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Environmental Regulation, Innovation, and Environmental Performance: Evidence from China*

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Will environmental regulations induce firms to innovate and improve their environmental performance? This paper examines the impact of a regulation that mandates heavy polluting industries to save energy and reduce emissions using data from Chinese listed companies. We show that the regulation significantly drive firms to improve their corporate environmental performance, while simultaneously inhibiting their innovation activities. We also identify that innovation activities generate a suppression effect between environmental regulation and corporate environmental performance.

Keywords: Environmental Regulation; Innovation; Environmental Performance

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I. Introduction

China has achieved rapid economic growth over the past four decades as a result of its reform and opening up policy. However, this success comes at the cost of serious environmental deterioration. China's environmental problems, including air pollution, water shortages and pollution, desertification, and soil pollution, have become increasingly pronounced over the years, and they are threatening the sustainability of the country's future growth. As the negative impacts of climate change are mounting, it is increasingly vital for China, the world's largest carbon emitter, to commit to saving energy and reducing emissions. In 2012, the National Development and Reform Commission (NDRC) put forward the implementation plan for energy-saving and low-carbon actions by 10,000 enterprises. This policy aims to allow these enterprises to carry out low-carbon pilot projects. With the introduction of the "New Environmental Protection Law" in 2015 and the "30.60" carbon peaking and carbon neutrality goals proposed by General Secretary Xi Jinping at the 75th United Nations General Assembly in 2020, China has since adopted a number of new policies and measures to reduce carbon emissions. It is therefore of great policy relevance to understand whether and how environmental regulations can promote corporate environmental performance. In addition, will innovation activities be induced by these more stringent environmental regulations, as predicted by the "Porter hypothesis"? Despite a large number of studies that have explored Chinese environmental regulations, these important questions have not been satisfactorily addressed, despite their apparent policy relevance in meeting the Sustainable Development Goals (SDGs).

There is a growing body of literature that explores the direct impact of environmental regulations on corporate environmental performance. Using data from 404 manufacturing firms in São Paulo, Féres and Reynaud (2012) confirm that environmental regulations affect firms' pollutant emissions, with formal and informal regulations working in tandem to improve corporate environmental performance. Graafland and Smid (2017), on the other hand, show that environmental regulations can improve the environmental performance of small and medium-sized enterprises, and governments should rely not only on directly regulating environmental performance but also on "soft" regulations to improve the transparency of such activities. Using data on 39 industries in China, Z. Zhang et al. (2015) demonstrate that there is a time lag before the impacts of environmental regulations can be realized on corporate environmental performance. In particular, their findings suggest that although current environmental regulations only exert a negative effect on environmental performance, their impacts will be positive one phase later. In addition, Wang and Yao (2021) analyze the performance of Shanghai and Shenzhen A-share industrial enterprises from 2011 to 2018, and study the impact of the newly implemented Environmental Protection Law on corporate performance. Liu and Duan (2021) selected 337 listed companies in China's petrochemical industry from 2015 to 2019 as research samples to verify the existence of the "Baud hypothesis" in the petrochemical industry. They find that the current environmental regulation has a positive effect on the performance of the lagging firms. Further research on the mediating effect shows that environmental regulations affect the performance of the firms through technological innovation. Mulaessa and Lin (2021) considered the relationships between environmental regulation and green innovation, corporate performance and green innovation, and explored the moderating role of environmental regulation and corporate performance in the relationship between active environmental strategy and green innovation. Their results show that environmental regulations promote green innovation practices. Similarly, corporate performance encourages green innovation practices.

Our paper is also related to the segment of the literature that examines the relationship

between environmental regulations and firms' innovation activities. It is widely believed that environmental regulations will produce a "crowding out effect" by increasing firms' operating costs and, thus, are not conducive to firms' innovation activities. Chintrakarn (2008) estimates the impact of environmental regulations on the technological efficiency of manufacturing industries in 48 U.S. states from 1982 to 1994 and shows that environmental regulations are not conducive to the improvement of technological efficiency. The conclusions of Kneller and Manderson (2012) also support the "crowding out effect". Zhang and Lv (2018) show that the negative impact of environmental regulatory policies on corporate innovation significantly reduces corporate innovation investment. Shao et al. (2020) summarized the impact of environmental regulation on enterprise innovation from four perspectives: technological innovation, product innovation, institutional innovation, and ecological innovation. They show that whether or not the Baud hypothesis holds, and what version of the Baud hypothesis environmental regulation triggers in corporate innovation, depends on the characteristics of the firm, the means of environmental regulation, and the strategic behavior of the firm in the corporate ecosystem. Using the enterprise-level data from 2004 to 2009, Fang et al. (2020) study the impact of environmental regulation on enterprise innovation. Their results show that the National Special Monitoring Enterprise program improves the level of innovation of regulated enterprises and supports a weak version of the Baud hypothesis. The mechanism test shows that financial constraint is an important channel to influence enterprise innovation.

Porter (1991; 1995), on the other hand, suggests that contrary to the common belief, in reaction to environmental regulations, firms may choose to increase investment in R&D and innovation activities (the "Porter hypothesis"). Using data on the European economies from 1995 to 2008, De Santis and Jona-Lasinio (2015) show that the impact of environmental regulations on firms' innovation activities is positive, and thus the "weak" Porter hypothesis cannot be rejected. P. Liu (2016) and R. Liu (2017) also confirm that environmental regulations have a positive effect on technological innovation. At the same time, few studies have considered the relationship among environmental regulations, firms' innovation activities, and corporate environmental performance. Xie et al. (2014) and W. Yu et al. (2017) are the two exceptions. Xie et al. (2014) show that environmental regulations have a positive effect on innovation, but technological innovation has a lag effect on firms' operating performance. W. Yu et al. (2017), on the other hand, confirm that environmental regulations can promote firms' investment in innovation, but it cannot promote the performance of the overall economy. Elsewhere, using data from China, Chen et al. (2018) consider the impact of environmental regulation and corruption on environmental quality, while Yang et al. (2018) examine firms' location choices in response to environmental regulations. Yang and Peng (2021) argue that environmental regulation has a positive impact on corporate innovation, with technological innovation playing a part of the intermediary role, and that environmental regulation affects corporate performance through technological innovation. Zandi et al. (2019) explore the impact of ecological innovation and knowledge management on environmental performance. The results of the partial least squares structural equation model show that knowledge transfer and green innovation also have a positive and significant impact on environmental performance. The results further show that enterprises can improve their environmental performance by implementing sound environmental management accounting system. However, despite of the large literature, the research question that we aim to answer–How will environmental regulations impact firms' innovation activities and their environmental performance?–remains largely unanswered.

The aim of this paper is to fill this gap. With a view to achieving the energy conservation and emission reduction targets set by the State Council, 12 departments, including the National Development

and Reform Commission (NDRC), jointly issued the "Notice on Printing and Distributing 'Top 10,000' Enterprise Energy-Saving and Low-Carbon Action Implementation Plan" (Fa Gai Huan Zi (2011) No. 2873, December 7, 2011) (hereinafter the "Energy-Saving and Low-Carbon Action Plan") to encourage manufacturing enterprises, hotels, restaurants, commercial companies, and schools to carry out the Action plan. The "Energy-Saving and Low-Carbon Action Plan" allows us to evaluate the effects of an environmental regulation on corporate environmental performance and firms' innovation activities.

Our study finds that regulation significantly restrains corporate environmental performance, while reducing firms' innovation activities. We also show that innovation activities play an indirect role between environmental regulation and corporate environmental performance, which is identified as a suppression effect.

The rest of our paper proceeds as follows. In Section 2, we provide background information on the "Energy-Saving and Low-Carbon Action Plan" and present the hypothesis. In Section 3, we discuss our data collection, measurement, and analytical models. In Section 4, we present and discuss our empirical findings. Section 5 then concludes the paper.

Ⅱ. Background and hypothesis development

In this section, we first introduce the environmental regulation that we aim to examine in this paper, the "Energy-Saving and Low-Carbon Action Plan". We then propose multiple hypotheses concerning the relationships among environmental regulations, corporate environmental performance, and firms' innovation activities.

1. *"Energy-Saving and Low-Carbon Action Plan"*

In the "Energy-Saving and Low-Carbon Action Plan", the "Top 10,000" enterprises are defined as energy-consuming units with an annual comprehensive energy consumption of more than 10,000 tons of standard coal or equivalent and those designated by relevant departments that have an annual comprehensive energy consumption of more than 5,000 tons of standard coal or equivalent. A preliminary survey conducted by NDRC and other departments reveals that the number of target units were approximately 17,000 in 2010, which altogether accounted for more than 60% of the total energy consumption in China that year.

This action plan is widely regarded as a key step for China to achieve its goal of a 17% reduction in carbon dioxide emissions and a 16% reduction in energy consumption per unit of GDP, as stipulated in the "Twelfth Five-Year Plan". The plan mandates that the targeted units to (i) establish an internal energy-saving mechanism in accordance with "the Energy Management System Requirements (GB/T23331)", (ii) monitor energy use by installing proper measurement, data-collection, and monitoring equipment in accordance with "the General Rules for the Provision and Management of Energy Measuring Instruments for Energy-Using Units (GB17167)", (iii) conduct energy audits in accordance with the "General Principles of Enterprise Energy Auditing Technology (GB/T17166)", (iv) increase energy-saving technological transformation by making annual investments in energy-saving technologies, (v) speed up the elimination of inefficient energy-using equipment and production processes, and (vi) meet national/local energy-using standards. In total, the action plan calls for energy savings of 250 million tons of standard coal or equivalent. This paper will use this regulation to explore the impacts of an environmental regulation on corporate environmental performance and firms' innovation activities.

2. *Environmental regulation and corporate environmental performance*

The "Energy-Saving and Low-Carbon Action Plan" is a typical "command-and-control" instrument that involves explicit restrictions on the allowable levels of emissions and the use of energy-saving techniques. Hence, we propose the following:

Hypothesis 1a. Environmental regulation has a positive effect on corporate environmental performance.

3. *Environmental regulation and firms' innovation activities*

As mentioned above, the existing literature shows that environmental regulations can exert both positive and negative effects on firms' innovation activities. On the one hand, costly environmental regulations that mandate firms to meet the explicit restrictions on allowable levels of emissions or energy-saving requirements may increase production costs, thus forcing firms to reduce their investments in innovation activities. On the other hand, complying with costly environmental regulations may also force firms to offset the rising costs by reducing their production and operation costs through improvements in production efficiency, thus inducing firms to increase their investments in innovation activities. Put otherwise, the impacts of environmental regulations on firms' innovation activities depend on the balance of the positive and negative effects. Therefore, this paper proposes two opposing hypotheses:

Hypothesis 2a. The effect of an environmental regulation on firms' innovation activities is negative.
Hypothesis 2b. The effect of an environmental regulation on firms' innovation activities is positive.

4. *Role of firms' innovation activities*

According to the "Porter hypothesis" (Porter 1991; 1995), environmental regulations may induce firms' innovation, and thus improving their competitiveness and profitability. This is because an increase in firms' innovation activities that include environmental innovation can drive firms to increase their green productivity, thereby reducing environmental pollution and improving corporate environmental performance. Singh et al. (2020) examine how green human resource management (Green HRM) plays a role in the link between green transformational leadership, green innovation and environmental performance. By using covariance-based structural equation modeling (SEM), their results suggest that Green HRM practices play a mediating role in the impact of green transformational leadership on green innovation. Therefore, we propose the third hypothesis:

Hypothesis 3. Functioning as a mediator variable, an environmental regulation can influence corporate environmental performance through firms' innovation activities.

Ⅲ. Methodology

In this section, we first introduce the sample and data collection and then discuss how we measure environmental regulations, corporate environmental performance, and firms' innovation activities.

1. *Sample and data collection*

Since the "Energy-Saving and Low-Carbon Action Plan" was announced at the end of 2011 and its actual implementation period was 2012-2020, we collected data on the listed companies in heavy polluting industries from 2009 to 2020. On January 1, 2018, the Environment Protection Tax Law came into effect, effectively suspending the collection of pollution charges nationwide and levying an environmental protection tax in accordance with the law. Therefore, we kept the data from 2009 to 2017 for our analysis. The listed companies in heavy polluting industries are based on the 16 categories of heavy polluting industries stipulated in the "Guidelines for Environmental Information Disclosure of Listed Companies", issued by the Ministry of Environmental Protection in 2010. We exclude ST, *ST companies, and samples with incomplete or abnormal data.[1)] In addition, data is also excluded due to incomplete statistics in some years and the lack of certain variables for some of the companies. The samples create an unbalanced panel dataset. In total, we obtained 865 observations for 134 companies. financial data and property

rights data are derived from the CSMAR database. Whether or not a firm belongs to the policy group is judged according to the "List of Enterprises and Energy Conservation Target of the 'Energy-Saving and Low-Carbon Action Plan'".

2. *Environmental regulation*

In line with the existing research, we use the "Energy-Saving and Low-Carbon Action Plan" as a measurement index of environmental regulation.[2)] If the listed enterprise is on the "Energy-Saving and Low-Carbon Action Plan", the dummy variable (G) of the policy group takes a value of 1, otherwise 0. The dummy variable (D) before and after the year of implementation of the policy is 1 for 2012 and after, and 0 for before 2012. This paper will use this policy as a measure of environmental regulation to explore the impact of environmental regulation on enterprise environmental performance.

3. *Corporate environmental performance*

Most existing research uses the Committee on Environmental Policy (CEP) index or the data on toxic chemical releases from the U.S. TRI database as indicators for corporate environmental performance. However, in China, there is no such ranking of environmental performance, and there is no database of pollutant emissions. Hence, it is necessary to use other indicators to measure environmental performance. Previous research has focused on the following areas: comprehensive assessment system of environmental performance, emission intensity of enterprises (Zhou 2018), environmental rewards obtained by enterprises using methods in Klassen and Laughlin (2016).

This paper follows Hu (2012) and uses the ratio of sewage charges and operating income as a proxy variable for environmental performance. "Regulations on the Administration of the Collection and Use of Sewage Charges" stipulates that all units in China that directly discharge pollutants to the environment should pay the sewage charges on time. The sewage charges are collected by the state, and the relevant data can be obtained from the financial statements of the firms, which can be regarded as accurate and objective. Moreover, the lower the sewage charges per unit of operating income, the less damage is generated by the production activities on the environment, and the better the environmental performance of the firm. Hence, we use the sewage charges per unit of operating income to reflect the environmental performance of a particular firm.

4. *Innovation activities*

The measurement of enterprise innovation behavior is mainly from the perspective of innovation input and innovation output, and innovation input includes enterprises' expenditure on R&D and investment on R&D personnel (Gu and Zhai 2012), innovation output includes patent number or innovation number of enterprises and new product value of R&D (Tang and Wu 2020). The innovation behavior of enterprises studied in this paper mainly refers to the investment and change in innovation caused by environmental regulation, so it focuses on the innovation investment of enterprises. Because the data of R&D personnel of listed companies are missing in many years, this paper uses the expenditure of R&D investment to measure the innovation behavior of enterprises, that is, R&D investment expenditure as a proportion of operating income (Yu and Chi 2021).

5. *Control variables*

As control variables in our regression analyses, we include (i) enterprise size (SIZE): the natural logarithm of the total assets of the firm at the end of the year; (ii) asset-liability ratio (LEV): the ratio of total enterprise liabilities to total assets; (iii) return on equity (ROE): the ratio of the net profit for the year to the total assets at the end of the year; (iv) enterprise growth (GROWTH): changes in operating income divided by the operating income of the previous year; and (v) nature of property rights (STATE): the value for state-owned enterprises is 1, and that of other enterprises is 0.

6. *Model specifications*

In this paper, we investigate the effect of the "Energy-Saving and Low-Carbon Action Plan" on corporate environmental performance and whether firms' innovation behavior plays a mediating role. Fortunately, the setting and data lend themselves well to a differences-in-differences approach. We divide the sample time (2009-2017) into two periods according to the implementation time of the plan. The change in environmental performance and the role of firms' innovation activities in the two periods are analyzed. In addition, we use the approach of Wen and Ye (2014) to test the mediating effect of the firms' innovation activities. The mediating effect can be shown in Figure 1 below. Symbol c represents the total effect of the explanatory variable X on the interpreted variable Y, c' is a direct effect, M is a mediating variable, and a, b represents the mediation that X affects Y through M.

$$EP_{it} = \alpha_0 + \alpha_1 G_i \times D_t + \alpha_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \quad (1)$$

$$TEC_{it} = \beta_0 + \beta_1 G_i \times D_t + \beta_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \quad (2)$$

$$EP_{it} = \gamma_0 + \gamma_1 G_i \times D_t + \gamma_2 TEC_{it} + \gamma_3 X_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \quad (3)$$

where EP_{it} denotes the sewage charges per unit of operating income for firm i during period t, which is used to measure corporate environmental performance. TEC_{it} measures firms' innovation activities. G_i captures whether firm i belongs to the policy group; if firm i belongs to the policy group, then G_i=1, otherwise G_i=0. D_t is a dummy variable of the experimental period, indicating whether period t is before or after the promulgation of the regulation. If time t is before the promulgation of the regulation, i.e., when $t < 2012$, then D_t=0, and if t is after the promulgation of the policy, i.e., when $t \geq 2012$, then D_t=1. The interaction term $G_i \times D_t$ thus measures the policy effect of the treated group. The coefficients α_1, β_1, and γ_1 are the core variables to be examined, reflecting the net impacts of policy implementation on corporate environmental performance and innovation activities. X_{it} is used to represent the control variables, including enterprise size, asset-liability ratio, return on equity, enterprise growth, and nature of property rights. μ_i is an individual fixed effect, which measures the characteristics of firm i that do not change with time. λ_t is a time effect, which can control some factors affected by time, such as natural conditions. ε_{it} is a random error term.

Table 1 Variable Definition Table

Variable	Symbol	Definition
Enterprise Environmental Performance	EP	Sewage charges / Operating incomes
Policy Group Virtual Variable	G	Belonging to the policy group = 1, otherwise 0
Virtual Variable Around the Year of Policy Implementation	D	Year < 2012, D = 0; Year ≥ 2012, D = 1
Enterprise Innovation Behavior	TEC	Number of technical personnel / Total number of employees
Enterprise Size	SIZE	Ln (total assets at the end of the year)
Asset-liability Ratio	LEV	Total liabilities / Total assets
Return on Equity	ROE	Net profit of the year / Total assets at the end of the year
Enterprise Growth	GROWTH	Changes in operating income / Operating income of the previous year
Nature of Property Rights	STATE	State-owned enterprises, STATE = 1; otherwise, STATE = 0

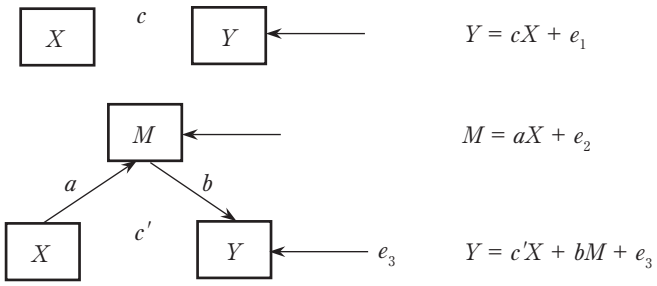

Figure 1

Intermediate Variable Schematic Diagram

Based on the above analysis and our hypotheses, the following model is constructed:

Ⅳ. Results and discussion

1. *Summary statistics*

We report the basic summary statistics in Table 2. The EP values range from 0 to 0.0281, with an average of 0.0015, suggesting that the sewage charges per unit of operating income for the sample firms are generally low. The TEC values are between 0.0002 and 0.8699, indicating that there is a large discrepancy among firms with respect to innovation activities. The average asset-liability ratio is 51.03%, which indicates that the financial risk is relatively large. The average return on equity is relatively low, although the growth rate of operating income is relatively high. As to the nature of property rights, the proportion of state-owned enterprises is 62.31%.

2. *Correlation analysis*

The Pearson correlation analysis for the variables involved in the model are shown in Table 3. The results show that there is a positive correlation between the environmental performance (*EP*) and the two variables of the policy, the time-dependent interaction *G*×*D* and the Enterprise Innovation Behavior (*TEC*), the correlation between *G*×*D* and *TEC* was negative and significant at the level of 5%. Overall, the absolute correlation coefficients for most variables were all below 0.5 and significant at significance levels of 1%, 5%, and 10%, indicating that the multicollinearity between variables was weak, hence there is no serious multicollinearity issues. At the same time, the expansion factor VIF was calculated. The results show that the VIF values are all below 2 and far below 10, which proves that the model has no multicollinearity.

3. *Regression analysis*

Table 4 summarizes the regression results.

(1) Regression results of environmental regulation

Table 2 Summary Statistics

Variables	N	Mean	SD	Min	Max
EP	865	0.0015	0.0023	0.0000	0.0281
TEC	865	0.1018	0.0891	0.0002	0.8699
SIZE	865	22.7235	1.2428	19.8215	26.2963
LEV	865	0.5103	0.2014	0.0447	1.3448
ROE	865	0.0279	0.0531	-0.4697	0.2960
GROWTH	865	0.2151	1.5566	-0.6342	38.1197
STATE	865	0.6231	0.4849	0.0000	1.000

Table 3 Pearson Correlation Analysis

	EP	G×D	TEC	SIZE	LEV	ROE	GROWTH	STATE
EP	1.000							
G×D	0.099**	1.000						
TEC	0.098**	-0.099**	1.000					
SIZE	-0.195***	-0.126**	-0.031	1.000				
LEV	-0.063	-0.027	-0.000	0.515***	1.000			
ROE	-0.024	-0.015	-0.056	-0.110**	-0.490***	1.000		
GROWTH	-0.022	-0.037	-0.032	0.013	-0.004	0.122***	1.000	
STATE	0.024	-0.078*	-0.166***	0.366***	0.393***	-0.199***	-0.035	1.000

and corporate environmental performance

Model (1) in Table 4 shows the effect of environmental regulation on corporate environmental performance. It can be seen that *G×D*, being an interaction term, has a coefficient that is significant and negative at the 10% level. This means that after the implementation of the regulation, the sewage charges per unit of operating income decrease and corporate environmental performance increases. It shows that the policy has indeed played a role in improving the environmental performance of enterprises, and environmental regulation has a positive effect on the environmental performance of enterprises. Hypothesis 1 is verified.

Table 4 Estimation Results

	model(1) EP	model(2) TEC	model(3) EP
G×D	-0.000283* (-1.77)	-0.0282*** (-2.82)	-0.000329** (-2.15)
TEC			-0.00162* (-1.83)
SIZE	-0.000614** (-2.37)	-0.00744 (-0.88)	-0.000626*** (-2.42)
LEV	-0.000642 (-1.17)	-0.0152 (-0.66)	-0.000667 (-1.21)
ROE	-0.00180 (-1.27)	0.0397 (0.53)	-0.00174 (-1.25)
GROWTH	-0.000325* (-1.92)	-0.00259 (-0.46)	-0.000329* (-1.95)
STATE	-0.00102*** (-4.20)	-0.0392** (-2.50)	-0.00108*** (-4.54)
_cons	0.0164*** (2.86)	0.303 (1.36)	0.0169*** (2.93)
Firm	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	865	865	865
R-sq	0.132	0.139	0.439

Note: *t* values for each coefficient are shown in parentheses, and ***, **, and * indicate the significance levels of 1%, 5%, and 10%, respectively.

(2) Regression results of environmental regulation and firms' innovation activities

Model (2) in Table 4 shows the relationship between environmental regulation and firms' innovation activities. The coefficient of *G×D* is significantly negative at the 1% level, indicating that environmental regulation and firms' innovation activities have a negative correlation, and the "Porter hypothesis" is not supported. Hence, H2a is established, i.e., costly environmental regulation will force firms spend less on innovation activities.

(3) Results of mediating effect test

We also conduct a mediating effect test to test the relationships among environmental regulation, firms' innovation activities, and environmental performance. From model(3) of Table 4, we can see that the environmental regulation has a significant negaive effect on the per unit sewage charges. At the same time, the effect of firms' innovation activities on the per unit sewage charges is also negative, indicating that both the environmental regulation and corporate innovation activities have a positive impact on corporate environmental performance. The mediating effect is shown in Figure 2, in line with

Wen and Ye (2014).

According to the testing process stipulated in Wen and Ye (2014), the first step is to test the significance of the coefficient, α_1, and find whether the coefficient value is significant at the 10% level, i.e., the regulation has a significant impact on corporate environmental performance. The second step is to check the significance of the coefficients β_1 and γ_2, respectively. We find that they are significant at the 1% and 10% levels, respectively, i.e., the policy has a significant effect on firms' innovation activities, while the impact of firms' innovation activities on corporate environmental performance is also significant. Therefore, the indirect effect is significant.

The significance of the test coefficient γ_1 is also significant, indicating that after controlling for firms' innovation activities, the regulation still has a significant impact on environmental performance. Furthermore, if the signs of $\beta_1\gamma_2$ and γ_1 are the same and the two terms are different, the final result would be a suppression effect. Our results suggest that firms' innovation activities play an indirect role between environmental regulation and environmental performance, and the indirect effect is a suppression effect rather than a mediating effect. Given its significant indirect effect, it can still be considered that environmental regulation impacts environmental performance by affecting firms' innovation activities; hence, H3 holds.

(4) Impact of control variables

The control variables that we consider are generally consistent with the existing theoretical studies. The coefficient of firm scale is negative and significant in model(1) and model(3), which indicates that the expansion of firms' scale is conducive to the improvement of corporate environmental performance. The coefficient is negative but not significant in model(2), which indicates that the promotion effect of firms' scale on innovation activities is not fully manifested. The asset-liability ratio coefficients and the return on equity coefficient are not significant in any of the three models, and their roles need to be explored further. The coefficients of firms' growth in model(1) and model(3) are significantly negative, which means that a firm's growth potential has a positive impact on its environmental performance. The nature of property rights is significantly negative in the three models, indicating that the environmental performance of state-owned enterprises is better, but their investment in innovation activities is less than that of other types of firms.

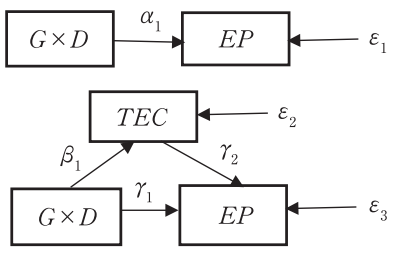

Figure 2

Intermediate Variable Schematic Diagram

4. *Robustness test*

Li et al. (2015) and N. Yu et al. (2017) find that firms' governance structures influence corporate environmental performance, and governance structure includes ownership concentration, the proportion of independent directors, the combination of two positions, and other variables. Therefore, in order to clarify the impact of environmental regulation on environmental performance and the mediating role of firms' innovation activities, we add three control variables: (i) the proportion of ownership of the largest shareholder (*LSI*), (ii) firm age (*AGE*) (the year of observation - the year of listing), (iii) the proportion of independent directors among the number of directors (*IBD*).

The results obtained are basically consistent with those of the main analysis. The estimated results of the variables are shown in Table 5. It can be seen that the coefficients of the interaction terms and firms' innovation activities are still significant.

V. Conclusion and policy implications

Using the "Energy-Saving and Low-Carbon Action Plan" as a natural policy experiment, this paper explores the impacts of an environmental regulation on corporate environmental performance and the mediating effect of enterprise innovation behavior. Our main findings are as follows.

Firstly, there is a significant positive relationship between the environmental regulation and corporate environmental performance, indicating that after the implementation of the "Energy-Saving and Low-Carbon Action Plan", firms improved their environmental performance by adopting actions that could save energy and reduce emissions.

Secondly, the environmental regulation has a negative effect on firms' innovation activities, indicating that the "Porter hypothesis" has not been supported by our sample data of Chinese heavy pollution industries, i.e., costly environmental regulation hinders firms from engaging in innovation activities.

Thirdly, firms' innovative activities play an indirect role between the environmental regulation and environmental performance, which is manifested as a suppression effect. The policy hinders firms' innovation activities, but the impact of these innovation activities on environmental performance is positive. The direct and indirect effects of environmental regulation on corporate environmental performance are opposite to one another. This means that when the variable of enterprise innovation behavior is controlled, the incentive effect of environmental regulation on environmental performance increases, which is reflected by the fact that the absolute value of the coefficient of γ_1 is greater than that of α_1.

By clarifying the impacts of environmental regulations and policies in the Chinese context, the above results have important policy implications. On the one hand, governments should formulate more targeted and nuanced environmental regulations and policies in light of firms' actual situations. On the other hand, environmental regulations can also inhibit firms' innovation activities, resulting in a negative impact on environmental performance. Therefore, when introducing environmental regulations, the governments should also adopt policies, such as subsidies and tax breaks, to induce firms to undertake technological innovations. Governments should give some policy support and financial rewards to enterprises with more innovation input and output, promote enterprises to adopt independent innovation and become environmentally conscious, thus forming a win-win relationship between economy development and environmental protection.

Table 5 Regression Results of Robustness Test

	Model(1) EP	Model(2) TEC	Model(3) EP
G×D	-0.000288*	-0.0271***	-0.000334**
	(-1.82)	(-2.76)	(-2.24)
TEC			0.000172*
			(-1.93)
SIZE	-0.000628**	-0.00667	-0.000639**
	(-2.51)	(-0.67)	(-2.58)
LEV	-0.000603	-0.0179	-0.00634
	(-1.14)	(-0.77)	(-1.20)
ROE	-0.00177	0.0376	-0.00170
	(-1.23)	(0.50)	(-1.20)
GROWTH	-0.000344**	-0.00344	-0.000349**
	(-2.07)	(-0.60)	(-2.12)
STATE	0.000865***	-0.0401***	-0.00101***
	(-3.95)	(-2.65)	(-4.31)
LS1	0.00121	0.0143	0.00123
	(1.12)	(0.28)	(1.16)
AGE	0.0000357	0.0110***	0.0000547
	(0.63)	(3.20)	(0.98)
IBD	-0.000264	-0.0755*	-0.000394
	(-0.33)	(-1.69)	(-0.51)
_cons	0.0161***	0.234	0.0165***
	(2.88)	(1.07)	(2.96)
year	yes	yes	yes
firm	yes	yes	yes
N	865	865	865
R2	0.137	0.448	0.145

Note: t values for each coefficient are shown in parentheses, and ***, **, and * indicate the significance levels of 1%, 5%, and 10%, respectively.

Notes

1) According to the stock listing rule of Shanghai and Shenzhen Stock Exchanges in China, the stocks of the listed companies identified with abnormal financial conditions or other abnormal conditions would be given special treatment (ST) or delisting risk warning in order to indicate the risk to investors. “ST” or “*ST” will be prefixed with the short name of a stock receiving special treatment or delisting risk warning.

2) Existing measurement indicators include pollutant emissions, investment amount, per capita income level, the number of environmental regulation policies, and the implementation of a specific policy.

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