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Original Research

The Impact of Environmental Regulatory Instruments on Firm Investment Efficiency: Evidence from Chinese Listed Heavy Polluters

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Abstract

Environmental regulation policies demonstrate a tendency toward diversification, and different environmental regulation tools have different effects on the investment efficiency of heavy polluters. Little is known about the effect of various forms of environmental restrictions on the efficacy of company investment. This paper uses a fixed-effects model and a threshold-effects model to investigate the differential effects and synergies of environmental regulatory instruments on firms' investment efficiency using a sample of Chinese heavy polluters listed on A-shares in Shenzhen and Shanghai between 2011 and 2019. According to the study's findings, command-and-control environmental regulations have a considerable detrimental impact on the investment efficiency of state-owned heavy polluters. Market-incentivized environmental regulations significantly increase the efficiency of investment by heavy polluters, and the effect is successful in the long run. Further analysis reveals that command-and-control environmental regulations and market-incentive environmental regulations influence each other; there is a threshold effect for one environmental regulation when another environmental regulation influences the investment efficiency of heavy polluters. The two types of environmental regulations also play a synergistic role within a reasonable intensity to improve the investment efficiency of heavily polluting enterprises. The study's findings provide empirical evidence for firms to improve their ability to respond to external environmental policy changes in pursuit of high-quality development, as well as guidance for governments to optimize environmental regulation policies and better coordinate the use of environmental regulation tools to achieve better environmental and economic benefits.

Keywords: command-and-control environmental regulation, market-incentivized environmental regulation, investment efficiency, threshold effect

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Introduction

From a worldwide perspective, investment is one of the three central issues in the financial theory of corporate finance, along with investment and dividend distributions. From a macro perspective, investment, consumption, and exports are the driving forces of economic growth. From a micro perspective, investment is the source of company growth, the foundation of future cash flow growth, and the key to enhancing corporate value. The investment level of enterprises influences the country's overall investment level, and the micro subjects' investment behavior deserves attention.

Since 2011, China's GDP growth rate has increased somewhat, as a general trend of protracted slowing and economic development enters a new normal in pursuit of high quality and efficiency. With this change in the economic growth model, environmental protection has also made considerable strides, and numerous environmental regulation tools coexist, showing a trend of policy diversification [1]. The "Action Plan for Carbon Peaking by 2030" was announced in October 2021 by the State Council. Its main requirement is to promote economic and social growth based on the effective use of resources and green low-carbon development and achieve the goal of carbon peaking by 2030. This situation indicates that environmental protection in China has entered a new stage, characterized by diverse and rationalized means of environmental regulation and an increasing intensity of regulation. Changes in the external policy environment have a significant influence on microeconomic agents, and the efficiency of corporate investment, which is a driving force of future growth, is particularly crucial for the survival and development of businesses. For this class of enterprises, which is more influenced by external environmental regulation policies, exploring the impact of environmental regulation tools on their investment efficiency is of representative importance and is conducive to exploring a balanced model of enterprise development and environmental protection, which is a crucial issue for the current sustainable development of heavily polluting enterprises.

Environmental regulation tools are potent instruments for governments to achieve environmental regulation policies and can provide effective incentives for companies to fulfill their environmental responsibilities. External environmental regulation has a complicated effect on businesses; on the one hand, environmental responsibility raises the expense of pollution management and institutional compliance, constraining regular investment and resulting in inefficient investment [2]. On the other hand, Porter's hypothesis suggests that various environmental regulations have varying effects on fostering technical innovation in businesses. Compared to command-and-control environmental regulations, market-incentive environmental regulations are more likely to stimulate enterprise technological innovation, the upgrading of equipment, and the improvement of technology to reduce the high costs caused by environmental regulations, and the innovation compensation effect is more pronounced for increasing the efficiency of enterprise investment [3]. How do the impacts of various types of environmental regulation instruments on the investment efficiency of businesses differ? Are there synergies between various sorts of environmental regulatory tools?

To answer the above questions, this paper selects a sample of Chinese listed heavy polluters in A-shares in Shenzhen and Shanghai from 2011-2019 and employs a fixed effects model with a threshold effect model. It is found that (1) command-and-control environmental regulation instruments have a significant negative impact on the investment efficiency of state-owned heavy polluters but have no significant impact on the investment efficiency of non-state-owned businesses. (2) The effect of market-motivated environmental regulatory tools on the investment efficiency of major polluters is long-term and significant. (3) There is a threshold effect for one environmental regulatory instrument when another environmental regulatory instrument influences the investment efficiency of heavily polluting firms; the command-and-control and market-incentive environmental regulation tools play a synergistic role within a reasonable intensity to improve the investment efficiency of heavy polluters. Compared to those of past research, the potential contributions of this article include the following: (1) A comparative analysis of the effects of different types of environmental regulatory instruments on the efficacy of corporate investment, complementing and extending the study of the effect of environmental regulation on corporate growth. (2) Considering that the role of different environmental regulatory tools is not isolated, the interaction between environmental regulatory tools is studied to provide future governments with a reference for optimizing the relevant environmental regulatory policies and utilizing different environmental regulatory tools to achieve greater environmental and economic benefits.

Literature Review

Existing research on the effect of environmental regulations on the efficiency of corporate investment may be categorized into two primary areas. On the one hand, there is the effect of overall environmental regulation on corporate investment efficiency. Regarding the impact of global environmental regulation on the efficiency of corporate investment, there are now a variety of scholarly perspectives. On the basis of the "innovation compensation effect," some academics contend that environmental legislation can increase the efficiency of business investment. Li et al. argue that the government's environmental regulatory policy is a mandatory legal obligation that might drive the investment behavior of businesses. For instance, enterprises that meet certain

criteria can issue green securities and green credit for financing; these criteria encourage them to pay attention to environmental issues, consciously reduce pollutant emissions, and commit to upgrading environmental protection equipment, thus solving their financing dilemma via external financing for projects with positive net present value and alleviating the shortage of capital [4]. Cao et al., using the new Environmental Protection Law as a quasinatural phenomenon, found that environmental regulation has a significant enhancement effect on the investment efficiency of heavily polluting firms, but that the effect is only significant for large-scale firms, competitive industries, and favorable legal environments. In contrast, some scholars have suggested that lenient environmental rules lower the burden on businesses, lessen external environmental uncertainties, and enhance the investment efficiency of businesses [5]. Dong et al. discovered that after Canada's departure from the Kyoto Protocol, more permissive environmental rules had a substantial beneficial effect on the investment efficiency of oil and gas corporations, with this effect being more prominent among firms with lower investment efficiency [6]. Kong et al. argued that uncertainty in external economic policies might diminish the extent and efficiency of business investment and exacerbate the risk of over- or underinvestment [7]. In addition, some academics have contended that different environmental regulatory policies have varying effects on the effectiveness of business investment. Farooq et al. proved that government environmental restrictions significantly impact the investment decisions of businesses. Carbon tax policies have a detrimental effect on company investment, but renewable energy generation, renewable energy consumption, and green growth productivity all have a positive effect on real business investment [8].

On the other hand, there is the effect of specific environmental regulatory instruments on the investment efficiency of enterprises, particularly market-based instruments. Chang et al. using firm-level data on renewable energy, discovered that government subsidies and rebate programs greatly increased the efficiency of enterprises' technical investments [9]. Yu et al. discovered that environmental management systems can improve the effectiveness of corporate investment, primarily by reducing corporate underinvestment [10]. Zhang et al. discovered that green credit policies can improve the efficiency of enterprises' overseas investment, especially for state-owned enterprises and enterprises in low environmental regulation areas [11]. Nga claimed that green banking efficiently balances the costs of the economic and environmental advantages of business in banking operations and contributes to the stability and sustainability of company development and the country's economy as a whole [12]. Chen et al. studied the effect of the ETS (carbon emissions trading system) on firms' investment efficiency and discussed the heterogeneous effects under different levels of corporate governance and property rights. They discovered that the ETS improves firms' overall investment efficiency, particularly by reducing overinvestment. This connection is particularly significant at higher levels of corporate governance and state-owned firms [13].

Scholars have examined the impact of several specific environmental regulation tools on corporate investment efficiency; opinions still differ on the impact of overall environmental regulation on corporate investment efficiency, yet few studies have examined the differences in the impacts of different types of environmental regulation tools. In addition, the majority of studies have adopted a comparison viewpoint, but few studies have been conducted on the synergistic relationship between various types of environmental regulatory instruments. Consequently, this paper explores the differential impact of various types of environmental regulation instruments on the efficiency of corporate investment and its synergistic effects, enriching the research on the relationship between environmental regulation and corporate investment efficiency.

Theoretical Analysis and Research Hypothesis

The classification of environmental regulation differs according to different perspectives. Environmental regulation is divided into two categories: explicit environmental regulation and invisible environmental regulation [14]. Explicit environmental regulation refers to a binding force in tangible laws, regulations, and agreements, whereas invisible environmental regulation refers to the intangible environmental ideology embedded in individuals. Explicit environmental regulations can be further divided into command-and-control, market-incentive, and voluntary participation environmental regulations. Command-and-control environmental regulation refers to the government and national legislature's administrative legislation and regulations that restrict enterprises' use of environmental resources; market-based incentive environmental regulation is designed based on the "polluter pays" principle and uses market-based incentives to guide enterprises to reduce pollution; and voluntary participation environmental regulation refers to agreements, promises, or plans to safeguard the environment in which firms seek to participate voluntarily. This paper focuses on command-and-control environmental regulations and market-incentive environmental regulations since voluntary and invisible environmental regulations are not sufficiently practiced in China and there is no reliable mechanism by which to measure them [15].

Command-and-control environmental regulations are mandatory and binding. From the perspective of investment cost, the production of heavily polluting enterprises is accompanied by the consumption of resources and the emission of pollutants. According to environmental policy, enterprises will incur certain costs, such as investment in environmental protection

equipment to meet environmental standards or payment of certain fines for noncompliance with environmental standards, resulting in an increase in costs and a decrease in profitability [16-18]. From the perspective of investment opportunities, the original investment opportunities of enterprises are no longer feasible due to the implementation of environmental impact assessment policies and relevant policy regulations, which forces polluting enterprises to lose investment opportunities and reduce investment efficiency. From the perspective of policy risk, environmental policies are uncertain, and enterprises choose to delay investment to avoid losses due to violations of environmental policy, thus missing the optimal moment to invest and reducing the efficiency of enterprise investment [19,20]. Most of the relevant laws and regulations are long-term and will continue to affect enterprises' investment behavior in the present and future, while the uncertainty of environmental policies will continue to have an impact over time. Therefore, this paper proposes the following hypothesis:

Hypothesis 1: Command-and-control environmental regulations have a negative effect on the investment efficiency of heavy polluters, and this effect has a lag.

Market-incentive-based environmental regulation is flexible and noncoercive. From the perspective of investment cost, tax relief policies and financial subsidies for environmental protection projects of heavy polluters reduce the pressure of enormous costs invested by enterprises for green production and increase production profits. In contrast, the policies of green credit and green securities provide cheap external financing for heavy polluters to invest in green projects and reduce financing costs, hence decreasing enterprise investment costs. From the perspective of investment opportunities, the inclination of government funds and policy preferences toward green projects has created new investment opportunities [21]. From the perspective of information asymmetry, carbon trading policy reduces the information asymmetry among enterprises and alleviates their policy burden by constructing a trading market while promoting a good allocation of market resources and improving their investment efficiency. Environmental protection taxes, emission fees, and other instruments not only directly affect the production costs of enterprises in the current period but also have a continuous impact on the investment opportunities and investment behavior decisions of enterprises in the future period. Based on this relationship, this paper proposes the following hypothesis:

Hypothesis 2: Market-incentive-based environmental regulations have a positive effect on the investment efficiency of heavy polluters, and this effect has a lag.

While pursuing resource conservation and environmental protection, the government also considers the efficiency of enterprises and leaves leeway for the survival and development of heavy polluters. Therefore, the implementation of environmental regulation policies is seldom isolated; it often combines command-and-control environmental regulation and market-incentive environmental regulations to achieve the common goal of environmental protection and enterprise development. For example, in 2015, the Ministry of Environmental Protection issued the Work Plan for the Comprehensive Implementation of Ultralow Emission and Energy Conservation Transformation of Coal-fired Power Plants, which requires coal-fired power plants to install desulfurization, denitrification, and dust removal equipment, eliminate backward production capacity and units that do not meet relevant mandatory standards, and simultaneously give subsidies for electricity tariffs, incentivize power generation, halve emission fees, and provide special funds for air pollution to sustain business survival and development. Different types of environmental regulation tools have their own requirements. The effect of one environmental regulation tool on the efficiency of enterprise investment may be affected by the simultaneous implementation of another environmental regulation tool. For example, the effect of command-and-control environmental regulation on the investment efficiency of heavy polluters may be influenced by the simultaneous existence of a market-incentive type of environmental regulation. Based on this relationship, this paper proposes the following hypothesis:

Hypothesis 3: Interactions occur between different types of environmental rule tools.

Materials and Methods

Model Setting

The majority of panel data models are used to investigate regression correlations between several variables, with one factor serving as the explanatory variable and the rest serving as response variables, with linear and nonlinear relationships between the variables. This study includes several variables, and the data contain both firm cross-sectional and time-series dimensions; hence, a panel data model is used. The Hausman test suggests that the fixed effects model is applicable to this research.

Based on the above theoretical analysis, we have chosen a fixed-effects model as the basic regression model in this paper to analyze the effects of command-and-control environmental regulations and market-incentive environmental regulations on the investment efficiency of heavy polluters.

$$Eff_{it} = \alpha_0 + \alpha_1 \cdot ER_{i,t-j} + \alpha_2 \cdot Size_{it} + \alpha_3 \cdot Cash_{it} + \alpha_4 \cdot Lev_{it} + \alpha_5 \cdot Rota_{it} + \alpha_6 \cdot Soe_{it} + \alpha_7 \cdot Patrnt_{it} + \alpha_8 GDP_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

In equation (1), i denotes a firm, t denotes a year, μ_i denotes individual differences that do not change over time, and ε_{it} is a random error term. Eff_{it} denotes a firm's investment efficiency; the greater Eff_{it} is, the

higher the investment efficiency of the firm. $ER_{i,t-j}$ is the environmental regulation, including command-and-control environmental regulation (Eoer) and market-incentive environmental regulation (Mier); the higher the value is, the stronger the environmental regulation. j denotes the number of impact delays. α_1 denotes the impact coefficient of environmental regulation intensity on enterprise investment efficiency, with a positive value indicating a positive imp act and a negative value indicating a negative impact.

The panel threshold model can capture rapid changes in the sample data and handle nonlinearities produced by variable jumps or structural breakdowns in regression analysis. Compared to adding squared terms, the performance of the panel threshold model is superior, while the problem of collinearity between explanatory variables and their squared terms is successfully avoided. To further examine whether the two types of environmental regulation instruments interact, a panel threshold model (2) with firm investment efficiency as the dependent variable, one type of environmental regulation as the independent variable, and the other type of environmental regulation as the threshold variable is established based on Equation (1) to explore the nonlinear effects of the other type of environmental regulation on firm investment efficiency when one type of environmental regulation is at the threshold. The specific model is as follows:

$$efficiency_{it} = \alpha_0 + \alpha_{11} \cdot ER_{i,t} * I(v_{it} \le \eta) + \alpha_{12} \cdot ER_{i,t} * I(v_{it} > \eta) + \alpha_2 \cdot Size_{it} + Cash_{it} + \alpha_4 \cdot Lev_{it} + \alpha_5 \cdot Rota_{it} + \alpha_6 \cdot Soe_{it} + \alpha_7 \cdot Patrnt_{it} + \alpha_8 GDP_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

(2) In the equation, I(·) is the indicative function, v_{it} is the threshold variable, and in this paper, environmental regulation intensity is the threshold variable and η is the threshold value.

Variable Definitions

Explained Variables

Corporate investment efficiency refers to the extent to which the actual investment size of a company matches the optimal investment size. Referring to Richardson and Huo's study [22, 23], this paper measures the size of corporate investment using three indicators, net investment in fixed assets, net intangible assets, and net other assets of assets at year-end, and constructs an optimal investment model containing explanatory variables related to investment opportunities, gearing, cash flow, firm size, firm operating life, and stock returns, utilizing residuals to measure the efficiency of corporate investment. The specific model is as follows:

$$Invest_{i,t} = \beta_0 + \beta_1 Growth_{i,t-1} + \beta_2 Lev_{i,t-1} + \beta_3 Cash_{i,t-1} + \beta_4 Age_{i,t-1} + \beta_5 Size_{i,t-1} + \beta_6 Returns_{i,t-1} + \beta_7 Invest_{i,t-1} + \sum Industry + \sum Year + \varepsilon_{i,t} \quad (3)$$

Invest is the magnitude of the corporate investment size. Growth is the firm's growth level, measured by the operating income growth rate. Lev is the gearing ratio. Cash is the cash holding level. Age is the number of years the firm has been listed. Size is the firm's size. Return is the firm's annual rate of return. The residuals ε represent the enterprise's inefficient investment, and the opposite of the absolute value of ε is used to indicate the efficiency of corporate investment; the higher the value is, the more efficient the corporate investment.

Core Explanatory Variables

The current research measures environmental regulation primarily from two perspectives: one is performance-based, in which scholars use indicators such as industrial wastewater compliance rate and total solid waste utilization rate to measure the intensity of environmental regulation [24], which is suitable for measuring the overall intensity of environmental regulation. The other is input-based, wherein researchers select input indicators such as total investment in industrial pollution control to measure the intensity of environmental regulation, which is suitable for the measurement of categorical environmental regulation intensity [25-27]. This research selects input-based indicators to measure the intensity of environmental regulation tools separately. Using Wang's technique [28] as a reference, an indicator system is developed, and the entropy method is employed to measure the two types of environmental laws. Due to the difficulty of data collection and the nondisclosure of certain indicators by the state, the following three indicators are selected to measure command-and-control environmental regulation. (1) The number of people in the environmental protection system at the end of the year. The staff of the environmental protection system is the support system for the successful implementation of the command-based environmental regulation policy, and a higher number of staff indicates that the government places a greater emphasis on the implementation of environmental regulation and the intensity of regulation. (2) The number of environmental administrative penalty cases, which is a direct measure of the intensity of regulation. (3) The number of environmental regulations and government rules reflects the government's attention and focus; the higher the number is, the stricter the environmental controls. (4) Industrial pollution control investment refers to the overall amount of investment in different regions to control the industrial "three wastes" and other potential environmental contamination; the more investment there is, the stricter the environmental regulation. Restricted

by data availability and the consistency of disclosure quality, this paper selects the following two metrics to assess market-based environmental regulation. (1) Emission fee revenue (environmental protection tax). In general, the higher the emission charge is, the more stringent the environmental regulations in the region. China ceased collecting pollution fees in favor of environmental taxes in 2018. Hence, figures after 2018 employ an environmental protection tax. (2) Resource tax. Environmental control is more stringent when resource taxes are levied at a higher rate. The system of environmental regulation indicators is shown in Table 1.

Control Variables

This study selects the following two categories of control variables, taking into account the company itself and its location. First, there are firm-level control variables. (1) Enterprise growth. It is commonly assumed that the higher the revenue growth rate of an enterprise, the more probable it is to have short-term investments, which reduce investment efficiency. (2) Enterprise size. A company's size dictates the amount of resources it possesses and its propensity to expand, which in turn influences its investing behavior. (3) Corporate cash holdings. A larger free cash flow suggests that there may be agency issues for management, limiting investments that are less efficient. (4) Corporate Debt Ratio. Companies with higher debt ratios can compensate for their resources and mitigate underinvestment. (5) Return on total assets. Businesses with greater profitability are more likely to experience fast expansion accompanied by increased investments. (6) Nature of enterprise property rights. State-owned and non-state-owned enterprises have different development strategy goals, which affect investment decisions. (7) The level of green innovation technology. The innovation compensation effect of enterprises with a higher innovation level is obvious and affects the efficiency of investment. Second, the control variables are at the provincial (municipal) level. Considering that the primary explanatory variable is the intensity of environmental regulation in the region where the enterprise is located and that there are significant differences in the level of economic development and industrial structure between regions, this paper adds the regional development level variable to control the regional effect. The symbols and explanatory notes for the specific variables are shown in Table 2.

Data Source and Processing

The firm-level data in this study originate from the China Securities Market and Accounting Research Database (CSMAR) and the China Research Data Service Platform (CNRDS), while the data at the provincial (city) level come from the China Environment Yearbook and the China Statistical Yearbook. Since the China Environment Yearbook is currently updated only through 2019, data on various indicators measuring environmental regulations beyond 2019 are unavailable; therefore, this paper selects data on heavily polluting enterprises listed in Shenzhen and Shanghai A-shares from 2011-2019 to measure the impact of environmental regulations on the investment efficiency of heavily polluting enterprises.

Considering the reliability of the data, the original data are filtered as follows in this paper: (1) Nonregularly traded enterprises such as ST, ST*, and PT were excluded. (2) Samples with missing data were excluded. (3) Companies with business locations in Tibet were deleted because there were no data for Tibet in the government environmental regulation data. (4) To eliminate the influence of outliers, all data in this study were subjected to an upper and lower 1% tailing. A total of 3906 panel data points from 434 heavily polluting enterprises were finally obtained.

For the screening of heavily polluting enterprises, according to the "Guidelines for Industry Classification of Listed Companies" revised by the China Securities Regulatory Commission in 2012, the "List of Listed Companies' Environmental Verification Industry

Table 1. Environmental regulation index system.

Type of regulation	Selected indicators	Properties	Indicator Meaning
Command and control type	Number of people in the environmental protection system at the end of the year (pcs)	Positive	Total number of people in the environmental protection system at the end of the year
	Number of environmental administrative penalty cases (cases)	Positive	Number of cases with administrative penalties for environmental incidents in the current year
	Number of environmental regulations and administrative rules (pcs)	Positive	Number of currently effective environment-related laws and regulations and administrative regulations
	Industrial pollution control investment (million yuan)	Positive	The total amount of investment in the treatment of industrial "three wastes" and other possible environmental pollution in that year
Market incentive type	Sewage discharge fee (environmental protection tax) (million yuan)	Positive	Total amount of sewage charges (environmental protection tax) collected and deposited in the current year
	Resource tax (million yuan)	Positive	Total resource tax collected in the year

Table 2. Control variables.

Variable Name	Variable Symbols	Explanatory notes
Business growth	Growth	Enterprise revenue growth rate for the year
Enterprise size	Size	Log of total assets of the enterprise for the year
Corporate cash holdings	Cash	Ratio of monetary funds and financial assets held for trading to total corporate assets
Corporate debt ratio	Lev	Total liabilities divided by total assets
Return on total assets	Rota	Net income divided by total assets
Nature of business ownership	Soe	Whether the proportion of state-owned shares in the enterprise exceeds 50% is assigned; if yes, it is defined as 1, otherwise it is 0
Green innovation technology level	Patent	Enterprise green patent ownership
Regional development level	GDP	Gross regional product of enterprise location

Classification Management" formulated by the Ministry of Environmental Protection in 2008, and the "Guidelines for Environmental Information Disclosure of Listed Companies", the heavily polluting industries consist mostly of the coal, mining, textiles, tanneries, paper, petrochemical, pharmaceutical, chemical, metallurgical, and thermal power industries, as well as 16 others. After screening, this paper selects B06, B07, B08, B09, B10, B12, C15, C17, C19, C22, C25, C26, C27, C28, C29, C30, C31, C32, and D44 for a total of 19 categories of heavily polluting enterprises.

Descriptive Statistics

Table 3 presents descriptive statistics for all variables, where the mean value of corporate investment efficiency is 0.9621, the median is 0.9756, the standard deviation is 0.0456, and the maximum and minimum values are 0.9996 and 0.7163, respectively. This finding indicates that the investment efficiency of heavily polluting enterprises has a certain gap within the sample, and although most of them have a certain degree of inefficient investment problems, the overall level is high. The mean value of command-and-control environmental regulation intensity is 0.0041, the median value is 0.0031, the standard deviation is 0.0027, and the maximum and minimum values are 0.0120 and 0.0005, respectively, indicating that the intensity of the command-and-control environmental regulation to which the company is subject varies to some extent within the sample. The mean value of market-incentivized environmental regulation intensity is 0.0038, the median value is 0.0023, the standard deviation is 0.0037, and the maximum and minimum values are 0.0219 and 0.0001, respectively, indicating that within the sample, the intensity of the market-incentivized type of environmental regulation to which the business is subject changes more than the command-and-control type. The mean value of the enterprise green innovation technology level is 1.2268, the median is 0, the standard deviation is 4.6764, and the maximum and minimum values are 37 and 0, respectively, which show

Table 3. Descriptive statistics.

Variable	N	Mean	p50	sd	Max	Min
Eff	3906	0.9621	0.9756	0.0456	0.9996	0.7163
Eoer	3906	0.0041	0.0031	0.0027	0.0120	0.0005
Mier	3906	0.0038	0.0023	0.0037	0.0219	0.0001
Growth	3906	0.1366	0.0713	0.4139	2.7267	-0.5576
Size	3906	22.6864	22.5528	1.3588	26.4119	19.8522
Lev	3906	0.4965	0.5021	0.2090	0.9796	0.0625
Cash	3906	0.1372	0.1116	0.1016	0.5099	0.0087
Rota	3906	0.0336	0.0272	0.0638	0.2260	-0.2243
Soe	3906	0.6633	1.0000	0.4726	1.0000	0.0000
Patent	3906	1.2268	0.0000	4.6764	37.0000	0.0000
GDP	3906	32723.54	26392.07	22251.67	99631.52	2522.66

that the level of green technology innovation in heavily polluting enterprises varies widely and is generally low. All other variables fall within acceptable limits.

Results and Discussion

Basic Regression Analysis

Before a regression analysis was performed, an inflated factor test was performed on each variable. The highest variance inflation coefficient (VIF) of each variable in Table 4 is 2.9, which is much less than 10, suggesting that there is no multicollinearity between the variables and that the regression findings are accurate and genuine.

Table 5 reports the regression results of command-and-control environmental regulations and market-incentive environmental regulations on the investment efficiency of heavily polluting firms. In the current period as well as the lagged period, the regression coefficient is negative when command-and-control environmental regulation is the explanatory variable, but the results are not significant, indicating that there is no significant effect of command-and-control environmental regulation on the investment efficiency of heavily polluting enterprises, and hypothesis one is not tested. To investigate the reasons for this result, the sample is divided into two groups of non-state enterprises (Soe = 0) and state enterprises (Soe = 1) for regression; the regression results are shown in Table 6. The analysis shows that the effect of command-and-control environmental regulation on the efficiency of firms' investments is not significant when the sample is non-state enterprises. When the sample is SOEs, the regression coefficient is -0.991 at the 10% significance level, indicating that command-and-control environmental regulation has a significant negative effect on the investment efficiency of state-owned heavy polluters. The main reason for this result is that different equity types of firms have different behavioral characteristics when facing environmental regulations. Compared to non-SOEs, SOEs play a crucial role in meeting government requirements and achieving policy goals due to their unique political relevance, pursuing the fulfillment of political expectations, linking business goals to government will, and providing feedback on various environmental regulation policies. They are also more vulnerable to the impact of environmental regulations on the efficiency of corporate investments [29, 30]. The development of China's major polluters is often dependent on resource and energy inputs. The more command-and-control management of the environment there is, the higher the cost of resource consumption and the cost of pollution emissions for businesses, which eventually results in higher production costs. Simultaneously, in the current transformation of China's economic development, state-owned enterprises actively assume social responsibility and are strongly motivated by the desire to innovate, with more funds invested in equipment upgrades and technology research and development, thus squeezing out normal investment and reducing investment efficiency. In conclusion, command-and-control environmental regulation has a negative effect on the investment efficiency of state-owned heavy polluters.

Table 4. Variance inflation coefficient.

Variable	VIF	1/VIF
Eoer	2.90	0.344961
GDP	2.65	0.377804
Lev	1.64	0.611426
Rota	1.51	0.663993
Size	1.47	0.680073
Mier	1.24	0.805542
Cash	1.21	0.828949
Patent	1.20	0.834953
Soe	1.14	0.877387
Growth	1.06	0.939490
Mean VIF	1.60	

The regression coefficient is 2.81 at a 1% level of significance when market incentive-based environmental regulation is the explanatory variable in the current period, indicating that market-incentive environmental regulation significantly and positively affects the investment efficiency of heavy polluters, and the higher the intensity of regulation is, the higher the investment efficiency. In the lag period, the regression coefficient is 2.20 at the 5% significance level, and the coefficient value is smaller than in the current period, indicating that market-incentive environmental regulation has a continuous effect on the investment efficiency of enterprises and that the degree of this effect decreases over time. This result occurs because market-incentivized environmental legislation employs incentives to encourage businesses to actively save energy, decrease emissions, and pursue development via technology. Enterprise expenses are compensated through government subsidies, tax rebates, technical assistance, etc. A carbon trading market is created that reduces information asymmetry and alleviates financial strain. Policy funds are tilted toward green projects and thus bring more investment opportunities, all of which effectively reduce inefficient corporate investments. Market-incentivized environmental regulation accounts for enterprises' own interests and development while pursuing environmental protection, alleviates the development pressure brought by enterprises' environmental transition with government power, improves the efficiency of enterprises' investment, and helps enterprises achieve green and sustainable development.

Table 5. Regression results.

J	j = 0		j = 1		J = 2
VARIABLES	Eff	Eff	Eff	Eff	Eff
Eoer	-0.617				
	(-1.11)				
Mier		1.088***			
		(2.81)			
L.Eoer			-0.805		
			(-1.60)		
L.Mier				0.988**	
				(2.20)	
L2.Mier					0.771
					(1.58)
Growth	-0.030***	-0.030***	-0.030***	-0.030***	-0.028***
	(-8.25)	(-8.27)	(-7.68)	(-7.64)	(-6.50)
Size	-0.003	-0.004	-0.005	-0.005	-0.009**
	(-1.08)	(-1.21)	(-1.42)	(-1.45)	(-2.17)
Lev	-0.006	-0.005	-0.006	-0.005	-0.003
	(-0.57)	(-0.48)	(-0.45)	(-0.40)	(-0.20)
Cash	-0.035**	-0.035**	-0.040**	-0.040**	-0.047**
	(-2.36)	(-2.38)	(-2.37)	(-2.41)	(-2.47)
Rota	-0.057***	-0.056***	-0.053**	-0.053**	-0.054**
	(-3.00)	(-2.95)	(-2.50)	(-2.52)	(-2.25)
Soe	0.018**	0.018**	0.023***	0.023***	0.019**
	(2.45)	(2.41)	(3.09)	(3.01)	(2.39)
Patent	0.000	0.000	0.000	0.000	0.000
	(1.46)	(1.58)	(1.00)	(1.10)	(1.25)
GDP	0.000***	0.000***	0.000***	0.000***	0.000***
	(4.30)	(3.76)	(4.34)	(3.86)	(3.52)
Constant	1.021***	1.026***	1.056***	1.055***	1.147***
	(16.30)	(16.23)	(14.30)	(14.20)	(12.98)
Observations	3,906	3,906	3,472	3,472	3,038
R-squared	0.114	0.116	0.120	0.121	0.115
Number of stkcd	434	434	434	434	434
F test	0	0	0	0	0
r2_a	0.112	0.114	0.118	0.119	0.112
F	15.53	15.65	12.98	12.98	9.972

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 6. Grouping regression result.

	Soe = 0	Soe = 1
Variables	Eff	Eff
Eoer	0.858	-0.991*
	(0.64)	(-1.73)
Growth	-0.029***	-0.030***
	(-5.57)	(-5.67)
Size	0.001	-0.004
	(0.31)	(-0.99)
Lev	-0.003	0.003
	(-0.15)	(0.18)
Cash	-0.050*	-0.024
	(-1.91)	(-1.45)
Rota	-0.094***	-0.033
	(-2.76)	(-1.48)
Patent	0.001	0.000
	(0.96)	(1.28)
GDP	0.000*	0.000***
	(1.74)	(3.65)
Constant	0.927***	1.047***
	(9.93)	(12.25)
Observations	1,315	2,591
R-squared	0.119	0.098
Number of stkcd	165	304
F test	8.86e-09	0
r2_a	0.114	0.0954
F	7.736	9.774

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Threshold Effect Analysis

Before conducting the threshold regressions, the presence of threshold effects and the number of thresholds were first tested. The results are shown in Table 7. The double threshold test is not significant when the explanatory variable is command-and-control environmental regulation and the threshold variable is market-incentive environmental regulation. The single threshold test, with a p value of 0.0167, indicates that there is a threshold effect based on market incentive-based environmental regulation when command-and-control environmental regulation affects the investment efficiency of heavy polluters at a significance level of 5% and a threshold value of 0.0115. When the explanatory variable is market incentive-based environmental regulation and command-and-control environmental rules are the threshold variable, the p value for a single threshold test is 0.0833, indicating that there is a threshold effect based on command-and-control environmental regulation when market incentive-based environmental regulation affects the investment efficiency of heavy polluters at the 10% significance level with a threshold value of 0.0006. The test demonstrates that command-and-control environmental regulation and market-incentive environmental regulation influence each other while also affecting the investment efficiency of heavy polluters; thus, conducting separate threshold regressions for these regulations has a scientific basis.

The regression results are shown in Table 8. When the core explanatory variable is command-and-control environmental regulation, the regression coefficient is negative, and the effect is not statistically significant when the intensity of market incentive-based environmental regulation is less than the threshold value of 0.0115. When the intensity of market incentive-based environmental regulation exceeds the threshold value of 0.0115, command-and-control environmental regulation positively affects the investment efficiency of heavily polluting enterprises at a significance level of 10%, and the direction of the influence of command-and-control environmental regulation on the investment efficiency of enterprises reverses. This result may occur because when market incentive-based environmental regulations reach a certain intensity, the advantages offered to enterprises, such as low-cost external financing and tax incentives, effectively buffer the negative consequences of rising production costs for firms. Moreover, with strong incentives, the command-and-control regulatory environment may play a greater role in promoting enterprise innovation and technical upgrading, as well as the innovation compensation effect.

When the core explanatory variable is market-incentivized environmental regulation and when the intensity of command-and-control environmental regulation is less than the threshold value of 0.0006, market-incentivized environmental regulation has a positive effect on the investment efficiency of heavily polluting enterprises at the 1% significance level, with a coefficient value of 68.521. When the intensity of command-and-control environmental regulation is greater than the threshold value of 0.0006, market-incentive environmental regulation still positively affects the investment efficiency of heavily polluting enterprises at the 1% significance level, but its coefficient value is 1.091, which indicates that the promotion effect of market-incentive environmental regulation on the investment efficiency of heavily polluting enterprises is diminished. To analyze the reasons for this relationship, the spillover effects of command-and-control environmental regulatory tools are considered. As the intensity of command-and-control environmental regulations increases, the cost burden on firms increases, and the role of market-incentive environmental regulations in influencing firms' investment efficiency is limited.

Table 7. Threshold effect test.

Explained variables	Threshold variables	Models	Threshold value	F value	P value	Threshold value		
						10%	5%	1%
Eoer	Mier	Single threshold	0.0115	14.91	0.0167	9.937	12.359	15.850
		Double threshold	0.0003	3.55	0.7833	13.624	21.844	43.773
Mier	Eoer	Single threshold	0.0006	10.18	0.0833	9.977	11.172	16.153
		Double threshold	0.0020	9.79	0.1467	12.162	14.266	21.875

Table 8. Threshold regression results.

Explained variables	Eoer	Mier
0b._cat#c.Eoer	-0.677	
	(-1.21)	
1._cat#c.Eoer	2.314*	
	(1.84)	
0b._cat#c.Mier		68.521***
		(3.06)
1._cat#c.Mier		1.091***
		(3.08)
Growth	-0.030***	-0.030***
	(-16.90)	(-16.93)
Size	-0.003**	-0.004**
	(-2.03)	(-2.17)
Lev	-0.006	-0.006
	(-0.79)	(-0.82)
Cash	-0.035***	-0.035***
	(-3.26)	(-3.27)
Rota	-0.057***	-0.055***
	(-3.70)	(-3.58)
Soe	0.018***	0.018***
	(3.32)	(3.30)
Patent	0.000	0.000
	(1.40)	(1.46)
GDP	0.000***	0.000***
	(4.85)	(4.35)
Constant	1.028***	1.028***
	(27.38)	(27.57)
Observations	3,906	3,906
R-squared	0.116	0.118
Number of stkcd	434	434
F test	0	0
r2_a	0.00251	0.00551
F	45.28	46.46

t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

According to the above descriptive statistics, the mean value of market-incentive type environmental regulation intensity is 0.0038, the maximum and minimum values are 0.0001 and 0.0219, respectively, and the threshold value of 0.0115 is close to the right endpoint, indicating that the market incentive-based environmental regulation intensity in most of the locations of heavy polluters does not reach the threshold value and therefore fails to fulfill its intended purpose. The mean value of the command-and-control environmental regulation is 0.0041, the minimum and maximum values are 0.0005 and 0.0120, respectively, and the threshold value of 0.0006 is close to the left endpoint, indicating that the intensity of the command-and-control environmental regulation in the regions where the majority of heavy polluters are located exceeds the threshold value and acts as a suppressant. According to the above analysis, when command-and-control environmental regulation is at a low level and market-incentive environmental regulation is at a high level, the efficiency of enterprise investment can most effectively improve, which is the opposite of the current situation faced by the majority of heavy polluters in China. Therefore, when the government introduces relevant environmental regulation policies in the future, it can consider that market incentive-based environmental regulation tools play a positive role in the efficiency of enterprise investment, while command-and-control environmental regulation tools control the spillover effect, thus concurrently advancing environmental protection and enterprise development.

Robustness Tests

The choice of the measures of the explanatory variables has an important impact on the conclusions. This research chooses to replace the investment efficiency measures to test the robustness of the previous paper's empirical conclusions. In measuring enterprise investment efficiency, using the research method of Chen [31], the growth rate of sales revenue in the previous period (Growth) is used as the independent variable, and the dummy variable NEG is introduced, which takes the value of 1 if the growth rate of sales revenue is less than 0 and 0 otherwise. The model for measuring investment efficiency is designed as follows:

Table 9. Regression results.

J	j = 0		j = 1		j = 2
Variables	Eff	Eff	Eff	Eff	Eff
Eoer	-0.492				
	(-0.79)				
Mier		1.347***			
		(3.01)			
L.Eoer			-0.343		
			(-0.59)		
L.Mier				1.284***	
				(2.78)	
L2.Mier					0.853
					(1.62)

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

$$Invset_{i,t} = \beta_0 + \beta_1 Growth_{i,t-1} + \beta_2 NEG_{i,t-1} + \beta_3 Growth_{i,t-1} * NEG_{i,t-1} + \varepsilon_{i,t}$$

The regression results are shown in Table 9. Consistent with the regression results above, there is no significant effect of command-and-control environmental regulation on the investment efficiency of heavy polluters, and there is a significant positive effect of market-incentive environmental regulation on the investment efficiency of heavy polluters in both the current and lag periods. The study's conclusions pass the robustness test despite the replacement of the explanatory factors' measurements.

Conclusions

Currently, environmental laws are becoming more stringent, environmental policies are becoming more diverse, and the impact of macroenvironmental regulations on microeconomic agents cannot be ignored. Using a fixed-effects model and a threshold-effects model, this paper examines the different impacts of different environmental regulations on the investment efficiency of heavily polluting enterprises, as well as the interactions between the two types of environmental regulation instruments, using financial data of heavily polluting enterprises and environmental regulation data of their regions from 2011 to 2019. The study results are as follows: first, command-and-control environmental regulations inhibit the investment efficiency of state-owned heavy polluters, and the effect is not significant for non-state-owned firms. Second, the market incentive type of environmental regulation significantly enhances the investment efficiency of heavily polluting enterprises, and the effect is durable. Third, there is a threshold effect based on market-incentive-based environmental regulation when command-and-control environmental regulation influences the investment efficiency of heavy polluters. Above the threshold value, command-and-control environmental regulation can significantly improve the investment efficiency of heavily polluting enterprises, but most enterprises fail to achieve it. Fourth, there is a threshold effect based on command-and-control environmental regulations when market incentive-based environmental regulations impact the investment efficiency of heavy polluters. Below the threshold value, market-incentivized environmental regulations have a greater impact on enhancing the investment efficiency of heavily polluting enterprises, but most of the enterprises are larger than the threshold value.

This study makes the following policy suggestions based on the above findings. First, it is necessary for the government to formulate environmental regulation policies in a timely and appropriate manner, taking into account the survival and development of enterprises when regulating their production and operation behaviors without overintensifying the regulation to the point where it hinders the future development of enterprise investment and, by extension, regional economic growth. Second, the intensity of market-incentivized environmental regulations should be strengthened, utilizing modern market instruments such as green credit, green taxes, and carbon emissions trading, so that the government can pursue energy conservation and environmental protection while considering the interests of heavy polluters and enhancing their investment efficiency. Third, while utilizing market-based environmental regulation tools, enterprises should consider their impact on the lag period, maintain policy stability, and build a long-term control mechanism to reduce management costs while maximizing

regulatory tool efficacy. Fourth, when the government simultaneously introduces two types of environmental regulation policies that play a collaborative role, it should scientifically combine environmental regulation tools and pay attention to the intensity of the two types of regulation to keep command-and-control environmental regulation within a reasonable range and reduce its spillover effect while increasing the intensity of market-incentive environmental regulation; this tactic can support a positive regulatory role, thus maximizing its positive effect and improving the investment efficiency of heavily polluting enterprises while achieving the common development of environmental and economic benefits. Fifth, with the current pursuit of high-quality development, the continuous strengthening of environmental regulation intensity is inevitable. Heavy polluters should pay attention to environmental protection, adjust their investment strategies, and flexibly use the various market incentives introduced by the government, focusing on new investment opportunities and the long-term development of enterprises, to better cope with the short-term impact brought by the policy.

Finally, this study has certain limitations. First, due to the availability of environmental regulatory data, the sample selection for this study was limited to panel data from provinces. Future research can go further into prefecture-level cities, and more detailed data can provide a more accurate response to the specific situation. Second, due to the insufficient practice of voluntary environmental regulations in China, which makes it difficult to collect data and for which there is no reasonable measurement method, only two types of environmental regulations, command-and-control and market incentive, are examined in this paper, which is not sufficiently comprehensive. With the development of media networks and the improvement of the general quality of the public, however, the impact of voluntary environmental regulations on the efficiency of corporate investment is gradually increasing, and future studies can attempt to include voluntary environmental regulations as an indicator to improve the relevant research.

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Conflict of Interest

The authors declare no conflict of interest.

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