form of the race-to-the-top.

Table 8 Robustness test of environmental regulation implementation interaction mechanism

Variable	rpercent_s (1)	rpercent_d (2)
$W \times ER$ ($D_{it} = 1, I_{it} = 1$)	0.93*** (56.93)	0.95*** (20.86)
$W \times ER$ ($D_{it} = 1, I_{it} = 0$)	0.94*** (58.70)	0.97*** (24.03)
$W \times ER$ ($D_{it} = 0, I_{it} = 1$)	0.98*** (159.98)	1.00*** (207.70)
$W \times ER$ ($D_{it} = 0, I_{it} = 0$)	0.98*** (139.11)	1.00*** (111.27)
Control variable	Yes	Yes
Regional fixed effect	Yes	Yes
Time fixed effect	Yes	Yes
R^2	0.960	0.960
Log-L	− 656.32	4160.08

*Indicates significant at the 10% level

**Indicates significant at the 5% level

***Indicates significant at the 1% level

Endogenic treatment

To solve the endogenous problem of environmental regulation, this paper takes the degree of environmental regulation of last year as the instrumental variable of environmental regulation. We tested the relationship between the two variables and found that the degree of environmental regulation of the last phase and the degree of environmental regulation of the current period showed a positive relationship at the 1% significant level, with a correlation coefficient of 0.47. Because the degree of environmental regulation in the last period affects the environmental pollution in the current period by influencing the degree of environmental regulation in the current period, there is no other mechanism between the degree of environmental regulation of the last phase and the environmental pollution of the current phase. Therefore, the degree of environmental regulation of the last stage, as an instrumental variable of environmental regulation, is exogenous.

Table 9 reports the impact of the degree of environmental regulation of the previous year as the instrumental variable of the degree of environmental regulation on environmental pollution. The results are consistent with those in Table 6; the influence of environmental regulation on environmental pollution was not affected by the change of environmental regulation variables, which indicated that environmental regulation effectively suppressed environmental pollution. It indicates that the above research conclusion on the relationship between environmental regulation and environmental pollution is not affected by the reverse causal relationship between environmental regulation and pollutant emission, which again verifies the accuracy of the above conclusion.

Conclusions and recommendations

In the context of increasingly serious environmental pollution, it is difficult to sustain the traditional economic growth model that relies on resource consumption. Therefore, it is particularly critical to adjust the economic structure, speed up the economic transformation, and realize the green economic development model of *We want both golden, silver hill and clean water, green mountains as well*. For a long time, although the central government has been constantly improving the environmental laws and regulations, the strategic interaction of local governments in the implementation of environmental regulations often leads to unsatisfactory environmental governance effects. Therefore, the understanding and understanding of the interaction of local government's implementation of environmental regulation is not only related to the reasonable design of local government's environmental governance structure, but also related to the smooth transition of the economy to a higher quality growth track. This paper, by establishing a spatial econometrics model of two-district system and based on three spatial weight matrices of geographical proximity, economic proximity, and distance proximity, analyzes the interactive mechanism of environmental regulation enforcement and its heterogeneous impact on environmental pollution in 284 prefecture-level cities in China from 2005 to 2016.

This paper first provides empirical evidence of local governments' participation in different forms of environmental regulation enforcement interaction. Specifically, the strategic interaction of environmental regulation enforcement between Chinese cities is *race-to-the-top*. The degree of enforcement of environmental regulation exists game interaction between cities. Regardless of the environmental regulation degree of neighboring cities (low or high degree of environmental regulation, enhanced or reduced degree of environmental regulation), the impact on the environmental regulation degree of central cities is significantly positive, and the interaction intensity of environmental regulation enforcement between cities of the same economic level is the strongest. On the basis of this, this paper further examines the influence of the heterogeneity of local government environmental regulation on environmental pollution. It finds that the influence of environmental regulation on environmental pollution is nonlinear. When the degree of environmental regulation is the weakest, the impact of environmental regulation on environmental pollution is the weakest. However, when the degree of environmental regulation is strong, the impact of environmental regulation on environmental pollution does not increase with the enhancement of environmental regulation. At the same time, the spillover path of environmental regulation on environmental pollution varies with the degree of environmental regulation. Finally, through scenario analysis, this paper analyzes the impact of environmental regulations on environmental

Table 9 Results of environmental regulation on endogenous treatment of environmental pollution

Variable	W1 (1)	W2 (2)	W3 (3)	W1 (4)	W2 (5)	W3 (6)
ER	− 0.07***	− 0.08***	− 0.07***			
	(− 5.06)	(− 5.82)	(− 4.79)			
ER (DL = 1)				− 0.07***	− 0.05**	− 0.04**
				(− 3.10)	(− 2.38)	(− 2.20)
ER (DM = 1)				− 0.10***	− 0.07***	− 0.05***
				(− 5.44)	(− 3.55)	(− 2.72)
ER (DX = 1)				− 0.08***	− 0.15***	− 0.13***
				(− 3.09)	(− 6.67)	(− 5.59)
W × ER	− 0.14***	− 0.09**	− 0.36***			
	(− 5.22)	(− 2.42)	(− 3.33)			
W × ER (DL = 1)				− 0.11***	0.10	0.08
				(− 2.64)	(1.56)	(0.36)
W × ER (DM = 1)				− 0.16***	− 0.23***	− 0.46***
				(− 4.60)	(− 3.92)	(− 2.90)
W × ER (DX = 1)				− 0.09	− 0.11*	− 0.49**
				(− 1.58)	(− 1.71)	(− 2.45)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Regional fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.86	0.85	0.85	0.86	0.85	0.85
Log-L	− 1615.94	− 1664.45	− 1630.80	− 1609.87	− 1648.95	− 1621.77

*Indicates significant at the 10% level

**Indicates significant at the 5% level

***Indicates significant at the 1% level

pollution under different levels of environmental pollution, and finds that environmental shelters exist under special circumstances, and this paper identifies 5 types of environmental shelters.

As a policy suggestion, we believe that further optimizing the environmental governance structure of local governments is a key content to be considered in the top-level design for realizing the transformation of economic development mode. To be specific, firstly, we should establish pilot cities for pollution control and emission reduction, focusing on cities with different levels of economic development, increase the degree of environmental regulation in the pilot cities, and build the pilot cities into regions with higher degree of environmental regulation. Secondly, to strengthen targeted supervision and adaptive incentives for the implementation of environmental regulations by local governments, in particular, to make the cities with neighboring economies reach a consensus on collaborative regulation, so as to maximize the Porter effect. After more than 30 years of rapid economic growth, China's current economic growth is facing the risk of lack of motivation and potential. It is increasingly important for China's long-term sustainable economic growth to fully exploit the role of environmental regulation in promoting enterprise productivity. Thirdly, the implementation of pollution control and emission reduction policies should be strengthened in regions with low environmental regulation level, so as to prevent regions with low environmental regulation level from becoming pollution paradise or environmental refuge for other regions.

Environmental regulation is one of the main policy measures of the pollution reduction, and how to adjust the environmental regulation, and make environmental regulation more effective to suppress the environmental pollution is the most important problem of the government's door. And the intensity of environmental regulation policy or implementation of the region's economic development level and achievement. So, the study of environmental regulation implement interactive mechanism not only can enhance the inhibition degree of pollution of the environment, but also help the local government department, scientific and reasonable adjustment of environmental regulation in the region. However, due to the differences in regional economic levels and environmental pollution levels, it is impossible to accurately measure the interactive intensity of environmental regulation implementation between each region and neighboring regions. Therefore, it is necessary to study the interaction of environmental regulation execution between regions more accurately, to provide a marginal reference for the central government to adjust the implementation degree of regional environmental regulation.

This paper discusses the interactive mechanism of environmental regulation implementation and its impact on environmental pollution from two aspects: the degree of environmental regulation and the degree of environmental pollution. In the later stage, the main research work is to build a dynamic system of the implementation degree of intergovernmental environmental regulation, to serve the government's policy implementation degree adjustment in dealing with environmental issues, and to provide a marginal reference for the central government to make overall plans for China's economic construction and environmental pollution control.

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