

The Effect and Mechanism of Regional Environmental Regulation on Corporate Green Investment Efficiency - An empirical study based on heavily polluting listed companies in Shanghai and Shenzhen A-shares

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Abstract. Based on the input-output data of Chinese A-share listed companies in the heavy pollution industry in 2018-2019, SBM-DEA model was used to measure the corporate green investment efficiency, and Tobit model was used to examine the influence mechanism of regional environmental regulation on the corporate green investment efficiency using a hierarchical multiple regression method, and finally the group regression was used to further explore according to the nature of property rights. The results show that: (1) regional environmental regulation enforcement has an inverted "U" shape effect on corporate green investment efficiency. The moderating effect shows that the inverted U-shaped relationship between regional environmental regulations and green investment efficiency is positively moderated by public concern, i.e., the inverted U-shaped relationship between environmental regulations and green investment efficiency is significantly strengthened when enterprises face stronger public concern about environmental pollution. The inverted U-shaped relationship between environmental regulation and green investment efficiency is significantly strengthened when firms face strong public concern about environmental pollution. In contrast, the moderating effect of technological innovation on this inverted U-shaped relationship is not significant. (2) The paper further finds that the inverted "U" shaped relationship between regional environmental regulations and green investment efficiency is particularly significant in non-state enterprises, and the moderating effect of public concern is also more significant in non-state enterprises. Finally, the paper puts forward relevant policy recommendations.

Keywords: Regional Environmental Regulation; Green Investment Efficiency; Moderating Effect; Environmental Protection Input; SBM-DEA; Hierarchical Regression.

1. Introduction

In recent years, China has reached a new level of attention to the environment. The report of the 19th Party Congress emphasizes the key areas, key issues and weak links of environmental protection, proposes key tasks to strengthen the management of air, water and soil pollution, and strengthens the construction of an industrial system with green, circular and low-carbon development, an ecological civilization system with both incentives and constraints, and a green action system with joint government and public governance.

Green investment, as a new investment model that can achieve sustainable economic, social and environmental development (Eyraud, 2012), becomes the key to promote the green transformation of energy-intensive enterprises (Xiao, Liming et al., 2020). In the research on green investment, some scholars introduced the concept of green investment efficiency as a measure of input-output efficiency of enterprise green investment, and combined financial information of enterprise green investment with environmental information of various pollutant emissions to achieve a non-parametric measurement and analysis of green investment efficiency at the enterprise level (Chen, Yu-Tao et al., 2020). China has introduced a large number of environmental regulation policies to urge enterprises to increase green investment efficiency, however, when making investment decisions, enterprises are also influenced by other external factors such as public concerns about pollution, and the choice between technological innovation and environmental protection investment is also considered when allocating funds. In addition, due to the special characteristics of SOEs in China's economic system, their responses to regional environmental regulations differ from those of non-SOEs. Therefore,

studying the heterogeneity of corporations' responses to regional environmental regulations can help local governments to implement more targeted and differentiated environmental policies.

Based on this, this paper selects the data of heavy polluting enterprises, measures the green investment efficiency of enterprises using SBM-DEA model, and further investigates the influence mechanism of regional environmental regulations on the green investment efficiency of enterprises using Tobit model. The marginal contributions of this paper are mainly reflected in the following three aspects (1) The research sample is novel. This paper selects micro firm-level data from 2018-2019 for the study; existing studies mostly use data from 2017 and before and focus on macro-province-level studies. (2) Using technological innovation and public concern as moderating variables, we study how regional environmental regulations affect the efficiency of corporate green investment. We explore the operation mechanism of the binary green investment portfolio of "technological innovation - environmental protection input", and investigate the effect of the green action system of government-public governance, which has some practical insights for improving the environmental governance system. (3) The inverted "U" effect of regional environmental regulation is studied from the perspective of property rights, which proves the heterogeneity of regional environmental regulation by enterprises and provides more in-depth empirical evidence for the road of environmental regulation change in China.

2. Theoretical Analysis and Research Hypothesis

2.1 The Impact of Regional Environmental Regulation on the Corporate Green Investment Efficiency.

The various environmental policy regulations set by the central government are mainly implemented by local governments in a concrete manner, so regional environmental regulations have a direct impact on the environmental behavior of enterprises. In existing literatures, most scholars have explored the impact of environmental regulation on green investment, and most have found that environmental regulation promotes firms' green investment (Du Hongwen et al. 2021; Wang Haifeng et al. 2021; Xin Yu et al. 2019), while some studies have found a non-linear relationship between environmental regulation and firms' green investment (Liu Chuanzhe et al. 2019). A few scholars have explored the impact of environmental regulation on the efficiency of corporate green investment from the perspective of efficiency, but the existing studies have not reached a consistent conclusion. "(2020) found that the implementation of the new Environmental Protection Law significantly improved the investment efficiency of heavily polluting enterprises by inhibiting over-investment. In studies on environmental regulation and corporate environmental behavior, most scholars found a nonlinear relationship between government environmental regulation and corporate environmental behavior (Yu et al., 2018; Tang et al., 2013). That is, when the strength of regional environmental regulation is within the moderate range, enterprises will actively seek efficient environmental protection inputs and reduce pollutant emissions in order to reduce environmental costs and establish a good corporate image. However, as regional environmental regulations continue to increase beyond the moderate range, enterprises, especially the heavily polluting enterprises, will not be able to efficiently balance the relationship between production necessary emissions and green emission reduction, and a decline in green investment efficiency will occur under the basic production and operation priority and performance priority. Based on this, hypothesis 1 is proposed.

H1: Regional environmental regulation has the effect of first promoting and then inhibiting the green investment efficiency of enterprises.

2.2 Moderating Effect of Public Attention

Internet information enhances public concern about environmental issues and makes public environmental participation play an increasingly important role (Li, Xin et al., 2017), which is different from formal environmental regulation led by the government, and Sun, Jinhua et al. (2021) define this type of public opinion pressure derived from public environmental demands and

participation in environmental governance actions under the role of Internet media information as informal environmental regulation. Public concern about environmental pollution, as a kind of informal environmental regulation, affects the implementation effect of formal government environmental regulation and the green behavior of enterprises, and most existing studies on public concern focus on the level of green investment rather than the efficiency of enterprises' green investment (Zhou, Hs. et al. 2022; Wu, Lipo, 2022; Sun, Jinhua et al. 2021). Zhou, Hs. et al. (2022) found that in an environmental co-governance system involving the central government, local government, and the public, local public monitoring plays a moderating role between local government strategic regulation and corporate environmental governance investment. In summary, if the production decisions of enterprises conflict with the ecological civilization demands of the public, the public will express their environmental demands through the Internet, thus creating public opinion pressure on enterprises to force them to invest in environmental protection and pollution control more efficiently. That is, public concern about environmental pollution, as a kind of informal environmental regulation, will amplify the impact of regional environmental regulation on the efficiency of enterprises' green investment. Based on this, hypothesis 2 is proposed.

H2: The relationship between regional environmental regulation and firms' green investment efficiency will be significantly strengthened when firms face stronger public concern about pollution.

2.3 Moderating Effect of Technological Innovation

The relationship between technological innovation and environmental investment under environmental regulation has not been consistently concluded by existing studies. Qin et al. (2020) argue that the marginal contribution of environmental investments to the future value growth of firms is limited, so firms are likely to focus their remaining funds on technological innovation after meeting the government's minimum environmental improvement requirements, i.e., environmental regulation increases the degree of substitution between technological innovation and environmental investment by firms in heavily polluting industries. Yang and Huidan (2021) argue that based on the Porter hypothesis, the benefits of technological innovation will offset the costs of compliance with environmental regulations under environmental regulation, resulting in an "innovation compensation effect", under which firms will take the initiative to increase green Shen et al. (2012) found that there is a "U" shaped relationship between the intensity of environmental regulation and technological innovation, and the "Porter hypothesis" can be realized only when the intensity of environmental regulation crosses a specific threshold. In this paper, we consider that at the micro-enterprise level, technological innovation is devoted to solving environmental pollution problems by optimizing and upgrading enterprise products, which has a long waiting period and uncertainty in research and development, and has a lagging effect on the environmental protection effect of enterprises; while environmental protection investment is devoted to upgrading existing equipment and production processes for pollution prevention and control, which has a more obvious effect. Therefore, the impact of technological innovation on the relationship between regional environmental regulation and the efficiency of corporate green investment is uncertain. Based on this, hypothesis 3 is proposed.

H3: The moderating effect of technological innovation on the relationship between regional environmental regulation and enterprise green investment efficiency is not significant.

3. Research Design

3.1 Model Design and Variable Descriptions

3.1.1 SBM-DEA Model

DEA method and its model have been proposed since 1978 by American operations researcher A. Charness and W.W. Cooper. DEA model is a modeling method based on linear programming in the way of distance function, which has absolute advantage in dealing with multi-indicator inputs and multi-indicator outputs. In the solution process, the DEA model evaluates the relative efficiency of

each decision making unit DMU (Decision Making Unit) and constructs the optimal production frontier, and the efficiency value of DMU on the optimal production frontier is 1; for DMU not on the optimal production frontier, the efficiency value is determined by the distance from DMU to the optimal production frontier.

In the measurement of the environmental performance of enterprises, it is usually necessary to include the consideration of the unsatisfactory non-desired output of environmental pollution emissions, therefore, this paper chooses the SBM-DEA model to measure the efficiency of the green investment of enterprises. The SBM-DEA model can differentiate the output in the directional distance function model, incorporate the non-desired output, and effectively solve the error problem brought by the slack variables, avoid the radial. The SBM model was proposed and refined by Tone (Tone, 2002) and is defined as follows.

$$\min \rho = \frac{1 - \frac{1}{m} \sum_{i=1}^m \frac{s_i^-}{x_{ia}}}{1 + \frac{1}{q_1 + q_2} \left(\sum_{r=1}^{q_1} \frac{s_r^+}{y_{ra}} + \sum_{t=1}^{q_2} \frac{s_t^{b-}}{b_{ra}} \right)}$$

$$\text{s.t. } X\mu + s^- = xa$$

$$Y\mu - s^+ = ya$$

$$B\mu + s^{b-} = ba$$

$$\mu, s^-, s^+, s^{b-} > 0$$

where ρ measures the efficiency value of the evaluated unit DMU_a; x_a , y_a and b_a represent the actual input, desired output and undesired output of DMU_a; X , Y and B are the optimal target values of input, desired output and undesired output, respectively. s^- is the slack value of input, i.e., input redundancy, which is equal to the difference between the actual input and the optimal target input; s^+ is the slack value of desired output, i.e., desired output deficiency, which is equal to the difference between the target value of desired output and the actual value; s^{b-} is the slack value of non-desired output, i.e., non-desired output excess, which is equal to the difference between actual non-desired output and the target value.

The input indicators in this paper are selected as the green investment of enterprises, i.e., environmental protection input, and the non-desired output indicators are selected as sulfur dioxide and chemical oxygen content COD, which is because sulfur dioxide is the main proxy of air pollution and chemical oxygen content COD is the main proxy of water pollution. The sample companies that disclose both SO₂ and COD are selected to provide a more representative measure of the non-expected output of green investment.

3.1.2 Tobit Model

Since the data range of corporate green investment efficiency measured by SBM-DEA is [0,1], which shows the imputed data, Tobit model is used to regress the restricted dependent variables.

To test hypothesis 1 that regional environmental regulation has a promoting and then inhibiting effect on corporate green investment efficiency, model 1 is developed as follows.

$$GIE = \alpha + \beta_1 Env + \beta_2 Env^2 + Controls + Industry + Year + Area + \varepsilon \quad (1)$$

To test hypothesis 2, the relationship between regional environmental regulation and the efficiency of green investment of enterprises will be significantly strengthened when enterprises face stronger public concern about environmental pollution, the interaction term is established by referring to the method of Hu Wangbin et al. (2014), and model 2 is established as follows.

$$GIE = \alpha + \gamma_1 Env + \gamma_2 Env^2 + \gamma_3 Env \times PCP + \gamma_4 Env^2 \times PCP + \gamma_5 PCP + \gamma_6 RD + Controls + Industry + Year + Area + \varepsilon \quad (2)$$

To test hypothesis 3, the moderating effect of technological innovation on the relationship between regional environmental regulation and the efficiency of corporate green investment is not significant, model 3 is developed as follows.

$$GIE = \alpha + \delta_1 Env + \delta_2 Env^2 + \delta_3 Env \times RD + \delta_4 Env^2 \times RD + \delta_5 PCP + \delta_6 RD + Controls + Industry + Year + Area + \varepsilon \quad (3)$$

The variables in Tobit model were selected as follows.

(1) Explained variables

Green investment efficiency (GIE). In this paper, the green investment efficiency measured in the previous section is used as the explanatory variable in the Tobit regression.

(2) Explanatory variables

Regional environmental regulation (Env). Drawing on the modified method of Shen Neng et al. (2012), the regional environmental regulation variable Env is designed, $Env_{it} = AR_{it}/RS_{it}$, where AR_{it} denotes the proportion of the completed industrial pollution control in year t of province i to the corresponding industrial value added; RS_{it} denotes the proportion of industrial value added in year t of province i to the GDP of the province, i.e., the industrial industrial structure. This index can include the actual amount of industrial pollution control investment in each province, and also avoid the error caused by the difference of regional industrial structure on the evaluation of environmental regulation intensity.

(3) Moderating variables

Public concern (PCP). Following the practice of Zhang Sanfeng et al. (2015), the index of public concern about environmental pollution in the cities where the sample enterprises are registered is obtained by using "environmental pollution" as a keyword in the "Baidu index".

Technological innovation (RD). From the perspective of technological innovation output, the widely used proxy indicator in current research is the number of patents granted for inventions; from the perspective of technological innovation input, some scholars measure it from the financial investment in the research stage of enterprises (Tang Qingquan et al. 2012; Zhai Shuping et al. 2016). Combined with the purpose of this paper, this paper selects indicators from the perspective of technological innovation investment, and based on the availability of data, enterprise R&D investment is selected as a proxy indicator of technological innovation and logarithmized.

(4) Control variables

Drawing on relevant studies, the following variables were selected as control variables: firm size (Size), firm ownership nature (PN), firm age (Age), total green investment size (Giscale), gearing ratio (ALR), operating cash flow (OCF), financial performance (ROA), firm growth (Growth), equity concentration (OSC), dual-occupancy (TJI), average board age (MAGE), per capita gross regional product (PGDP), and industrial industrial structure (IndS).

In addition, industry effect (Industry), time effect (Year), and area effect (Area) are also controlled for in this paper with reference to common practice.

3.2 Sample Selection and Data Sources

This paper selects A-share listed companies in the heavy pollution industry in Shanghai and Shenzhen as the research sample from 2018-2019, and the screening of the heavy pollution industry is based on the sixteen categories of heavy pollution industries specified in the Guidelines for Disclosure of Environmental Information of Listed Companies (Draft for Public Comments) issued by the Ministry of Environmental Protection, and the sample is screened as follows: (1) exclude ST and ST* companies; (2) exclude companies that were delisted during the 2018-2019 (3) excluding companies listed after January 1, 2016, to ensure that the companies maintain stable operation during the sample period; (4) excluding sample companies that do not disclose both SO₂ and COD, and finally obtaining 224 company annual observations as the research sample of this paper. The data on corporate environmental protection investment are obtained from Juchao Information Network, and collected manually from the social responsibility reports, environmental reports and sustainable development reports disclosed by listed companies, etc. The missing values are borrowed from Zhang Qi et al. (2019), and the investment expenditure items related to environmental treatment and green production (such as desulfurization and denitrification, sewage treatment, waste gas and waste residue treatment, clean production, etc.) in the construction-in-progress note table are summed up and Get the full complement. The data of public attention is obtained from the Baidu index website, which is organized according to the city where the enterprise is registered. The data on industrial structure are

based on China Statistical Yearbook and China Industrial Statistical Yearbook. The rest of the data are obtained from Guotaian database.

4. Empirical Results

4.1 SBM-DEA Results Analysis

From Table 1, the mean value of corporate environmental inputs is much larger than the median, indicating that some of the sample companies have invested a lot of money in environmental protection; while the minimum value of corporate environmental inputs is 0, which means that in some companies in any report disclosed to the public, no information related to environmental inputs is available. At the same time, the standard deviation of corporate environmental investment is very large, reflecting the fact that the decision of corporate management on corporate environmental investment varies greatly among the sample companies. The reported results of green investment efficiency show that only 9.375% of the sample companies have a green investment efficiency value of 1, which means that the green investment efficiency is optimal. The mean and median values of green investment efficiency do not exceed 0.5, which proves that the green investment efficiency of heavy polluting companies is generally low at present, and appropriate methods should be found to stimulate companies to allocate resources efficiently and improve green investment efficiency.

Table 1. Descriptive Statistics of Enterprises' Environmental Protection Investment and Major Pollutant Emissions and Green Investment Efficiency Measurement

	Sample Size	Mean	Median	Standard Deviation	Min	Max
GI(ten thousand yuan)	224	17454.62	2050.620	77251.605	0	1071500
SO ₂ (t)	224	1223.236	30.552	7359.297	0.001	104000
COD(t)	224	295.589	57.215	1748.261	0.026	26000
GIE	224	0.463	0.460	0.242	0.127	1
Optimal number		Optimal Number of Percentage				
GIE	21	9.375%				

4.2 Tobit Regression Results Analysis

Table 2. Descriptive statistics of the main variables of Tobit regression

Variable	Sample Size	Mean	Median	Standard Deviation	Min	Max
GIE	224	0.463	0.460	0.242	0.127	1
Env(‰)	224	0.685	1.799	0.557	0.021	2.742
PCP	224	47.393	27	45.899	0	157
RD	224	18.355	18.779	3.32	-6.908	23.77
Size	224	23.043	22.789	1.399	19.774	28.52
PN	224	0.549	1	0.499	0	1
Age	224	20.625	20	4.739	10	43
GIscale	224	0.023	0.001	0.09	0	1.111
ALR	224	0.42	0.412	0.197	0.063	1.645
OCF(%)	224	0.073	0.07	0.069	-0.463	0.259
ROA	224	0.047	0.042	0.115	-1.125	0.466
growth	224	0.096	0.031	0.608	-1.065	7.204
OSC(%)	224	36.945	33.34	15.48	9.56	80.87
TJI	224	0.192	0	0.395	0	1
MAGE	224	50.941	50.855	2.57	41.43	57.53
PGDP	224	11.143	11.102	0.399	10.404	12.009
IndS	224	0.321	0.339	0.061	0.109	0.402

Table 2 reports the results of descriptive statistics for the main variables in the Tobit regression. Corporate green investment efficiency GIE is calculated by the SBM-DEA model. The median value of regional environmental regulation Env is 1.799, which is much larger than the mean value of 0.685, indicating that some of the sample companies are located in provinces with extremely low

environmental regulation efficiency; the maximum value of public concern PCP is 157, the minimum value is 0, and the standard deviation is 45.899, indicating that the public concerns about environmental pollution faced by the sample companies vary greatly.

To test the hypotheses proposed in the previous paper, this paper draws on Hu Wangbin et al. (2014) and uses a cascading multiple regression approach to analyze the data using a cascading regression model with progressive inclusion of control variables, independent variables, and independent variable interaction terms. To avoid the problem of multicollinearity after the inclusion of interaction terms, in accordance with the prevailing practice, the independent and moderating variables are separately centered in this paper before the interaction terms are calculated and brought into the regression equation.

Table 3 shows the results of the hierarchical regressions of regional environmental regulations and other variables on the efficiency of green investment of enterprises, where Model 1 is the regression model of control variables on the dependent variable; Model 2 is the regression model of main effects of control variables, independent variables on the dependent variable; Model 3 is the regression model of main effects of control variables, independent variables, and squared terms of independent variables on the dependent variable; Model 4 is the regression model after adding moderating variables; Models 5 and Model 6 is a full-effects regression model with the addition of interaction effects. Table 3 shows that models 1-6 are significant.

4.2.1 The Impact of Regional Environmental Regulation on Green Investment Efficiency

In Table 3, Model 3, in order to test the Hypothesis 1, the primary term of the independent variable, and the squared term of the independent variable are added to the regression model in order to test Hypothesis 1. Analyzing the regression results, we can see that the regression results of only the primary term of regional environmental regulation in model 2 are not significant, while the estimated coefficients of the primary term of regional environmental regulation in model 3 are significantly positive at the 5% level and the estimated coefficients of the squared term are significantly negative at the 5% level, indicating that the implementation of regional environmental regulation has a significant inverse "U" type effect. Hypothesis 1 is verified.

Table 3. Hierarchical regression results

Variable	Dependent variable: GIE					
	Model1	Model 2	Model 3	Model 4	Model 5	Model 6
Control variables	YES	YES	YES	YES	YES	YES
Industry Time Regional Effects	YES	YES	YES	YES	YES	YES
Env		0.02 (0.44)	0.28** (2.24)	0.24** (2.44)	0.38*** (3.06)	0.28*** (2.73)
Env Square			-0.05** (-2.21)	-0.04** (-2.18)	-0.09*** (-2.85)	-0.06** (-2.30)
PCP				0.0003 (0.59)	-0.002** (-2.06)	0.0003 (0.72)
RD				-0.007 (-1.16)	-0.007 (-1.21)	-0.007 (-1.12)
PCP×Env					0.607** (2.34)	
PCP×Env Square					-0.112** (-2.56)	
RD×Env						0.024 (-0.31)
RD×Env Square						-0.008 (-0.53)
Pseudo R2	0.3556	0.3576	0.4079	0.3537	0.4246	0.4375
Prob>chi2	0.0011	0.0018	0.0006	0.0034	0.0010	0.0011

Note: *** p<0.01, ** p<0.05, * p<0.1; t-values are in parentheses; regression results for control variables are not presented by the author due to space limitations.

4.2.2 Mechanism of Regional Environmental Regulation on Green Investment Efficiency

In Table 3, Model 5, in order to test Hypothesis 2, the corresponding interaction term is added to Model 3. For the moderating effect of the inverted "U"-type relationship, this paper draws on Haans et al. " curve inflection point shifts to the left or to the right.

The results of model 5 show that: (1) compared with model 3, the estimated coefficients of regional environmental regulation and regional environmental regulation squared are positive (0.38) and negative (-0.09) respectively and change from significant at the 5% level to significant at the 1% level, indicating that the inverted "U"-shaped relationship between regional environmental regulation and enterprises' green investment efficiency remains unchanged and becomes more significant. The estimated coefficient of public concern multiplied by the square of regional environmental regulation is less than 0 (-0.112) and significant at the 5% level, indicating that the inverted U-shaped relationship between regional environmental regulation and firms' green investment efficiency is positively moderated by public concern, making the inverted U-shaped curve steeper. That is, the relationship between regional environmental regulations and green investment efficiency of enterprises is significantly strengthened when enterprises face strong public concern about environmental pollution. (2) In model 5, the primary term coefficient of regional environmental regulation γ_1 is 0.38, the secondary term coefficient γ_2 is -0.09, the public concern $\times$ regional environmental regulation coefficient γ_3 is 0.607, and the public concern $\times$ regional environmental regulation squared coefficient γ_4 is -0.112, $\gamma_1\gamma_4-\gamma_2\gamma_3$ is greater than 0, indicating that the inflection point shifts rightward as the moderating variable increases, which proves that the high public concern will make the weakening effect of high-intensity environmental regulation on the efficiency of corporate green investment come later, further demonstrating the importance of a green action system of government-public governance.

In Model 6 of Table 3, in order to test Hypothesis 3, the corresponding interaction term is added to Model 3. The results of model 6 show the estimated coefficient of technological innovation multiplied by regional environmental regulation square is -0.008, and the estimated coefficient of technological innovation multiplied by regional environmental regulation is -0.024, which are not significant. This shows the moderating effect of technological innovation on the inverted U-shaped relationship between regional environmental regulation and green investment efficiency is not significant because (1) firms adjust the relative proportions of technological innovation and environmental investment in their green decisions under different degrees of environmental regulation pressure. (2) Technological innovation will not only squeeze out part of the environmental protection investment and bring down the efficiency of green investment in the short term, but also optimize and upgrade the products to solve the environmental pollution problem and improve the efficiency of green investment by reducing pollutant emissions in the long term. Hypothesis 3 is verified.

4.2.3 Further Research

According to existing research, the impact of environmental regulations on firms' green behavior differs significantly between SOEs and non-SOEs. One view is that SOEs have richer resources in government-enterprise relations and are able to grasp more information about future environmental regulation policies, so that they can invest more rationally in environmental protection and gain more "first-mover advantage"; (Ma, Hong et al., 2018); another view is that non-SOEs invest more in environmental protection than SOEs, and private In order to increase the economic efficiency and value of the enterprise, entrepreneurs will actively take social responsibility in order to establish close ties with the more resourceful government agencies. (Wisdom Xie et al., 2018) However, there is a lack of empirical evidence on whether there is heterogeneity in the nature of property rights in the moderating effect of public concern on the inverted "U" shaped relationship between environmental regulation and corporate green investment efficiency.

Therefore, the hypotheses of this paper are tested again in Table 4 after grouping the sample firms by the nature of their property rights. Due to the limitation of space, Table 4 only shows the main

effect regression models of control variables, independent variables, and squared terms of independent variables on the dependent variable (Model 7, Model 10); and the full effect regression models after adding interaction effects (Model 8, Model 11; Model 9, Model 12)

Table 4. Tobit hierarchical regression results for groups with different property rights properties

Variable	Non-state enterprises (sample size 101)			State-owned enterprises (sample size 123)		
	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Control variables	YES	YES	YES	YES	YES	YES
Industry Time Regional Effects	YES	YES	YES	YES	YES	YES
Env	0.61*** (3.15)	0.52*** (2.73)	0.66*** (2.96)	0.09 (0.61)	0.18 (0.92)	0.31* (1.77)
Env Square	-0.105*** (-2.90)	-0.078** (-2.25)	-0.133* (-1.92)	-0.017 (-0.63)	-0.002 (-0.99)	-0.030*** (-2.68)
PCP		-0.002 (-1.31)	0.001** (2.39)		-0.002 (-1.37)	-0.0007 (-1.07)
RD		-0.023* (-1.77)	-0.009 (-0.01)		-0.003 (-0.51)	0.037** (2.27)
PCP×Env		0.879*** (3.51)			0.409 (0.97)	
PCP×Env Square		-0.253*** (-2.62)			-1.213 (-0.97)	
RD×Env			0.013 (0.71)			-0.009 (-1.41)
RD×Env Square			0.0004 (0.22)			0.001** (2.46)
Pseudo R2	0.8877	1.4430	1.2086	0.6505	0.6993	0.8167
Prob>chi2	0.0025	0.0000	0.0003	0.0011	0.0034	0.0004

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; t -values are in parentheses; interaction terms are centered.

Models 7 and 10 show that the inverted U-shaped relationship between regional environmental regulations and firms' green investment efficiency is particularly significant among non-state firms, while the relationship is much weaker among state firms. The moderating effect of public concern is also significant only in non-state enterprises. This is consistent with the second view above, as environmental penalties and loss of environmental reputation affect non-SOEs more than SOEs, and because non-SOEs have fewer resources at their disposal, they are more likely to use their available resources to efficiently invest in environmental protection when faced with appropriate levels of regional environmental regulation to improve the efficiency of their green investments. It is worth noting that, when examining the moderating effect of technological innovation in model 12, the coefficients of regional environmental regulation and the square of regional environmental regulation in the SOE group become significant at the 10% and 1% levels, respectively, compared to models 10 and 11, and the square of technological innovation multiplied by regional environmental regulation is significantly positive at the 5% level. The inverted U-shaped relationship between regional environmental regulations and green investment efficiency of SOEs is significantly weakened when SOEs invest more in technological innovation. It is assumed that this is because SOEs have strong financial support and innovative resources to carry out technological innovation, and are less affected by changes in the intensity of environmental regulations and are more capable of offsetting the negative impact of their environmental investments on technological innovation.

5. Research Findings and Policy Recommendations

In this paper, following conclusions are obtained: (1) Regional environmental regulation has an inverted "U" shape effect on the efficiency of green investment. The moderating effect shows that the inverted U-shaped relationship between regional environmental regulations and green investment efficiency is positively moderated by public concern, i.e., the inverted U-shaped relationship between environmental regulations and green investment efficiency will be significantly strengthened when

enterprises face stronger public concern about environmental pollution. The inverted U-shaped relationship between environmental regulation and green investment efficiency is significantly strengthened when firms face strong public concern about environmental pollution. In contrast, the moderating effect of technological innovation on this inverted U-shaped relationship is not significant. (2) Further analysis reveals that the inverted "U"-shaped relationship between regional environmental regulations and green investment efficiency is particularly significant in non-state enterprises, and the moderating effect of public concern is also more significant in non-state enterprises. In response to the findings of this paper, the following policy recommendations are proposed.

(1) China's current regional environmental regulation intensity is generally low, and is generally on the left side of the inverted "U" curve, i.e., the government can still moderately increase the intensity of environmental regulation to induce enterprises to improve the efficiency of green investment. (2) The high public concern about environmental pollution will strengthen the influence of regional environmental regulations on enterprises' green investment efficiency, and will make the weakening effect of high-intensity environmental regulations on enterprises' green investment efficiency come later, therefore, the establishment of public participation in the government's public governance system is beneficial to the further achievement of China's environmental effectiveness. (3) Local governments should fully consider the heterogeneity of environmental regulation tools and optimize the combination of environmental policy tools. For non-state-owned enterprises, a combination of formal environmental regulation led by the government and informal environmental regulation with public participation should be used to stimulate enterprises to improve the efficiency of green investment, build a good corporate image, and fulfill their corporate social responsibility. For state-owned enterprises, a combination of environmental regulations will result in state-owned enterprises passively catering to government regulation. The government should make more use of market-based instruments and market-based tools to stimulate enterprises to take the initiative to fulfill their social responsibility and improve the efficiency of green investment.

References

- [1] Luc Eyraud, Abdoul Wane, Changchang Zhang, Benedict Clements, Sun Lizheng, Wang Huanchun. Development trends and determinants of green investment[J]. Financial Development Review,2012(05):139-151.DOI:10.19895/j.cnki.fdr.2012.05.012.
- [2] Cao Y, Xin HX, Zhang ZORAN. The impact of the implementation of the new Environmental Protection Law on the investment efficiency of heavy pollution industries[J]. China Soft Science,2020(08):164-173.
- [3] Chen Yutao, Feng Jian. Does corporate green investment enhance corporate environmental performance--empirical evidence based on efficiency perspective[J]. Accounting Research,2020(01):179-192.
- [4] Zhai S.P., Bi X.F.. Environmental uncertainty, management confidence and firms' dual innovation investment[J]. Journal of Zhongnan University of Economics and Law,2016(05):91-100+159.
- [5] Du Hongwen, Zheng Zijie, Xu Jingyu. Evaluation of the impact of environmental regulation on green investment of listed companies in chemical industry[J]. Evaluation and Management,2021,19(03):20-24+30.
- [6] Hu Wangbin, Zhang Yuli, Yang Jun. Homogeneity or heterogeneity: A study on the moderating effect of entrepreneurial orientation on the relationship between technology entrepreneurial teams and new venture performance[J]. Management World,2014 (06) :92-109+187-188.DOI:10.19744 / j. cnki.11-1235 / f.2014.06.009.
- [7] Li X, Yang Zhaoyuan, Cao Jianhua. Does internet opinion help alleviate haze pollution? -and on the spatial spillover effect of haze pollution[J]. Economic Dynamics,2017(06):45-57.
- [8] Liu Chuanzhe, Zhang Tong, Chen Huiying. A study on the threshold effect and heterogeneity of environmental regulation on corporate green investment[J]. Financial Development Research,2019(06):66-71.DOI:10.19647/j.cnki.37-1462/f.2019.06.009.
- [9] Ma H, Hou Guisheng. Environmental protection input, financing constraints and corporate technology innovation--a research perspective based on the impact of long- and short-term heterogeneity[J]. Securities Market Herald,2018(08):12-19.

- [10] Shen Hongtao, Feng J. Public opinion supervision, government regulation and corporate environmental information disclosure [J]. *Accounting Research*,2012(02):72-78+97.
- [11] Shen N, Liu Fengzhao. Can high intensity environmental regulation really promote technological innovation? --A re-test of the Porter hypothesis[J]. *China Soft Science*,2012(04):49-59.
- [12] Sun, Jinhua, Xu, Linlin, Hu, Jian. The impact of informal environmental regulation on firms' green technology innovation from the perspective of environmental responsibility--a mediated moderation model[J]. *Technology Economics*,2021,40(10):10-22.
- [13] Qin Y, Wang YH. Environmental regulation, financing constraints and the choice of greening investment path for heavy polluters[J]. *Finance and Economics Series*,2020(10):75-84.DOI:10.13762/j.cnki.cjlc.2020.10.007.
- [14] Tang G. P., Li L. H., Wu D. J. Environmental regulation, industry attributes and corporate environmental investment[J]. *Accounting Research*,2013(06):83-89+96.
- [15] Tang QQ, Xiao HL. Financing constraints and corporate innovation investment-cash flow sensitivity - based on corporate R&D heterogeneity perspective[J]. *Southern Economy*,2012(11):40-54.
- [16] Wang, H.F., Hou, Junxia. The impact of heterogeneous environmental regulatory instruments on green investment in industrial enterprises[J]. *Financial Development Review*,2021(08):17-31.DOI:10.19895/j.cnki.fdr.2021.08.006.
- [17] Wu Libo, Yang Meimin, Sun Kezheng. The influence of public environmental concern on corporate and government environmental governance[J]. *China Population-Resources and Environment*,2022,32(02):1-14.
- [18] Xiao, L., Li, X. Q.. The impact of green securities on corporate green investment efficiency--a test based on listed enterprises in six energy-consuming industries[J]. *Financial Regulation Research*,2020(12):78-97.DOI:10.13490/j.cnki.frr.2020.12.006.
- [19] Xie W., Sun Y. X., Wang Y. N.. The impact of environmental regulations on corporate environmental protection investment--a panel data study based on heavy pollution industries[J]. *Arid Zone Resources and Environment*,2018,32(03):12-16.DOI:10.13448/j.cnki.jalre.2018.034.
- [20] Xin Yu. An empirical study on the impact of environmental regulation on green investment - based on media monitoring perspective [J]. *Friends of Accounting*,2019(14):91-96.
- [21] Yang Huidan. The impact of environmental regulation on the efficiency of corporate green investment [D]. *Nanjing University of Information Engineering*,2021. doi:10.27248/d.cnki.gnjqc.2021.000731.
- [22] Zhang Q, Zheng Y, Kong D-M. Regional environmental governance pressure, executive experience and corporate environmental investment: a quasi-natural experiment based on the Ambient Air Quality Standard (2012) [J]. *Economic Research*,2019,54(6):183-198.]191.
- [23] Zhang Sanfeng, Bu Maoliang. Embedding in global value chains, informal environmental regulation and ISO14001 certification of Chinese enterprises-an empirical study based on inter-provincial panel data from 2004-2011[J]. *Finance and Trade Research*,2015,26(02):70-78. doi:10.19337/j.cnki.34-1093/f.2015.02.009.
- [24] Zhou X, Ma YB, Zhang YQ. Local government strategic regulation and corporate environmental investment under a shared governance system-evidence from heavily polluting firms[J]. *Finance and Economics Science*,2022(03):82-96.
- [25] Zhou Fengxiu, Wen Huwei. How Chinese OFDI affects corporate pollution emissions - micro evidence from industrial firms[J]. *International Business (Journal of the University of International Business and Economics)*,2021(01):65-80.DOI:10.13509/j.cnki.ib.2021.01.005.
- [26] Haans R F J, Pieters C, He Z L. Theorizing and testing U- and inverted U-shaped relationships in strategy research [J]. *Strategic Management Journal*, 2016, 37(7):1177-1195.
- [27] TONE K. A slacks-based measure of super-efficiency in data envelopment analysis [J]. *European Journal of Operational Research*,2002,143(1):32-41.
- [28] Yu, Y., J. Huang, N. Luo.Can More Environmental Information Disclosure Lead to Higher Eco-Efficiency? Evidence from China. *Sustainability*,2018,10(2): 528.