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Original Research

Does Public Participation Reduce Regional Carbon Emissions? A Quasi-Natural Experiment from Environmental Information Disclosure in China

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Abstract

Informal environmental regulation, represented by public participation, has an increasingly significant role in environmental governance. This paper utilizes panel data of 285 cities in China from 2003 to 2017. It examines the difference-in-differences (DID) and instrumental variable method (IV) to investigate the causal effect of public participation represented by Environmental Non-Governmental Organizations(ENGOs) on regional carbon emissions. The empirical results show that public participation reduces regional carbon emissions, which still holds after a series of endogeneity and robustness tests. This paper proves an inverted U-shaped nonlinear relationship between the intensity of public participation and regional carbon emissions. Furthermore, this paper demonstrates that regional green technology innovation and strengthening formal environmental regulations are the primary mechanisms for public involvement in promoting regional carbon emission reduction. Finally, this paper discusses the heterogeneity governance effect among cities and finds that the governance effect of the sample is more pronounced in eastern cities, non-resource-based cities, large cities, and provincial capitals. The results reveal the importance of public participation in regional carbon emission reduction and provide an empirical basis for promoting informal environmental regulation.

Keywords: public participation, carbon emissions, environmental information disclosure, difference-in-differences, instrumental variable

Introduction

Global warming has attracted worldwide attention, and greenhouse gas emissions such as CO2 are the leading cause of climate warming [1]. Excessive emissions of CO2 exacerbate climate change and impede sustainable economic development. Along with ecological degradation, numerous developing countries have been awakened to the necessity to reduce emissions [2]. The extensive economic development model for many years has resulted in severe environmental pollution and ecological damage to China [3], and China has become the world's major emitter of greenhouse

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gases. Faced with the pressure to reduce CO2 emissions and achieve high-quality ecological development, China has developed and implemented a range of environmental policies from the 1970s onward [4] and has pledged to reduce the intensity of CO_2 emissions at international conferences on several occasions [5].

Having adopted environmental governance, many countries worldwide have implemented environmental regulations [6-7]. Binding environmental regulations are more inclined to mandatory policies of decrees and regulations, requiring stakeholders to comply strictly [8]. Market-based environmental regulations involve using market instruments such as environmental taxes and emissions trading to act on regional environmental performance and indirectly improve environmental quality through economic incentives to increase the financial costs paid by polluters [9]. Informal environmental regulations, also known as voluntary environmental regulation, include information disclosure, environmental agreements, public participation, and environmental education [10]. Formal environmental regulation has a positive effect, represented by the carbon emission trading market pilot policy and the low-carbon city pilot policy on reducing regional carbon emissions [11-12]. Nevertheless, the effectiveness of formal environmental regulations depends to a large extent on the enforcement efforts of regional administrations, and there may be lax enforcement in concrete implementation [2]. Formal environmental regulations have high regulatory costs, and excessive environmental regulations have negative socioeconomic impacts [13-14]. Environmental governance, including regional carbon emission reduction, increasingly needs the power of informal environmental regulation, whose promotion of environmental management has been recognized by many scholars from different countries [15-17]. In recent years, environmental organizations and other interested parties have become increasingly involved in local environmental monitoring [18]. There are relatively few studies on the contribution of informal environmental regulation to the reduction of regional carbon emissions, such as Molthan et al. [19] which examines environmental education and Motoshita et al. [20] from the standpoint of carbon information disclosure. This paper will try to supplement the gap in this field with an analysis of public participation.

Public participation provides legitimacy for the expression of citizens' demands and the rectification of government actions and, to a certain extent, strengthens the effect of formal environmental regulation. Existing studies show that complaints from the public remind the government of the problems existing in the process of policy implementation [21]. Because the public is directly in contact with the environment, the public tends to be more aware of some of the most immediate environmental information, which may be more authentic than the government [22]. At the same time, public participation can significantly improve the shortcomings of inadequate government supervision. Theoretically, as one aspect of informal environmental regulation, public participation promotes regional environmental efficiency and green development mainly through pressure transmission [15, 23-25]. Specifically, the government is pleased to heed the public's voice on the environment. It has established corresponding rules and regulations to prevent environmental pollution and maintain social stability for legitimacy.

The possible marginal contributions of this paper are as follows: (1) This study uses regional carbon emissions as an entry point to enrich the environmental governance effects of public participation at the prefecture level. (2) This study finds that internet penetration rate and regional humidity can be good instrumental variables, and obtains more reliable empirical results, supplementing existing studies and providing new ideas. (3) This study discusses the heterogeneity of the carbon reduction effect of public participation from the aspects of geographic location, resource endowment, city size and city level, which enriches the existing research and provides a new perspective. (4) This study finds that strengthening formal environmental regulation and promoting green technology innovation are effective transmission channels for public participation in achieving carbon reduction, which provides evidence for further promotion of public participation. (5) This study verifies the non-linear relationship between public participation and regional carbon emissions, which provides assistance for further promotion of public participation.

The remainder of this paper is organized as follows. Section 2 reviews the literature in related fields. Section 3 introduces the identification strategies, data, and variables used in the research. Section 4 presents the empirical results and associated tests, followed by further analysis in Section 5. Section 6 summarizes the thesis and proposes relevant policy implications.

Literature Review and Hypothesis

Environmental Regulation and Carbon Emissions

Previous studies on formal environmental regulation and regional carbon emissions can be summarized into three perspectives: inhibition theory, promotion theory, and complex relationship theory. First, formal environmental regulation has a carbon reduction effect. Formal environmental regulations have a proactive role in reducing regional carbon emissions through the official nature of government implementation, such as imperative environmental regulations represented by low-carbon city pilot policies and market-based environmental regulations represented by carbon trading pilot policies [11-12]. Second, formal environmental regulation promotes regional carbon emissions. Due to the differences in social and economic development between regions, the policy effects of environmental regulations will be disconnected, potentially increasing regional carbon emissions [26]. Third, there is a more complex relationship between the two. Zhang et al. [27] find an inverted U-shape between environmental regulations and regional carbon emissions utilizing panel data at the provincial level in China, with similar findings at the prefectural level when the sample is further down-scaled [28]. The inverted N-shaped nonlinear relationship has been further confirmed by some scholars on this basis [14].

Informal environmental regulations include public supervision, environmental organization supervision, environmental education, and information disclosure. There are mainly two viewpoints of inhibition and irrelevance. First, informal environmental regulation will effectively reduce regional carbon emissions. Public participation plays a significant role in city governance, improving government governance capacity, increasing government credibility and promoting low-carbon city construction [29]. Compared with the individual involvement, environmental organization participation has a broader horizontal network and may have a more substantial social influence [30]. Based on the PITI list, Zhang et al. [16] demonstrated that environmental information disclosure promotes environmental efficiency, including industrial CO2. Their findings partially explain the carbon reduction effect of environmental information disclosure. People generally are psychologically distant from climate change; the efforts of educators can reduce this distance and promote environmental protection behavior [31]. A survey of engineering students in the United States also confirmed the potential role of environmental education in promoting regional carbon emission reduction [32]. Consumer carbon information disclosure from Japan shows that responsibility awareness and willingness to act will encourage consumers to engage in low-carbon consumption behaviors stimulated by information disclosure [20]. Additionally, some scholars have argued that informal environmental regulations do not have carbon reduction effects. Bali et al. [33] explored the impact of a series of governance behaviors of informal government organizations in 58 countries on global and local pollutants from 1996 to 2011. They found that the governance behaviors of informal government organizations had no significant impact on global pollutants such as carbon emissions and per capita carbon emissions.

Environmental Performance of Public Participation

Thanks to the increasing development of information technology, public participation in environmental governance are now unprecedented and convenient. The public's concern about environmental issues will help decision-makers carry out environmental governance [34]. There is an excellent interactive relationship between public participation and government governance, which plays a positive role in environmental governance [35]. The PITI report was released by IPE, a well-known environmental organization, as the participation of environmental organizations can effectively reduce pollutant emissions [36]. After considering the addition of 7 cities in 2013, this conclusion still holds [16, 37]. The most feasible approaches for public participation involve curbing pollutant emissions and improving environmental technology efficiency [38]. Reducing energy consumption is the main path to achieving pollution control, and public participation can improve energy-use efficiency by reducing total energy consumption [39]. In addition, public participation may stimulate regional green technology innovation [40]. Unlike macro-level research, micro-level research proves that public participation in environmental supervision will not increase the export scale of industrial enterprises [41].

Currently, China's promotion mechanism not only considers the evaluation of the central government but also directly accepts the supervision and evaluation of the local public. As the ecological environment is a typical public good, local governments have weak incentives for environmental protection. Public participation can effectively compensate for the limited incentives and lack of supervision in the central-local relationship, prompting local governments to make a difference in environmental affairs. Along with the development of internet technology, public opinion is playing an increasingly significant role. Concealment and false reporting by local governments will result in severe political problems and even result in officials' resignation. For this reason, local governments with a solid willingness to promote environmental protection will be more inclined to widely absorb public opinion and cultivate their responsible image and public trust by actively engaging in communication and feedback activities. Extensive environmental information disclosure is a manifestation of the government's environmental responsibility, which reflects that local governments are more active in dealing with environmental issues and can also improve the public's right to know about the environment, thereby promoting the level of local public participation [42].

Public Pressure and Environmental Governance Efficiency

The public's pressure to achieve an excellent ecological environment often affects the efficiency of local environmental governance. From the "environmental Kuznets curve", it can be seen that economic development and environmental pollution are positively correlated at the low stage of economic growth. As income levels rise, this relationship gradually changes to a negative one. In pursuing economic development, the public and the government often adopt "flexible" attitudes and measures regarding environmental pollution in pursuit of economic development. With the increase in income, the public's demand gradually shifted from focusing only on economic growth to the promotion of ecological quality and began to require the government to control pollution and reduce emissions from manufacturing entities. Therefore, the government implemented environmental regulations. According to the "Porter Hypothesis," appropriate environmental regulation can promote enterprise innovation to reduce emissions and achieve green production. Under public pressure, the emission of pollutants will be diminished, and the efficiency of the government's ecological and environmental governance will be improved. The dynamic change in pressure is the critical node and core mechanism of the nonlinear influence of environmental performance. In summary, the first hypothesis is proposed in this paper:

H1a: Public participation reduces regional carbon emissions.

H1b: The effect of public participation on carbon emissions is nonlinear

Relevant Mechanisms for Public Participation

Green technology innovation is built on the concept of environment-friendly innovation [43]. The Porter hypothesis suggests a "win-win" for both the environment and the economy. Environmental regulations will directly increase the operating costs of enterprises and indirectly reduce their production income [44]. Under such economic pressure, enterprises will try to offset the losses brought by environmental regulation through innovation and improve their competitiveness, which has been verified in different types of environmental regulation [44-45]. For their social legitimacy and sustainable profits, enterprises will also care more about public recognition, especially pollution-intensive enterprises with a more positive attitude toward this issue [46]. Therefore, the second hypothesis is proposed in this paper:

H2: Public participation reduces regional carbon emissions by promoting green technology innovation.

The implementation of formal environmental regulations has the problems of lax enforcement [2] and excessive costs [13-14]. The public requires an excellent ecological environment, and its governance costs urgently need large amounts of financial expenditure. Therefore, local governments will suffer from a sense of environmental urgency and a significant lack of financial resources, which will induce deviation in environmental governance. Due to the particular promotion mechanism of the Chinese government, the priority of economic growth in political performance is much higher than that of environmental protection [47]. Driven by the pressure of performance, local governments often fail to thoroughly implement the environmental supervision tasks of the central government [38, 48]. Additionally, the pressure of competition prompts local governments to worry about falling behind the surrounding jurisdictions. Considering its performance, provincial governments will choose to pursue "flexibility" and relax environmental regulations, turning a blind eye to some polluters. A selection process affects the strength of its environmental regulations. Informal environmental regulations draw on forces other than the government, and the diverse environmental governance system considers the common interests of different subjects and improves environmental governance capabilities [35]. Informal environmental regulation lacks the official nature of government implementation and has a time lag in its impact on environmental performance [49]. To cultivate a responsible image and public trust, the government will widely listen to the public's environmental responsibility, so formal environmental regulation is also significantly influenced by informal environmental regulation [50]. Many previous studies have discussed formal environmental regulation in contrast to informal environmental regulation, including public participation [35, 51], environmental organizations [30], and community organizations [50]. As a typical environmental public good, the carbon emission environment is noncompetitive and nonexclusive. Due to the existence of nonexclusivity, the general environmental interest cannot simply rely on market mechanisms to achieve the result of effective regulation. As the manager of public goods and the provider of public services, the central government is responsible for formulating environmental laws and regulations and safeguarding public environmental interests. However, the drawbacks of formal environmental regulations make public participation play a supplementary role in environmental regulation. Public participation may strengthen the effect of formal environmental regulation to a certain extent. Thus, this paper proposes a third hypothesis:

H3: Public participation reduces regional carbon emissions by strengthening the policy effect of regional formal environmental regulations.

Experimental

Policy Background

China is late in environmental information disclosure at the legal level. The Environmental Information Disclosure Measures and the Government Information Disclosure Regulations, implemented simultaneously in 2008, marked the beginning of the environmental information disclosure system. Given the broader social reach of environmental organizations [30], their assessment of the level of environmental information disclosure provides the basis for public participation in environmental monitoring. Among them, the most representative is the PITI report released by The Institute of Public and Environmental Affairs (IPE) and The Natural Resources Defense Council (NRDC) in 2008, which is continuously updated. This paper takes the PITI list as a homogeneous impact to examine the effects of public participation on regional carbon emissions. The PITI list can be divided into two stages: in the first stage, from 2008 to 2012, the environmental information disclosure level of 113 cities was evaluated; and in the second stage, from 2013, the environmental information of 120 cities was assessed.

Model Construction

In previous studies, DID has been considered the best method for quasi-natural experiments [52-53]. The experiment included two time periods, "before" and "after", and two sample groups, "treatment group" and "control group". The incremental outcomes of the policy interventions were obtained through two within-group and between-group differentials. The two-way fixed effects DID method (TWFEDID) contains more individual and time information which obtains a more realistic policy effect [54].

Since the list of cities in 2013 increased from 113 to 7 cities (Zhenjiang, Sanmenxia, Zigong, Deyang, Nanchong, Yuxi, Weinan), a total of 120 cities have been identified. Therefore, a staggered DID is adopted for inspection [16, 38]. Among them, the cities on the list are the experimental group, and the cities not on the list are the control group. The effect of public participation on carbon emissions is examined by comparing different groups. The specific model settings are as follows:

$$Carbon_{it} = \beta_0 + \beta_1 did_{it} + \beta_2 Control_{it} + \delta_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where subscripts i and t indicate the region and year, respectively. The dependent variable $Carbon_{it}$ is the regional carbon emissions. DID_{it} is the core explanatory variable: $DID_{it} = treat_{it} \times time_{it}$. $treat_{it}$ represents whether the city is an experimental group. If a city was in the PITI list, the value of the variable $treat_{it}$ is 1; otherwise, its value is 0. $time_{it}$ represents the policy implementation time. The 113 cities on the list from 2008 to 2012 are set as 1 after 2008, and 7 cities added in 2013 are set as 1 after 2013; otherwise, they are

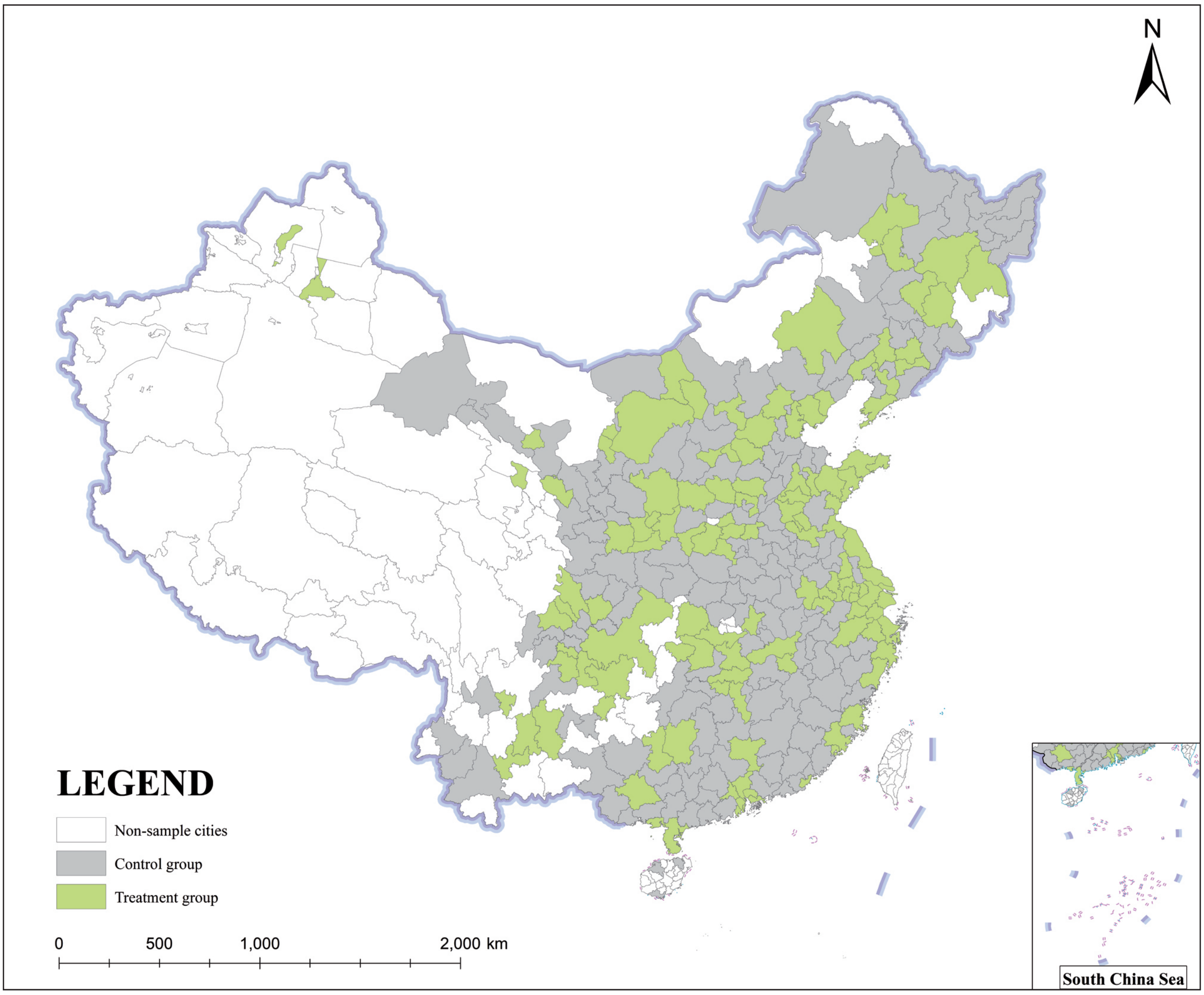

Fig. 1. Spatial distribution of PITI and non-PITI cities.

designated as 0. $Control_{it}$ represents the control variables that affect carbon emissions and change with i and t. δ_t represents the city fixed effect, and γ_t represents the time fixed effect, which controls the factors that affect all samples. ε_{it} is the stochastic disturbance term.

Variables and Data

Variable Description

Dependent variable and core explanatory variable: The dependent variable in this paper is regional carbon emissions, which are in the form of a natural logarithm. The core explanatory variable is whether the public participates in environmental supervision.

Control variable. According to the literature [16, 36, 38], control variables include the ratio of financial institution loans (*InFin*) [55-57], the industrial structure index (*Inindus*) [58-60], the ratio of technology expenditure (*Insci*) [61-62], population density (*Inpeople)* [63-64], the ratio of FDI (*InFDI*) [65-67], the ratio of financial expenditure (*InFIN*) [68-69], and GDP per capita (*InperGDP*) [70-72]. These variables reflect the level of social and economic development and pollution emissions. The selection of control variables is based on the literature, mainly considering the relevance of carbon emissions and public participation, to reduce the problem of omitted variables as much as possible. For specific explanations, see Table 1.

Other variables. Referring to Li et al. [36]) and Tu et al. [38], this paper introduces the capital-labor ratio (*InCLR*) as a characteristic variable of a city, measured by the natural logarithm of the percentage of regional fixed-asset investment to employment to assist empirical testing. To make the regression results more intuitive, the PITI-specific score (*score*) is reduced by 100 times.

Data Description

This paper utilizes panel data from 285 cities in China from 2003 to 2017 to evaluate regional public participation's carbon emission reduction effect. PITI data are extracted from the annual report of PITI on the IPE website. Carbon emission data come from CEAD [73]. Most of the carbon emission data used in previous related studies are calculated based on energy consumption data. The estimated carbon emission data may have significant errors and may be discontinuous due to the lack of energy data [16]. Chen et al. [73] used satellite data to fit data and nighttime light data to invert carbon emissions from 1997 to 2017. Due to the limitation of control variables, study's time scale was 2003-2017. The city average relative humidity is from the China Meteorological Network, the green patent data of prefecture-level cities is from The State Intellectual Property Office, and the other variables are from The Statistical Yearbook of Chinese Cities and The Statistical Yearbook of China over the years. Table 2 reports the main variables used in the study.

Table 1. Main variables and the associated definitions.

Variable	Definition
Dependent variable	
Carbon	Measured by the natural logarithm of regional carbon emissions.
Independent variables	
did	Determine whether the public in a region participates in environmental supervision, public is 1, otherwise it is 0.
Mediating variable	
Green	Measured by the number of green patent applications as a proportion of regional patent applications.
$InSO_2$	Ratio of regional SO_2 emissions to GDP.
Control variables	
InFin	Measured by the natural logarithm of the ratio of outstanding loans to GDP of regional financial institutions at the end of the year.
Inindus	The calculation formula is: 1×(the ratio of the primary industry to GDP) + 2×(the ratio of the secondary industry to GDP) + 3×(the ratio of the tertiary industry to GDP).
Insci	Measured by the natural logarithm of the ratio of regional science and technology expenditure to GDP.
Inpeople	Measured by the natural logarithm of the ratio of the total population of the region to the area of the administrative region.
InFDI	Measured by the natural logarithm of the ratio of the region's actual use of foreign capital to GDP in that year.
InFIN	Measured by the natural logarithm of the ratio of regional general budget fiscal expenditure to GDP.
InperGDP	Measured by the natural logarithm of the ratio of GDP to the regional household population at the end of the year.

Table 2. Descriptive Statistics.

VARIABLES	N	mean	sd	min	max
Carbon	4,240	2.893	0.815	0.425	5.441
did	4,240	0.275	0.446	0	1
InFin	4,128	-2.442	3.985	-10.83	2.185
Inindus	4,137	5.460	0.0626	4.604	5.635
Insci	4,137	9.084	3.876	-0.665	14.47
Inpeople	4,158	-3.485	0.915	-7.663	-0.250
InFDI	3,644	-8.566	4.331	-24.46	-3.092
InFIN	4,141	-4.492	3.965	-12.55	0.261
InperGDP	4,141	12.96	4.478	7.518	22.37
InCLR	3,753	2.080	0.781	-1.390	4.253
Green	4,035	0.103	0.0541	0	1
sd	4,240	45.43	33.45	0	88.35
hlw	4,135	4.859	4.896	0	17.76
InSO2	4,063	-2.135	4.466	-19.12	4.091
score	1,052	0.420	0.166	0.0830	0.853
score2	1,052	0.204	0.148	0.00689	0.728

Results and Discussion

Baseline Results

Table 3 presents the results of the baseline regression. Column (1) is the preliminary regression result without adding control variables. The coefficient of the interaction term is statistically significant at the 1% level (Coef. = -0.039, P-value = 0.015), indicating that public participation in environmental supervision can effectively reduce regional carbon emissions. Furthermore, to alleviate the possible problem of omitted variables, the coefficient of the interaction term increased after control variables at the regional level were added to the model. Nevertheless, the coefficient sign remained unchanged and significant (Coef. = -0.025, P-value = 0.077). The above results show that public participation will effectively reduce regional carbon emissions compared to cities not on the list. This conclusion strongly indicates that public participation is an effective means to achieve the target of "carbon peak" and "carbon neutrality" at the present stage. Thus, H1a is established. The coefficient is small compared to the previous formal environmental regulation literature [11, 28]. It is also easy to understand that public participation lacks the organizational rigor and mandatory nature of government regulations, so it cannot be close to formal environmental regulations regarding the governance effect. However, public participation and formal environmental regulations have thriving interactions, which positively affect environmental governance [35]. The baseline regression results in this paper are similar to the results of previous related literature. Public participation can reduce not only the emission of pollutants such as SO_2 [16], but also the regional carbon emission. This indicates that the environmental performance of public participation is widely available.

Differences in individual characteristics, such as the degree of economic and openness among cities within the sample, may influence their trends over time, leading to bias in the estimation results. With reference to previous studies [16, 36], this paper further uses the generalized PSM-DID for testing, limiting the sample and providing unbiased effect estimates with efficient and appropriate matching. In this paper, *Inpeople*, *InFDI* and *InCLR* are used as city characteristic variables, and the nearest neighbor matching method (1:4), caliper matching method, and kernel matching method are used for propensity score matching. Then, the experimental and control groups are conducted with difference-in-differences based on the matched samples. The results in Columns (3) to (5) in Table 3. It can be seen that the interaction term is still significantly negative at the statistical level of 1% (Coef. = -0.020, P-value = 0.001; Coef. = -0.022, P-value = 0.000; Coef. = -0.022, P-value = 0.000), indicating robustness of our baseline results.

Table 3. Estimation results of the baseline regression.

VARIABLES	DID	DID	PSM-DID	PSM-DID	PSM-DID
did	-0.039**	-0.025*	-0.020***	-0.022***	-0.022***
	(-2.37)	(-1.77)	(-3.30)	(-3.66)	(-3.65)
InFin		0.048***	0.050***	0.052***	0.052***
		(3.66)	(7.66)	(8.41)	(8.42)
Inindus		-0.035	-0.084	-0.002	-0.001
		(-0.34)	(-1.20)	(-0.05)	(-0.02)
Insci		0.014***	0.015***	0.014***	0.014***
		(2.95)	(5.10)	(4.87)	(4.91)
Inpeople		0.118	0.248***	0.229***	0.229***
		(1.31)	(5.89)	(5.86)	(5.87)
InFDI		-0.005*	-0.003	-0.004**	-0.004**
		(-1.71)	(-1.49)	(-2.31)	(-2.35)
InFIN		0.033**	0.032***	0.034***	0.034***
		(2.48)	(4.07)	(4.68)	(4.65)
InperGDP		0.129***	0.133***	0.135***	0.135***
		(4.96)	(14.89)	(15.87)	(15.86)
Constant	2.294***	1.609**	2.279***	1.771***	1.764***
	(271.81)	(2.29)	(5.54)	(5.37)	(5.35)
Control	NO	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	4,263	3,625	2,971	3,265	3,266
R-squared	0.904	0.923	0.929	0.930	0.930

Note: The value in the brackets is T-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

Robustness Tests

Dynamic Time Windows and Counterfactual Checks

To improve the credibility of the results, this paper conducted the regression of the policy time points one year (Coef. = -0.023, P-value = 0.103), two years (Coef. = -0.017, P-value = 0.221), three years (Coef. = -0.014, P-value = 0.339), and four years (Coef. = -0.012, P-value = 0.328) in advance, the results of which are shown in Table 4. It can be found that none of the interaction terms constructed at the time point of advance policy are significant, which once again proves the carbon emission reduction effect of public participation.

Parallel Tend Test under the Multiperiod and Multi-Individual DID Methods.

One of the prerequisites for the validity of the DID estimation is that both the experimental and control groups need to satisfy the parallel trend assumption before being treated. The staggered DID model with two-way fixed effects assumes that the treatment of the sample is invariant, but such an assumption often does not hold in reality. To solve such problems, this paper adopts a multiperiod and multi-individual DIDM model to test whether the model conforms to the setting of the expected trend. The results are illustrated in Fig. 2.

From Fig. 2, the coefficients in the first five years of the policy all contain the vicinity of baseline 0, indicating that there is no significant difference between the experimental group and the control group before the policy point, which satisfies the assumption of a parallel trend and suggests that the staggered DID strategy adopted in this paper is effective. The coefficient in the year of policy implementation still includes the baseline 0, but it is significantly negative one year later. This indicates that there may be a certain time lag in the effect of the policy, which will not be reflected until one year later.

Table 4. Dynamic time windows and counterfactual checks.

VARIABLES	Carbon	Carbon	Carbon	Carbon
dt_1	-0.023			
	(-1.64)			
dt_2		-0.017		
		(-1.23)		
dt_3			-0.014	
			(-0.96)	
dt_4				-0.012
				(-0.98)
Control	YES	YES	YES	YES
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: The value in the brackets is T-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

Placebo Test

This paper randomly selected 120 treatment groups to avoid the biased effect of specific treatment groups on the regression results, and the random sampling process was repeated 500 times and 1,000 times. The results are shown in Figures 3. We find that both the P value and the coefficients are significantly different from the baseline regression results, indicating that the regression results in Table 3 are robust.

Replace the Dependent Variable

To avoid the selective mistake caused by the carbon emission calculation method and the time scale limitation of carbon emissions and improve the robustness of the conclusion, this paper adopts the robust approach of replacing the dependent variable. As the PITI list was only published until 2018, this paper adopted the 2006-2018 carbon emission data that Wu et al. [74] calculated and performed regression through Model (1). The results showed that the interaction term coefficient was still significantly negative (Coef. = -0.136, P-value = 0.001). Therefore, the results were still significant after carbon emission data from different estimation methods were used to avoid the error of specific estimation methods, proving the robustness of the above conclusions.

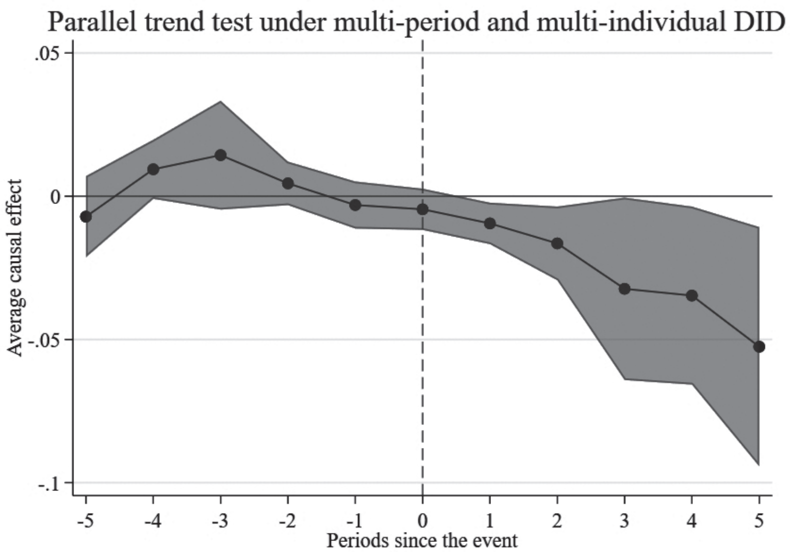

Fig. 2. Parallel trend test.

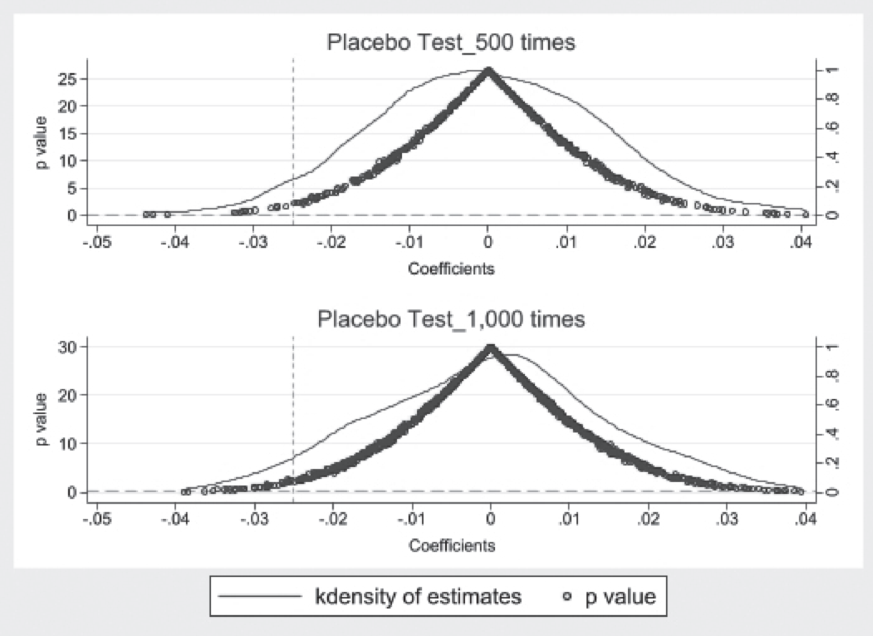

Fig. 3. Placebo testing for replacement cities.

Robustness Check Excluding Outliers

To exclude outliers, the dependent variable was winsorized to a win-win residual at the 1% level in both tails of its distribution and regressed by Model (1). Our conclusions above still hold at the 10% statistical level (Coef. = -0.026, P-value = 0.084).

Endogenous Test

Instrumental Variable Method

Existing studies on public participation mostly use proxy variables as measurements, but, limited by the acquisition of various indicators and measurement errors, it is easy to cause endogeneity problems. In the past, there have been studies to avoid mistakes through the impact of PITI, a homogeneous event. Nevertheless, IPE can choose cities to be included in the PITI list according to various environmental indicators of cities. For example, cities with higher pollutant emissions may attract more IPE attention. Therefore, we conclude that the experimental group cities have potential endogeneity problems caused by nonrandom selection. In this case, it is very important to select appropriate instrumental variables and use the IV method for estimation. As a booming emerging media, the internet has increasingly carried out the task of government information disclosure and provided convenience for public participation. The more accessible the internet is, the greater the possibility of public participation in environmental supervision [39, 75]. The natural attribute of environmental pollution makes it applicable to instrumental variables from natural factors. The environmental pollution of a region often affects the level of public participation in environmental supervision, such as temperature inversion [76], air flow coefficient [77], and wind direction [78].

Table 5. Estimation results of replacing the dependent variable and winsorize.

VARIABLES	new_Carbon	1% winsor
did	-0.136***	-0.026*
	(-3.42)	(-1.73)
Control	YES	YES
City FE	YES	YES
Year FE	YES	YES
Observations	2876	3,625
R-squared	0.530	0.918

Note: The value in the brackets is T-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

Here, we construct the number of internet broadband access subscribers by taking the logarithm and the average relative humidity with the interaction product of time (hlw × time and sd × time), respectively, as instrumental variables following Shi et al. [75] and Bu et al. [39]. On the one hand, the greater the number of broadband internet access users in an area, the greater the possibility of urban citizens monitoring the local environment on the internet, thus increasing the likelihood of being included in the PITI list, in which case, the relevance holds. On the other hand, the number of regional internet broadband access users will not significantly impact regional carbon emissions, and homogeneity is established. When the average humidity

Table 6. Estimation results of the IV method.

VARIABLES	First stage	Second stage	First stage	Second stage
	did	Carbon	did	new_Carbon
did		-0.0491***		-0.1209***
		(-4.22)		(-2.33)
hlw×time	0.1308***		0.1064***	
	(16.28)		(10.45)	
sd×time	-0.0093***		-0.0050***	
	(-6.25)		(-2.62)	
Control	YES	YES	YES	YES
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	3596	3596	2861	2861
R-squared		0.9229		0.531
First-stage test statistic of F	42.75		42.75	
K-P LM statistic		257.606***		123.410***
K-P Wald F statistic		207.451		203.971
Hansen J statistic		0.182		0.046

Note: The value in the brackets is T/Z-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

of a region is higher, the air pollution level of the area will be reduced because the high humidity will absorb and sink pollutants in the air, so the possibility of being included in the PITI city list will be lower, and relevance is established. In addition, there is no direct relationship between regional average relative humidity and regional carbon emissions, and homogeneity is established. Regressions were conducted on this set of instrumental variables; the results are presented in Table 6. In addition, the instrumental variables also passed the instrumental variable homogeneity test, the overidentification test, and the weak instrumental variable test.

Columns (1) and (2) of Table 6 show that the regressions between the instrumental variables and the core explanatory variable in the first stage are significant at the 1% statistical level, and relevance is established (Coef. = 0.131, P-value = 0.000; Coef = -0.009, P-value = 0.000) . In the second stage, the regression between the core explanatory variable and carbon emissions was also significantly negative at the statistical level of 1% (Coef. = -0.049, P-value = 0.000). The coefficient was close to the baseline regression coefficient in Table 3. In addition, the F values of the first and second stages are 42.75 and 257.606, respectively, which are much larger than 10, indicating that the instrumental variable selection passes the weak instrumental variable test. The Hansen test accepts the null hypothesis to prove that the set of instrumental variables is homogeneous. In conclusion, the regressions illustrate that our results remain robust after addressing the endogeneity problem of the model. This paper also estimates the dependent variables replaced by the instrumental variable method, and the results are shown in Columns (3) and (4). In the second stage of the regression, the coefficient is significantly negative, close to the coefficient in Table 5. The regression also passes the weak instrumental variable test, overidentification test, and homogeneity test, which further verifies the robustness of the model.

Treatment Effect Test

As cities with higher greenhouse gas and pollutant emissions may attract more attention from IPE, it can be considered that PITI cities are not randomly selected but endogenous, and there may be sample self-selection bias. This paper uses the interaction term of average relative humidity and time (sd×time) as a homogeneous variable. A treatment effect model is employed to reduce the estimation bias caused by sample self-selection. Table 7 reports the regression results.

Columns (1) and (2) of Table 7 report the regression results based on maximum likelihood estimation (MLE), and Column (2) adds robust standard errors. The core explanatory variable is still significantly

Table 7. Estimation results of the treatment effect model.

VARIABLES	MLE	MLE_r	TwoStep	First	Second
did			-0.371***		-0.175**
			(-4.23)		(-2.32)
1.did	-0.446***	-0.446***			
	(-9.71)	(-8.78)			
sd×time				0.022***	
				(16.87)	
imr					0.094*
					(1.90)
Constant	-5.208***	-5.208***	-4.561***	-4.147***	1.513**
	(-4.96)	(-4.01)	(-4.21)	(-10.09)	(2.08)
athrho	1.026***	1.026***			
	(16.84)	(14.47)			
lnsigma	-0.395***	-0.395***			
	(-21.70)	(-19.40)			
hazard lambda			0.475***		
			(8.79)		
Control	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	3618	3618	3618	3627	3618

Note: The value in the brackets is T-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

negative at the statistical level of 1%, and its coefficient is -0.4458, nearly 18 times the baseline regression, indicating that the inhibition effect of policies on regional carbon emissions has been underestimated without considering the self-selection bias. Column (3) reports a two-step estimated treatment effect model, and lambda is significantly positive at the 1% statistical level, indicating that the model has a nonnegligible self-selection bias. The model regression coefficients are close to the estimated coefficients under the MLE method. Nevertheless, they are pretty different from the baseline regression results, indicating that the policy effect is greatly underestimated without considering self-selection bias. Column (4) reports the manual two-step estimation method. Although the coefficient has increased and the significance level has decreased, it still indicates that the model has self-selection bias.

Heterogeneity Test

Subsample Regression by Geographic Location

Given China's vast territory, cities in different geographical locations vary significantly in terms of economic structure and policy implementation, which may result in different levels of effectiveness of public participation. Therefore, the whole sample is divided into three geographic units, East, Central and West, by the division regulations of the 5th session of the 8th National People's Congress in this paper. The regression results in Columns (1)–(3) of Table 8.

As seen in Table 8, our findings are verified in the subsample of eastern cities (Coef. = -0.051, P-value = 0.005). At the same time, there is not sufficient evidence for such findings in the subsample of the central and western regions. This may be attributed to the higher level of economic development of eastern cities, with more human capital, a better business environment and a more concentrated industrial agglomeration. Human capital with a higher level of education is more inclined to participate actively in public environmental governance. The government pays more attention to the environmental needs of general feedback to create a good business environment. With this trade-off, local governments are more inclined to promote the concept of green development. Under this combination of passive and active effects, the carbon reduction effect of public participation performs better

Table 8. Heterogeneity of geographic location and resource test.

VARIABLES	Eastern cities	Central cities	Western cities	Resource-based cities	General cities
did	-0.051***	0.010	-0.011	0.001	-0.038**
	(-2.66)	(0.39)	(-0.42)	(0.05)	(-2.12)
Control	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	1,442	1,626	557	1,355	2,270
R-squared	0.918	0.932	0.934	0.933	0.913

Note: The value in the brackets is T-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

in the eastern region. The informal environmental regulations explored in this paper achieved conclusions consistent with previous formal environmental regulations [37-38], indicating that the conditions for the application of public participation are similar to those of formal environmental regulations which deserve further implementation by local governments.

Subsample Regression by Resource Endowment

Unlike general cities, resource-based cities are dominated by industries that develop and process energy, which generates large amounts of CO2 emissions. Therefore, this paper divides the whole sample into resource cities and general cities. The division is based on the list of resource cities determined in the National Sustainable Development Plan for Resource-based Cities. The regression results are presented in Columns (4) and (5) of Table 8.

Based on the regression results, the carbon reduction effect of public participation is present in the general city subsample (Coef. = -0.038, P-value = 0.033) and absent in the resource city subsample. This is consistent with previous findings [7, 16]. The economic development of resource cities depends on the industries of mineral energy development, which leads local governments to choose to ignore regional carbon emissions, thus falling into the dilemma of the “resource curse” [79] and resulting in a decrease in the effectiveness of public participation in governance.

Subsample Regression by City Size

Based on the regional year-end household population, the sample cities are divided into three quintiles: large, medium and small. The regression results are in Columns (1)–(3) of Table 9.

As indicated by the regression results, the carbon reduction effect of public participation performs better in large cities (Coef. = -0.081, P-value = 0.006), decreases in medium-sized cities (Coef. = -0.047, P-value = 0.090), and does not exist in small cities. This may be because large cities have more population and industrial agglomeration, people find it more difficult to tolerate the harsh living environment, motivating general public participation in environmental supervision is easier. The industrial agglomeration effect can centrally regulate and control high-carbon emission industries, so large and medium-sized cities can better play the carbon emission reduction effect of public participation [16, 79]. Notably, this paper also found this good emission reduction effect on medium-sized cities, which is a step further than previous literature [16]. It indicates that public participation has a superior performance in the governance of regional carbon emissions compared to traditional pollutants such as SO_2.

Subsample Regression by City Administrative Grade

Compared with previous studies that focused mainly on geographic location and resource endowment, our results consider the active role of the carbon reduction effect of public participation in terms of the city administrative grade. China's provincial capitals and municipalities tend to concentrate a large number of social resources and policy support, which may lead to significant differences between the governance effect of public participation in these cities and that of general cities. Therefore, the whole sample is divided into provincial capitals, municipalities and general cities, and the regression results are shown in Columns (4) and (5) of Table 9.

From the regression results, the interaction term's regression coefficient is significantly negative in the subsample of provincial capitals and municipalities (Coef. = -0.196, P-value = 0.000) but not significant in the subsample of general cities. Based on previous literature [16, 38], this paper attempts to provide an explanation for this performance. Provincial capitals and municipalities have gathered many social resources and their economic development level, human resources, business environment, etc., are superior to that of general cities. Therefore, provincial capitals and municipalities can better promote regional carbon emission reduction through public participation.

Table 9. Heterogeneity of city size and city administrative grade test.

VARIABLES	Large cities	Medium cities	Small cities	Provincial capitals and municipalities	General cities
did	-0.081***	-0.047*	0.030	-0.197***	-0.018
	(-2.87)	(-1.73)	(0.59)	(-4.23)	(-1.15)
Control	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	795	767	633	409	3,209
R-squared	0.931	0.939	0.902	0.884	0.931

Note: The value in the brackets is T-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

Few researchers have previously focused on the role of public participation in environmental governance from a city administrative grade perspective.

Further Analysis

Mechanism Analysis

Green Technology Innovation

Thus far, this paper has obtained clear evidence that public participation significantly reduces regional carbon emissions. However, we still need to establish a potential transmission mechanism. Previous scholars have focused more on public participation in environmental governance and have explored less on how public participation affects pollutant emissions [38]. This paper utilizes the analytical idea of a mediating effects model to further explore the mechanism through which public participation promotes regional carbon emission reduction.

Previous studies have explored the selection of intermediary variables through which environmental information disclosure promotes regional green technology innovation [40, 80-81]. This paper chooses the share of green patents in cities as a proxy variable for green technology innovation. Green patents are selected based on the "International Patent Classification Green List" published by the World Intellectual Property Organization (WIPO) in 2010. The green patent data of enterprises are identified and extracted in combination with the “international patent classification numbers.” The data in this paper are from the State Intellectual Property Office of China. The green patent data are calculated according to the prefecture-level city to which the company belongs and divided by the total number of patent applications in the prefecture-level city in the year to obtain the proportion of green patents. Regression was performed according to the mediation effect model, and the results are shown in Table 10.

Regression is carried out after excluding the data of the green patent proportion in the whole sample. Column (1) is the regression result of the core explanatory variable on green technology innovation. The coefficient is significantly positive, indicating that public participation positively affects regional green technology innovation (Coef. = 0.010, P-value = 0.011). In terms of coefficients, public participation has a smaller impact on green technology innovation compared to formal environmental regulation [40]. This is mainly due to the fact that public participation, as an informal environmental regulation, lacks a certain degree of coercion. Column (2) is the regression result of green technology innovation on regional carbon emissions, indicating that green technology innovation has an apparent inhibitory effect on regional carbon emissions, consistent with previous research results (Coef. = -0.084, P-value = 0.015) [82]. Column (3) shows the regression results when the core explanatory and mediator variables are controlled. The absolute value of the coefficient of the core

Table 10. Mechanism analysis: The effect of green technology innovation.

VARIABLES	Green	Carbon	Carbon
did	0.010***		-0.015***
	(3.59)		(-2.70)
Green		-0.084**	-0.078**
		(-2.44)	(-2.27)
Control	YES	YES	YES
City FE	YES	YES	YES
Year FE	YES	YES	YES
Observations	3,487	3,487	3,487
R-squared	0.046	0.930	0.930

Note: The value in the brackets is T-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

Table 11. Mechanism analysis: The effect of formal environmental regulation.

VARIABLES	InSO2
did	-0.176***
	(-2.76)
Control	YES
City FE	YES
Year FE	YES
Observations	3,557
R-squared	0.987

Note: The value in the brackets is T-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

explanatory variable is less than the absolute value of the coefficient of the core explanatory variable of the total effect, indicating that the proportion of green patents is a partial intermediary variable. Referencing Table 10, it can be inferred that public participation can reduce regional carbon emissions by promoting regional green technology innovation, which confirms H2.

Formal Environmental Regulation

Compared with previous studies, our findings highlighted the positive role that formal environmental regulation plays in promoting public participation. This paper considers that public participation, as an informal environmental regulation, may positively interact with regional formal environmental regulation [30, 35]. The effect of formal environmental regulation on carbon emission reduction has been confirmed by many studies [7, 14]. Therefore, according to the practice of Wang et al. [14], this paper selects the ratio of industrial SO_2 to regional GDP, that is, the emission intensity of industrial SO2, as the proxy variable of formal environmental regulation and explores the relationship between public participation and formal environmental regulations. The results are shown in Table 11 below.

Regression results showed that the coefficient of the core explanatory variable was significantly negative (Coef. = -0.176, P-value = 0.006), indicating that public involvement would effectively reduce industrial SO_2 emission intensity and that public participation could promote formal environmental regulation, which could reduce regional carbon emissions. This is also a possible mechanism of public involvement in reducing regional carbon emissions. Thus, H3 is confirmed. There are fewer relevant findings in previous studies, this paper provides a new perspective to examine public participation.

Table 12. Estimation results of the nonlinear discussion.

VARIABLES	Carbon
score²	-0.377***
	(-2.66)
score	0.344***
	(2.68)
Control	YES
City FE	YES
Year FE	YES

Note: The value in the brackets is T-value; ***, **, * indicate significance at the level of 1%, 5%, and 10%.

Further Discussion of Public Pressure

Given the dynamic relationship between the environmental governance pressure and environmental governance effects imposed by public participation in local governments, there is a nonlinear relationship between environmental regulation intensity and carbon emissions [7, 27]. Then, the inappropriate power of environmental regulation may have a counterproductive effect on ecology, so this paper also discusses the intensity of the level of public participation. The higher the PITI score of a region, the greater the environmental pressure the public exerts; that is, the greater the public pressure [37]. Therefore, this paper adopts the exact score of PITI as an indicator to measure the pressure intensity of public participation in a region. For the sake of visibility of the regression results, the PITI score is reduced by a factor of 100, so the square of the exact score is reduced by 10,000. We substitute the variable representing the score and the quadratic term of the score instead of the interaction term of the core explanatory variable into Model (1) for regression. The results are shown in Table 12.

From the regression results, we find that the primary and secondary terms of the PITI scores are statistically significant at the 1% level. The sign of the second term is negative (Coef. = -0.377, P-value = 0.009), indicating that there is indeed an inverted U-shaped relationship between public participation pressure and regional carbon emissions. Thus, H1b is confirmed. This suggests that public participation, as a type of informal environmental regulation, also has similar limitations [27-28]. When further promoting public participation for carbon reduction, appropriate additional pressure is needed; otherwise, it may be counterproductive.

Conclusions and Limitations

Can public participation reduce regional carbon emissions? This answer is of great significance for China to meet the targets of "carbon peaking" and "carbon neutrality" and then to extend this governance model to global green governance based on the experience of developing countries. This paper uses the PITI report released by IPE as a quasi-natural experiment to explore the causal relationship between public participation and regional carbon emissions. Working from the panel dataset of 285 cities in China from 2003 to 2017 and the DID method, the results show that public participation significantly reduces regional carbon emissions. Through a series of robustness and endogenous tests, this conclusion still holds. This paper further proves that promoting regional green technology development and strengthening government environmental control are the primary mechanisms for public participation in reducing regional carbon emissions. From the perspective of public pressure, it is discussed that there is an inverted U-shaped nonlinear relationship between the level of public participation and regional carbon emissions. In addition, in the subsamples of eastern cities, non-resource-based cities, large cities, and provincial capitals, public participation has a more pronounced inhibitory effect on regional carbon emissions.

In general, the conclusions of this paper are in line with previous literature on the effects of formal environmental regulations on carbon emissions. It also fills the gap in the literature on the role of informal environmental regulations on regional carbon emissions. It provides more compelling evidence that public participation significantly promotes regional environmental governance. Although our analysis mainly focused on China, the results can be extended to other developing countries facing the contradiction between economic development and environmental protection, such as India, Vietnam, and Brazil. Specifically, this paper makes the following policy recommendations. (1) Countries facing the dilemma of economic development and environmental protection should actively promote environmental information disclosure represented by public participation. (2) Priority should be given to public involvement in environmental protection in areas with relatively high levels of economic development and superior human capital. (3) In areas dominated by pollution-intensive industries, the effect of public participation in reducing emissions is moderate, and environmental governance should still focus on formal environmental regulation, supplemented by informal environmental regulation represented by public participation. (4) When reducing regional carbon emissions through public involvement, attention should be given to the level of green technology innovation in the region and the emission reduction effect of formal environmental regulations. (5) Considering the inverted U-shaped relationship between the level of public participation and the emission reduction effect, the intensity of public participation should be strengthened to cross the threshold and avoid the opposite policy effect.

This paper may have the following points that can inspire future research. (1) IPE's original intention of releasing the PITI list was not to promote the region to achieve carbon emission reduction, however, the release of the list has gained unexpected environmental performance. This paper has not fully explored the positive environmental performance of this event due to data or some other unknown reasons, and suggests that more attention can be paid in future studies. (2) This paper uses environmental information disclosure conducted by ENGOs, which are playing an increasingly important role in environmental governance. There are still some gaps in the research on ENGOs in carbon reduction, and it is suggested that the research on the carbon reduction effect of ENGOs can be further deepened in the future.

Some limitations in this paper may inspire future research. First, due to data constraints, carbon emission data ended in 2017, and the PITI list was published until 2018. This paper's time scale of the baseline regression was limited to 2017. Nevertheless, this paper used carbon emission data with a more extended time scale calculated based on the IPCC method in the robustness test, and the results were still robust. Therefore, updated or more complete carbon emission data can be used to expand the results in the future. Second, some data in the China Urban Statistical Yearbook are omitted. For the robustness of the results, this paper does not use interpolation to supplement it but instead uses unbalanced panel regression.

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Conflict of Interest

The authors declare no conflict of interest.

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