Environmental Regulation, Green Technology Innovation and Environmental Performance: An Empirical Study Based on Micro-data of Heavy Polluting Enterprises

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Abstract. This paper first systematically reviews and analyzes the relevant literature, theories, and concepts, and then proposes research hypotheses. The study empirically investigates the relationship and mechanisms between environmental regulation and environmental performance. Finally, the paper draws conclusions and provides policy recommendations for both the government and enterprises. The study finds that environmental regulation improve environmental performance in heavily polluting enterprises. Mechanism tests show that environmental regulation optimizes corporate environmental performance and enhances environmental performance by compelling enterprises to engage in green technological innovation. The impact is more significant in non-state-owned, high-tech, central and western region enterprises and enterprises under high environmental regulatory presure. The research conclusions contribute to the the "dual carbon" goals.

1. Introduction

In recent years, the increasingly severe environmental issues have garnered widespread global attention. China has been continuously advancing ecological civilization and plays a crucial role in global climate governance. Since the onset of the 21st century, the concept of controlling pollution at its source and protecting the development from the outset has deepened. As a major contributor to environmental pollution, heavily polluting enterprises are progressively shifting towards green production. Presently, advancing environmental pollution control is a critical component of China's pursuit of high-quality economic development. Stringent environmental regulations may lead to increased production costs for heavily polluting enterprises, reduced profitability, and diminished competitiveness, but they could also stimulate green innovation, improve enterprise efficiency, and enhance competitive advantage, which is a crucial micro-mechanism for achieving dual carbon goals. Driven by these dual carbon targets, the environmental performance level of Chinese enterprises has been steadily improving. Ecological innovation and knowledge management can optimize environmental performance. Therefore, focusing research on heavily polluting industries, empirically examining the impact and mechanisms of environmental regulations on corporate environmental performance, is of significant theoretical and practical value for assessing the effectiveness of environmental regulations, guiding the transformation of heavily polluting enterprises.

This paper reviews and analyzes the relevant literature and theories on environmental regulation, environmental performance, and green technological innovation. We conduct an empirical study to examine the impact of environmental regulation on the performance. A series of robustness and endogeneity tests confirm the stability of the results. Further mechanism and heterogeneity analyses provide micro-level evidence supporting the "Porter Hypothesis.", which contributes to the balance between economic and environmental benefits for heavily polluting enterprises.

2. Literature Review

At the macro level, current research primarily examines emission leakage and economic activity (Zhang, Bing, and Daxuan Zhao, 2023; Xie, Tingting, and Ye Yuan, 2023).[1-2] At the micro level, some literature investigates the economic consequences of environmental regulation from the perspectives of productivity and green total factor productivity (Rigas Nikos, et al., 2024; Ai, H., et al.,2020).[3-4] Regarding the factors influencing corporate environmental performance, some scholars explore environmental investment, and technological innovation (Yan, Shipeng, et al., 2021).[5]

Whether environmental regulation can enhance corporate environmental performance has been a hot topic in the field of environmental economics. Governments aim to maximize social benefits by implementing appropriate environmental regulation policies that guide companies toward green development. Environmental regulation can alter business strategies, encouraging compliance with environmental laws and reducing adverse environmental impacts (Martinez Hernandez JJ, et al., 2021).[6] Existing research has systematically demonstrates that environmental regulation can reduce corporate pollutant emission intensity. However, current

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studies often focus on the impact of specific environmental regulation policies (Wu, Rongxin, and Boqiang Lin, 2022).[7]

Environmental regulation is a key topic of interest in academia. Most studies consider only specific environmental regulation policies, neglecting the comprehensive impact of different combinations of environmental regulations on firms. Additionally, existing literature predominantly focuses on the effects of regional-level environmental regulations on corporate environmental management behaviors and environmental performance, overlooking the role of local environmental regulations at the micro level. Overall, while many scholars have examined the effects of environmental regulation on environmental performance, research on the mechanisms of these effects remains relatively scarce. Few studies incorporate green technological innovation into the research framework.

3. Hypothesis Development

3.1. The Direct Impact

Environmental regulation employs a comprehensive range of policies, laws, and other measures to restrict high-pollution business practices and incentivize firms to actively engage in environmental management. With increasing legal pressures for environmental protection and the improvement of resource allocation mechanisms, companies are driven by motives of legal compliance and resource acquisition to enhance their environmental performance. Firms actively seek more environmentally friendly and sustainable business practices, transitioning their production towards greener methods. Such innovation can partially or wholly offset the costs associated with environmental regulation.

China's environmental regulation is transitioning from pollution control to improving environmental quality, with various regulatory tools being applied comprehensively to heavily polluting enterprises. Higher regulatory intensity enhances the level of environmental oversight, significantly improving corporate environmental performance by increasing firms' motivation for environmental management (Martinez Hernandez JJ, et al., 2021).[6] Firstly, command-and-control regulations, represented by restrictive emission standards and clean production industry standards, exert substantial constraints, mandating strict limits on wastewater and exhaust emissions in daily operations. Under stringent environmental regulations, firms must either reduce production or adopt energy-saving production processes or pollution control equipment to meet basic emission requirements. Secondly, market-based environmental regulations, through mechanisms such as emissions trading, guide firms towards cleaner production by increasing pollution treatment costs, thereby regulating resource use behavior. These regulations promote the use of clean energy and innovative resource management techniques to improve resource utilization rates, helping firms reduce emissions and enhance environmental performance. Both command-and-control and market-based regulations effectively promote the implementation of environmental practices in heavily polluting enterprises, achieving green development (Pan, Junyu, et al., 2024).[8] Additionally, public participation regulations leverage public pressure, allowing environmentally conscious stakeholders to engage in daily supervision. This encourages firms to concentrate on environmental issues and foster a positive corporate image, thereby improving their environmental performance. Hence, we propose the following hypotheses:

H1: Environmental regulation can significantly improve corporate environmental performance.

3.2. The Mediating Role

In the process of green transformation, heavily polluting enterprises need to balance economic performance with environmental performance to achieve sustainable development. Green technological innovation, as an intrinsic driver of high-quality development, can enhance the environmental performance of heavily polluting enterprises through both cleaner production and end-of-pipe treatment. Green technological innovation reduces pollutant emissions at the source through cleaner production technologies, significantly improving the level of front-end prevention and promoting a cleaner production process. It can also optimize the end-of-pipe treatment processes of heavily polluting enterprises, improving the efficiency of pollutant treatment and enhancing environmental performance (Cheng, Qiang, et al., 2024).[9] Given the difficulty of upgrading production equipment in large polluting enterprises in the short term, green innovation mainly focuses on end-of-pipe treatment to achieve emission reductions.

There is evidence that increased regulatory intensity promotes the progress of green technological innovation, and command-and-control environmental regulations are more effective in this regard compared to price mechanisms. Currently, environmental regulation can influence corporate green technological innovation through two dimensions: compliance costs and innovation compensation. The compliance cost effect is primarily reflected in the increased burden of pollution control on enterprises and the crowding out of investment in technological innovation. The innovation compensation effect is seen in the way technological innovation enhances productivity (Li, Zhenghui, et al., 2024).[10] Environmental regulation exerts pressure on heavily polluting enterprises, promoting positive environmental behaviors. As the intensity and variety of regulatory tools increase, the promotional effect of environmental regulation on green technological innovation is further strengthened. Advances in green technology, through cleaner and greener production processes, impact pollutant emissions, reducing or replacing polluting activities, and thus improving environmental performance (Li, Yi, et al., 2023).[11] Green technological innovation, as a crucial path for enterprises to achieve sustainable development, helps improve environmental performance. Environmental regulation internalizes the external costs of

enterprises, continuously advancing the level of green technological innovation. This enhances both source and end-of-pipe treatment levels, effectively reducing pollutant emissions and improving environmental performance. Hence, we propose the following hypotheses:

H2: Environmental regulation can enhance corporate environmental performance through the mechanism of green technological innovation.

4. Research Design

4.1. Data and Sample

We constructs a panel dataset of heavily polluting A-share listed companies from 2012 to 2020 as the initial research sample. Environmental regulation intensity data is sourced from the annual reports of listed companies and provincial statistical yearbooks from China Statistical Yearbook. Environmental performance data is from Bloomberg ESG ratings, while environmental expenditure data comes from the annual reports of the listed companies. To reduce data processing bias, company samples with missing indicator data were excluded, and ST and *ST data during the sample period were also removed. There were 7,610 observations. The main continuous variables were winsorized at the 1% percentile level to mitigate the influence of outliers.

4.2. Variable Definition

4.2.1. Dependent Variable

Environmental Performance. This study uses the environmental performance dimension scores from Bloomberg ESG ratings to assess corporate environmental performance. A higher score indicates better environmental performance by the company.

4.2.2. Independent Variable

Environmental Regulation Intensity. Following the approach of Tong Fu (2024) et al., the intensity of environmental regulation at the corporate level is measured using the per capita environmental protection expenditure of listed companies for the year.[12] In the robustness check section, per capita environmental investment is used as a substitute measure to assess the reliability of the research conclusions.

4.2.3. Mediator Variable

This study uses the number of high-technology green invention patent applications to measure the level of green innovation in enterprises.

4.2.4. Control Variables

The control variables included in this study are: company size (Size), leverage (Lev), return on assets (ROA), Tobin's Q (TobinQ), state-owned enterprise status (SOE), whether the company is audited by a Big Four firm (Big4), and management expense ratio (Mfee). Additionally, year (Year) and firm (Company) fixed effects are controlled for.

4.3. Model Construction

4.3.1. Baseline Model

To validate the intensity and direction of the impact of environmental regulation intensity on corporate environmental performance, this study constructs the following baseline model:

$$CEP_{it} = \lambda_0 + \lambda_1 ERI_{it} + \sum \lambda_2 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Here, i represents the region,t represents time， EI represents corporate green investment， ERI represents environmental regulation， Controls represents control variables, μ_i and λ_t represent individual and time fixed effects, respectively, and ε represents the random disturbance term.

4.3.2.Mechanism Verification Model

To verify the mechanism through which environmental regulation affects corporate environmental performance via green technological innovation, we first examine whether the core explanatory variable impacts the mediator variable. The following mechanism verification model is constructed:

$$Greeninno_{it} = \alpha_0+\alpha_1 ERI_{it}+\sum \alpha_2 Controls_{it}+\mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

Here, Greeninno is the mediator variable, representing corporate green technological innovation. If the coefficient in Equation (2) is significant, it indicates that environmental regulation has a significant impact on corporate green technological innovation. Building on this, and based on the theoretical analysis of the causal effects between green technological innovation and corporate environmental performance discussed in this study, the mechanism effect of green technological innovation can be validated.

5. Empirical Results

5.1. Descriptive Statistics

From Table 1, it can be observed that the maximum and minimum values of corporate environmental performance (CEP) are 80.15 and 0, with a standard deviation of 9.838, indicating significant variation in green investment among the sample companies. The maximum and minimum values of environmental regulation intensity (ERI) differ

by 8, with a standard deviation of 2.339, showing considerable variation in environmental regulation intensity within the sample. The means and medians of the sample companies' Size, Lev, ROA, TobinQ, and Mfee are close, suggesting that the sample tends to be normally distributed with respect to the basic characteristics of the companies.

Table 1 Descriptive statistics of the variables.

Variable	N	Mean	p50	SD	Min	Max
CEP	7610	60.30	60.98	9.838	0	80.15
ERI	7610	1.383	0	2.339	0	8
Greeninno	7610	1.167	0	4.005	0	28
Size	7610	22.28	22.08	1.263	20.09	25.86
Lev	7610	0.400	0.386	0.203	0.0550	0.882
ROA	7610	0.0480	0.0420	0.0610	-0.148	0.211
TobinQ	7610	1.922	1.553	1.196	0	7.322
SOE	7610	0.381	0	0.486	0	1
Big4	7610	0.0550	0	0.229	0	1
Mfee	7610	0.0790	0.0690	0.0510	0.0100	0.288

5.2. Baseline Results

According to column (4) in Table 2, the coefficient for the impact of environmental regulation on corporate environmental performance is positive, with a value of 0.152, and is significant at the 1% level. This positive regression coefficient indicates that during the study period, environmental regulation has generally improved the environmental performance, thereby supporting Hypothesis H1. This also suggests that China's environmental regulation policies have effectively guided companies to actively take on social responsibilities for environmental protection and achieve emission reduction goals. According to the Porter Hypothesis, while environmental regulations increase corporate costs and crowd out production and operational funds in the short term, they can negatively affect financial performance even as environmental performance improves. Thus, the return on assets, which measures short-term financial performance, is significantly positive at the 1% level.

Table 2 Baseline regression results.

VARIABLES	(1) CEP	(2) CEP	(3) CEP	(4) CEP
ERI	0.177***	0.023	0.285***	0.152***
	(3.02)	(0.45)	(6.29)	(2.60)
Size		1.688***	1.123***	1.278***
		(6.75)	(9.00)	(4.16)
Lev		-0.232	0.327	-0.428
		(-0.22)	(0.48)	(-0.40)
ROA		-12.336***	-7.242***	-9.231***
		(-5.20)	(-2.97)	(-3.95)
TobinQ		0.112	0.202*	0.301**
		(1.04)	(1.93)	(2.42)
SOE		0.848	-0.764***	0.466
		(1.28)	(-3.42)	(0.70)
Big4		1.890*	0.891**	1.882**
		(1.86)	(2.19)	(2.05)
Mfee		-22.234***	-23.315***	-8.590**
		(-5.94)	(-10.03)	(-2.40)
Constant	59.586***	24.471***	37.887***	32.336***
	(314.03)	(4.43)	(14.04)	(4.88)
Observations	7,610	7,610	7,610	7,610
Adjusted R^2	0.048	0.027	0.058	0.055
Year FE	YES	NO	YES	YES
Company FE	YES	Yes	NO	YES

Notes: *** p<0.01,** p<0.05,* p<0.1, t-values are in parentheses.

5.3. Robustness Check

5.4.1. Variable Substitution

Apart from using per capita environmental expenditure, scholars have also employed per capita environmental investment to measure environmental regulation at the enterprise level (Tong Fu et al., 2020).[12] This study substitutes per capita environmental investment for per capita environmental expenditure (ERI2) to perform robustness checks. Table 5 presents the results of the robustness checks for the model. From column (1) of Table 5, it can be seen that the regression coefficient for per capita environmental investment on environmental performance is 0.171, significant at the 5% level, indicating that environmental regulation is beneficial for improving the environmental performance of heavily polluting enterprises. This result confirms the robustness of the research findings. Additionally, the main explanatory variable ERI is replaced with a dummy variable (ERI3). The construction method is as follows: if a company incurs environmental expenditure in the year, ERI3 is assigned a value of 1; otherwise, it is assigned a value of 0. Column (2) of Table 3 shows that the coefficient of environmental regulation is significantly positive, consistent with the results of the baseline regression, indicating that environmental regulation helps improve corporate environmental performance.

Table 3 Robustness check results for variable substitution.

VARIABLES	(1) CEP	(2) CEP
ERI2	0.171**	
	(2.19)	
ERI3		0.832***
		(2.75)
Controls	Yes	Yes
Constant	35.357***	32.014***
	(5.41)	(4.84)
Observations	7,610	7,610
Adjusted R^2	0.055	0.055
Year FE	YES	YES
Company FE	YES	YES

Notes: *** p<0.01,** p<0.05,* p<0.1, t-values are in parentheses.

5.4.2. Adding Control Variables

In addition to micro-level indicators affecting environmental performance, external environmental factors in the region where a company is located may also impact its environmental performance. Therefore, this study includes macro-level control variables to test the robustness of the research model. Specifically, the study adds the proportion of regional environmental grants (ERG) and the degree of industry concentration (Ind) as control variables. The regression results are presented in Table 4. From this table, it can be seen that after adding the control variables, the coefficient for environmental regulation remains significantly positive at the 1% level, indicating that environmental regulation effectively promotes improvements in corporate environmental performance.

Table 4 Regression Results with Additional Control Variables.

	(1)	(2)
VARIABLES	CEP	CEP
ERI	0.244***	0.154***
	(5.60)	(2.62)
Controls	Yes	Yes
Constant	39.538***	33.480***
	(15.37)	(5.04)
Observations	7,610	7,610
Adjusted R^2	0.055	0.055
Year FE	NO	YES
Company FE	NO	YES

Notes: *** p<0.01,** p<0.05,* p<0.1, t-values are in parentheses.

5.4.3. Excluding Samples from Directly-Controlled Municipalities and Provincial Capital Cities

China's directly-controlled municipalities hold significant political and economic status and have stricter environmental regulations compared to other regions. To avoid potential bias, this study further excludes samples from companies located in these municipalities. Column (1) of Table 7 reports the regression results after excluding directly-controlled municipalities. The results indicate that even after excluding these specific samples, the impact of environmental regulation on corporate environmental performance remains significantly positive. Considering that provincial capital cities may also have unique economic characteristics, this study further excludes 27 provincial capital cities in addition to the 4 directly-controlled municipalities for the regression analysis. According to the results in Column (2) of Table 5, environmental regulation remains significantly positive at the 5% level, consistent with the empirical analysis results presented earlier.

Table 5 Regression Results Excluding Direct-controlled Municipalities and Provincial Capitals.

	(1)	(2)
VARIABLES	CEP	CEP
ERI	0.166***	0.155**
	(2.61)	(2.09)
Controls	Yes	Yes
Constant	35.381***	36.759***
	(4.94)	(4.55)
Observations	6,545	4,790
Adjusted R^2	0.050	0.050
Year FE	YES	YES
Company FE	YES	YES

Notes: *** p<0.01,** p<0.05,* p<0.1, t-values are in parentheses.

5.4.4. Changing the Measurement Model

If a listed company's environmental performance is above the median, it is assigned a value of 1, indicating good environmental performance; otherwise, it is assigned a value of 0, indicating poor environmental performance. A logistic regression model was used for the analysis, and Column (1) of Table 6 confirms the robustness of the core conclusion. Since the lower limit of a company's environmental performance is 0, which presents certain restrictions, this study employs a Tobit model for the regression, setting the lower limit to 0. The results, shown in Column (2) of Table 8, indicate that the conclusions are consistent with the baseline results after changing the model.

Table 6 Regression Results with Model Substitution.

	(1)	(2)
VARIABLES	CEP2	CEP
ERI	0.077***	0.182***
	(2.76)	(3.22)
Controls	Yes	Yes
Constant	0.689	28.741***
	(0.20)	(6.76)
Observations	4,124	7,610
Year FE	YES	YES
Company FE	YES	YES

Notes: *** p<0.01,** p<0.05,* p<0.1, z-values are in parentheses.

5.5.5. Lagging Control Variables

Changes in corporate environmental performance might also affect control variables. To address potential endogeneity issues with the control variables, this study lags all control variables by one period. As shown in Column (1) of Table 9, the coefficient for ERI is 0.149 and is significant at the 1% level. Compared to Column (4) of Table 3, the results remain largely unchanged, effectively supporting the conclusion.

5.5.6. Adding Industry and Province Fixed Effects

Due to the possibility that some enterprises may change their province or industry, merely controlling for individual and industry fixed effects might overlook important time-invariant variables. Therefore, Column (2) of Table 7 incorporates dummy variables for provinces and industries into the baseline regression. The conclusions remain robust.

Table 7 Regression Results with Lagged Control Variables and Added Fixed Effects.

VARIABLES	(1) CEP	(2) CEP
ERI	0.149***	0.146**
	(2.93)	(2.49)
Controls	Yes	Yes
Constant	44.430***	25.545***
	(6.16)	(3.36)
Observations	6,282	7,610
Adjusted R^2	0.070	0.056
Year FE	YES	YES
Company FE	YES	YES
Industry FE	NO	YES
Province FE	NO	YES

Notes: *** p<0.01,** p<0.05,* p<0.1, t-values are in parentheses.

5.5.7.Instrumental Variable Method

This study uses urban river density as an instrumental variable for environmental regulation. Since river density values do not change over time, they are interacted with lagged one-period environmental regulation in the model and estimated using two-stage least squares. Generally, cities with higher river density have more convenient transportation, leading heavily polluting enterprises to operate in these areas to reduce transportation costs. Consequently, areas with high river density often suffer from severe environmental pollution. The governments are likely to establish more environmental monitoring stations in such cities, resulting in higher environmental regulation intensity, which meets the relevance criterion. Additionally, urban river density is a natural geographical condition and does not directly affect corporate environmental performance, meeting the exogeneity criterion for instrumental variables. According to Column (1) of Table 8, the coefficient for urban river density is significantly positive, indicating a strong correlation between the two. According to Column (2) of Table 10, the coefficient for environmental regulation is positive and significant at the 1% level. This indicates that the conclusions remain robust.

Table 8 Instrumental Variables Regression Results.

VARIABLES	(1) ERI	(2) CEP
ERI		0.962***
IV	0.314***	(2.66)
	(7.76)	
Controls	Yes	Yes
Constant	-0.600	
	(-0.29)	
Observations	6,282	6,216
Adjusted R^2	0.242	-0.206
Year FE	YES	YES
	YES	
Company FE	41.950	
LM statistic	[0.0000]	YES
Wald F statistic	89.546	
	{16.38}	

Notes: *** p<0.01, ** p<0.05, * p<0.1, t-values are in parentheses, p-values are in square brackets, and F-values at the 10% level are in curly brackets.

6. Additional Results

6.1. The Green Technological Innovation Channel

Based on the analysis, this paper introduces green technology innovation as a mediating variable to explore its mediating effect. According to Column (4) of Table 9, environmental regulation is significantly positive at the 5% level, indicating that environmental regulation can significantly enhance green technology innovation within enterprises. From the theoretical analysis, it is evident that green technology innovation can significantly improve the environmental performance. Thus, the mechanism by which environmental regulation promotes environmental performance through green technology innovation is validated, confirming hypothesis H2.

Table 9 Mechanism Effects of Green Technological Innovation.

VARIABLES	(1) Greeninno	(2) Greeninno	(3) Greeninno	(4) Greeninno
ERI	0.044*	0.045**	0.053**	0.051**
	(1.81)	(2.10)	(2.34)	(2.10)
Controls	Yes	Yes	Yes	Yes
Constant	0.724***	-6.343**	-13.689***	-1.222
	(6.80)	(-2.51)	(-10.36)	(-0.38)
Observations	7,610	7,610	7,610	7,610
Adjusted R^2	0.008	0.006	0.079	0.011
Year FE	YES	NO	YES	YES
Company FE	YES	YES	NO	YES

Notes: *** p<0.01,** p<0.05,* p<0.1, t-values are in parentheses.

6.2. Heterogeneity Analysis

6.2.1. Regional Heterogeneity

The varying characteristics of the factor markets, product markets, and other aspects that enterprises face depending on their regional locations may result in differing impacts of environmental regulations on corporate environmental performance. Accordingly, we categorizes enterprises into two regions based on their provincial locations. As shown in Tables 10 (1) and (2), the effect of eastern region is not significant, whereas in the Central-Western region, environmental regulations have significantly improved environmental performance. The Central-Western region, characterized by lower levels of economic development, enterprise financing capability, and technological advancement, experiences a weaker incentive effect of environmental regulations on technological innovation, leading to a smaller "technological innovation compensation effect." Under the predominantly command-and-control type of environmental regulations, enterprises in this region improve their pollution control facilities, driving "pollution control technology advancement effect," which significantly enhances their environmental performance. In contrast, the Eastern region has higher levels of environmental regulation and tends to use incentive-based market-type regulations, which diminish the "pollution control technology

advancement effect." Additionally, due to its more developed economy and intense market competition, environmental regulations in the Eastern region better stimulate enterprises to engage in green technological innovation, thereby enhancing the "technological innovation compensation effect." The interaction of these two effects results in an overall insignificant impact in the Eastern region.

6.2.2. Ownership Heterogeneity

Corporate ownership can lead to different effects of environmental regulations. Therefore, this paper classifies enterprises with more than half of their paid-in capital owned by the state as state-owned enterprises, while the rest are classified as non-state-owned enterprises. According to the grouped regression results in columns (3) and (4) of Table 10, the estimated coefficient of environmental regulations is significant at the 5% level in the sample of non-state-owned enterprises. However, the estimated coefficient is smaller and not statistically significant in the sample of state-owned enterprises. This indicates that the environmental performance improvement under environmental regulations is more pronounced in non-state-owned enterprises compared to state-owned enterprises.

Non-state-owned enterprises face more intense market competition and have greater differences in environmental information transparency. Due to their more distant relationship with the government, they are often more sensitive to changes in the intensity of environmental regulations. This increases the incentive effect of environmental regulations, prompting heavily polluting non-state-owned enterprises to adopt more effective environmental management strategies, improve resource and energy efficiency, and reduce pollutant emission intensity.

Table 10 Regional and Ownership Heterogeneity.

VARIABLES	(1) CEP	(2) CEP	(3) CEP	(4) CEP
ERI	0.118	0.192***	0.087	0.187**
	(1.38)	(2.63)	(1.16)	(2.10)
Controls	Yes	Yes	Yes	Yes
Constant	31.346***	34.003***	44.603***	27.421***
	(3.31)	(3.64)	(4.74)	(3.00)
Observations	4,637	2,973	2,902	4,708
Adjusted R^2	0.060	0.050	0.034	0.068
Year FE	YES	YES	YES	YES
Company FE	YES	YES	YES	YES

Notes: *** p<0.01,** p<0.05,* p<0.1, t-values are in parentheses.

6.2.3. Industry Heterogeneity

To investigate whether the impact varies by industry technology level, we divide the research sample into heavily polluting high-tech industries and heavily polluting low-tech industries for separate regressions. From the grouped regression results in columns (1) and (2) of Table 13, it can be seen that environmental regulations significantly improve the environmental performance of high-tech industries. This indicates that environmental regulations force high-tech enterprises to enhance their environmental performance by improving green technology innovation and investing more in environmental protection. In medium and low-tech industries, the effect is not statistically significant. The main reason is that medium and low-tech heavily polluting enterprises have lower levels of green technology innovation and poorer environmental management effectiveness. Therefore, they cannot effectively improve environmental performance in response to environmental regulations.

6.2.4. Regulatory Intensity Heterogeneity

To further verify the potentially differentiated effects under different levels of government regulatory intensity, this paper measures the environmental regulatory intensity of each province using the ratio of environmental terms to total terms in government work reports. From the results of the grouped regressions in columns (3) and (4) of Table 11, it is evident that environmental regulations significantly improve environmental performance only in the sample of heavily polluting enterprises in regions with high environmental regulatory intensity. The estimated coefficient is significantly positive at the 5% level, indicating that compared to regions with lower regulatory intensity, the positive impact of environmental regulations is mainly observed in regions with stricter government environmental management requirements.

Table 11 Industry and Regulatory Intensity Heterogeneity.

VARIABLES	(1) CEP	(2) CEP	(3) CEP	(4) CEP
ERI	0.253**	0.061	0.175**	0.092
	(2.45)	(0.95)	(2.16)	(1.13)
Controls	Yes	Yes	Yes	Yes
Constant	38.257***	25.776***	47.627***	32.634***
	(3.52)	(2.73)	(4.75)	(4.04)
Observations	3,364	4,246	3,806	3,804
Adjusted R^2	0.064	0.052	0.052	0.059
Year FE	YES	YES	YES	YES
Company FE	YES	YES	YES	YES

Notes: *** p<0.01,** p<0.05,* p<0.1, t-values are in parentheses.

7. Conclusions

We find that environmental regulation contributes to the improvement of environmental performance in heavily polluting enterprises. Mechanism analysis indicates that green technological innovation is a crucial channel through which environmental regulation affects corporate environmental performance. Environmental regulation

can compel enterprises to engage in green technological innovation, where the innovation compensation effect offsets the cost effect, thereby promoting the enhancement of corporate environmental performance. Compared to other enterprises, the improvement effect of environmental regulation on the environmental performance is more significant for non-state-owned, high-tech enterprises, central and western enterprises and enterprises in areas under high environmental regulatory intensity.

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