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Environmental Penalties, Internal and External Governance, and Green Innovation: Does the Deterrence Effect Work?

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Abstract: There is a clear target and roadmap for the peaking of carbon emissions and achievement of carbon neutrality, and prior to this target being reached, penalties have been formulated to supervise enterprises and prompt green innovation. This study aimed to investigate the transmission mechanism between environmental penalties and green innovation using an empirical econometrical model and two sets of samples—punished firms and heavily polluting listed firms—amounting to 520 punished firms and 6043 firm-year observations. The main conclusions were threefold. Firstly, regarding the panel data, of the three parameters, namely, the times of penalties, the number of penalty fines, and the intensity of the penalty, only the number of penalty fines were statistically significant in terms of green innovation, indicating that only the hypothesis that, the higher the number of environmental penalties, the greater the green innovation that could be supported. Secondly, from a longitudinal perspective, there was one spontaneous effect on green patents, but the effect faded quickly in the second year after the punishment, indicating that firms did not seek green innovation as the solution for environmental penalties from a long-term perspective. Thirdly, the case number of external penalties in a province was significantly statistically associated with green innovation under an intertwined effect of the actual controller and shareholders. Therefore, there was a spillover of the deterrence effect from external penalties, with a higher number of penalty cases in a province corresponding to greater green innovation but with a very subtle coefficient. In addition, taking the median as the benchmark for group division, the group smaller than the median was statistically significant, while the group with a higher number of external penalties was not statistically significant, suggesting that firms were used to the penalties issued by environmental authorities.

Keywords: environmental penalty; internal governance; external governance; green innovation; deterrence effect



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1. Introduction

The goals of the peaking of carbon emissions by 2030 and achievement of carbon neutrality by 2060 were formulated by the Central Committee and State Council. Meanwhile, green innovation is regarded as a primary contributor to the carbon target, becoming a primary factor for the mitigation of climate change. Prior to reaching the settled strategic target, regulators have exerted continuous pressure on enterprises, but firms can deploy diversified solutions to offset the pressure of penalties, such as mimicking a green image [1], achieving profitability and emission reduction via options contracts [2], green bonds [3], avoidance of environmental regulations and corporate taxes [4], environmental regulations and corporate green investment [5], greenwashing [6], and being public and private companies aiming towards a net zero carbon economy [7]. Therefore, in this game between authorities and enterprises, could environmental penalties achieve the goals

of environmental protection and green innovation? This study aims to investigate the transmission mechanism between environmental penalties and green innovation. How do enterprises respond to environmental penalties? Do environmental penalties have a deterrence effect on green innovation? What are the intertwined mechanisms of internal and external governance that act upon green innovation?

The structure of this study is organized as follows. Section 2 describes a literature review, a summary, the problem formulation, and the research questions. Section 3 lays out the methodology and sample explanation. Section 4 discusses the empirical studies and results, and Section 5 follows with a discussion, a conclusion, policy implications, potential limitations, and directions for further research.

2. Literature Review

2.1. Environmental Penalties and Green Innovation

Regarding the definition of environmental penalties, they refer to the measures of fines, rectifications, shutdowns, etc., deployed by authorities to punish firms for their behaviors. Meanwhile, green innovation has been acknowledged to produce new products and processes that reduce environmental impacts, and in the empirical studies conducted here, the term refers to green patents.

Regarding the effect of environmental penalties, the previous literature mainly focused on the following aspects. Firstly, if penalties have a substantial impact on firms' profits that outweigh the benefits of environmental pollution, firms intend to comply with environmental laws and regulations. For example, penalties are detrimental to the intangible assets of firms' reputations and stock returns [8], corporate reputations, market value, customers, and suppliers in the supply chain [9]. Secondly, there are direct and indirect behaviors caused by the imposed penalties, such as an adverse effect on firms' environmental investment [10], an increase in audit fees [11], and a trade-off for subsidies [12], with the features of a major deterrent effect and a high cost of non-compliance [13]. Thirdly, focusing on the positive effects on innovation, such as open innovation and government support in enhancing green process innovation [14], digitalization capability significantly increases the use of open innovation as a moderation approach to government penalties [15]; meanwhile, the Two-Track approach of the stick and carrot positively mediates the relationship with green innovation [16]. Accordingly, this research supports the idea that penalties are positively and indirectly associated with green innovation, but a broader definition of green innovation is used here.

2.2. Internal and External Governance with Green Innovation

Why do firms vary regarding the level of green innovation, particularly under the constraints of penalties? There are diverse approaches and methodologies in exploring the relationship between internal and external governance and green innovation.

Initially, regarding internal governance and green innovation, the variables for an enterprise have different effects on green innovation, such as positive associations with firm profitability [14], stakeholder pressures [15], firms' environmental awareness [16], and board reforms [17], as well as negative associations with the proportion of family ownership and carbon performance [18]. Furthermore, it has been found that net income and eco-efficiency play a decisive role in increasing economic sanctions and innovation subsidies [19]; additionally, there is an inverse U-shaped relationship between the indirect environmental target and the quality of green innovation [20]. Moreover, internal driving factors, such as environmental honors and the political promotion of state-owned enterprises, have a positive association with green innovation behaviors [21], but this research was based on data pertaining to planned willingness. Accordingly, there are numerous internal variables affecting green innovation under different preconditions.

Secondly, there are several different perspectives on external governance and green innovation. The market structure is an important driver; a monopolist, under a regulatory penalty, has a rational motivation to strike a balance between the cost of green innovation

investment and the pressure of punishment [10]. Additionally, different variables of green innovation have been considered. For example, the board structure is more important than ownership structures in promoting green innovation [22], and the linkage of economic growth accelerates eco-innovation [23]; in addition, environmental regulation and technological innovation [24], norms and regulations [16], simultaneous green innovation in the upstream and downstream [12], the U-shaped impact on export technological sophistication and green innovation [25], and the positive moderating effects of labor and capital [26] have been explored. Meanwhile, stricter environmental regulation increases green innovation [27]. Firms switch to producing green patents when committing environmental violations with high legal costs in the long run [28]. Green credit policy inhibits green technology innovation, while for financial surpluses, it is the opposite [29]; however, public environmental awareness only prompts symbolic green innovation [30]. Therefore, these external variables exert different effects on green innovation.

2.3. Summary and Critique

These studies focused on single links in the green innovation ecosystem, such as enterprises' influencing factors, external governance, and internal governance in the transmission mechanisms between environmental penalties and green innovation. Firstly, these studies primarily relied on reviewed perception data, giving rise to disparities and discrepancies between cognitive and actual behaviors. Secondly, studies that investigated environmental regulations and green innovation primarily focused on the impacts in a single chain but lacked a mechanistic approach that assessed the linkages among penalties, internal and external governance, and green innovation. Thirdly, firms' behaviors in responding to environmental penalties are complicated, and there is distortion in the transmission process, demonstrating that different options can be deployed by punished firms to offset the detrimental influence of penalties instead of the sole option of green innovation.

2.4. Research Hypotheses

Hypothesis 1 (H1). *Environmental penalties lead to greater green innovation.*

Hypothesis H1a. *The more penalties issued by authorities, the greater the green innovation.*

Hypothesis H1b. *The higher the penalty fines, the greater the green innovation.*

Hypothesis H1c. *The higher the intensity of the penalties, the greater the green innovation.*

How do environmental regulations affect patterns of green innovation? There is an adverse effect on firms' environmental investment [10], and the intensity of green innovation is positively associated with firm profitability [14], stakeholder pressures, organizational learning, and green innovation [15]; propensity results are affected by internal variables, such as firms' environmental awareness, company staff, and capabilities [16], board reforms [31], the effect on corporate social responsibility [32], and indirect momentum for green innovation [33]. The proportion of family ownership is negatively associated [6] with corporate governance and carbon performance [18]. Meanwhile, environmental penalties can increase audit fees; the stronger the regional environmental regulation, the greater the positive impact [11]. Meanwhile, at the early stage, penalties have a more significant influence than of subsidies, but independent R&D investments are more reliable than subsidies [12]. Internal driving factors, such as environmental honors and the political promotion of state-owned enterprises, have a positive association with green innovative behavior [21]. Accordingly, there are numerous internal variables that have a positive association with green innovation.

Hypothesis 2 (H2). *There is a spillover of the deterrence effect from external penalties; the more penalty cases in a province, the greater the green innovation.*

Is there a spillover of the deterrence effect from imposed penalties? Previously, regarding the spillover of the deterrence effect, a positive relationship between environmental innovation and integrated environmental disclosure and regulations was demonstrated; it was found to be affected by norms and regulations, but the monetary and fiscal incentives were not revealed to be significant [16]. A positive moderating effect from labor and capital was found [26], which emphasized the importance of external influences. Meanwhile, penalties have an environmental deterrence effect and a positive effect on environmental investment; the heavier the penalty is, the more pronounced its effect, but firms receiving subsidies do not increase their investment in environmental governance and green innovation [9], thus laying out the parameters of the effects of penalties on firms' behaviors. In addition, the approaches that are deployed to enforce penalties affect the deterrence effect—for example, there can be a high deterrence effect and high cost of non-compliance instead of a one-off, one-size-fits-all strategies [13], and different peer effects can be used within the same province, industry, and product market by deploying spatial econometric techniques [34]. Therefore, there is a deterrence effect, but only under certain constraints and preconditions.

3. Methodology and Research Design

3.1. Data and Samples

Two sets of samples were used in this study; one included heavily polluting listed firms, while the other included listed firms punished by the environmental authorities. These two sets had a certain overlap, and the firms in both sets were listed in China's Shanghai and Shenzhen A-share markets over the period of 2010–2021. Meanwhile, the list of heavily polluting listed companies was based on their environmental information disclosure published by the Ministry of Environmental Protection in 2010. The financial data in this study were obtained from the China Stock Market and Accounting Research (CSMAR) database. The data on administrative environmental penalties and green patents came from the Chinese Research Data Services Platform (CNRDS). Additionally, the following step was taken for sample processing: the deletion of samples with special treatment (*ST, ST), missing samples, and extreme values. After this process, there were 19,255 firm-year observations in total, including 6043 firm-year observations for 520 firms punished by the environmental authorities. The heavily polluting listed firms were selected based on the guidelines of environmental information disclosure.

3.2. Empirical Econometric Model

The conventional econometric model was employed to test the hypotheses and the specific effects of penalties.

$$\text{green innovation}_{i,t} = \beta_0 + \beta_1 \text{Penalties}_{i,t} + \sum \beta_i \text{InterControls}_{i,t} + \varepsilon_{i,t} \quad (1)$$

$\text{green innovation}_{i,t}$ represents a green patent of firm i in year t , while Penalty represents the number of penalties, the number of fines due to penalties, and the severity of penalties of firm i in year t .

$$\begin{aligned} \text{green innovation}_{i,t} = & \beta_0 + \beta_1 \text{punishTime}_{i,t} + \beta_2 \text{PunishAmount}_{i,t} + \\ & \beta_3 \text{PunishIntensity}_{i,t} + \beta_4 \text{shrholder1}_{i,t} + \beta_5 \text{Controller1}_{i,t} + \beta_6 \text{Lnsizes}_{i,t} + \\ & \beta_7 \text{LiabilityA}_{i,t} + \beta_8 \text{ReturnOA}_{i,t} + \beta_9 \text{HiPollution}_{i,t} + \beta_{10} \text{Provpenalty}_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (2)$$

$$\begin{aligned} \text{green innovation}_{i,t+T(=1,2,3,4)} = & \beta_0 + \beta_1 \text{punishTime}_{i,t} + \beta_2 \text{PunishAmount}_{i,t} \\ & + \beta_3 \text{PunishIntensity}_{i,t} + \beta_4 \text{shrholder1}_{i,t} \\ & + \beta_5 \text{Controller1}_{i,t} + \beta_6 \text{Lnsizes}_{i,t} + \beta_7 \text{LiabilityA}_{i,t} \\ & + \beta_8 \text{ReturnOA}_{i,t} + \beta_9 \text{HiPollution}_{i,t} + \beta_{10} \text{Provpenalty}_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (3)$$

Formula (1) is a basic framework for the dependent variable of green innovation and independent variables represented by the parameters of penalties and internal and external variables. Formula (2) elaborates on the specific variables in Formula (1). Formula (3) demonstrates the function from a longitudinal perspective; the benchmark is 0, referring to the year of imposing the penalties, 1 is regarded as one year after the penalties, 2 is regarded as two years after the penalties, and so on for the other numbers. Additionally, because of the potential asymmetric, it deploys the values of natural log for some variables in the empirical studies, and being presented in the specific tables.

3.3. Parameters and Descriptive Analysis

Regarding the variables, as shown in Table 1, green innovation refers to the specific number of green patents each year and is the dependent variable. Meanwhile, regarding the independent variable, there are certain sub-groups depending on the measurement of environmental penalties; three dimensions are covered, namely, the number of penalties, the penalty fines, and the severity of the penalties. Additionally, the controlled variables refer to internal and external governance; internal governance includes financial variables, such as the return on total assets, asset–liability ratio, the shareholding of top shareholders, and actual controllers. External governance refers to the case of environmental penalties in the province where the headquarters of a specific firm is. Lastly, the different levels of penalties are shown in Table 2, the descriptive analysis of observations is shown in Table 3, and the correlation among the variables is shown in Table 4.

Table 1. List of the variables and their specific definitions.

Type	Variables	Definition
Dependent variables	greenPatent	Numeric variable referring to the number of green patents registered yearly.
	lngreenPatent	Numeric variable referring to the natural log of green patent numbers registered yearly.
	lngreenPatent1	Numeric variable referring to the natural log of green patents numbers plus 1 registered yearly for the data analysis.
Independent variables	HiPollution	Dummy variable; 1 refers to the firm being listed as a high-pollution firms, while 0 indicates otherwise.
	Penalty	Dummy variable; 1 refers to firms being punished by the environmental authorities, and 0 indicates otherwise.
	Growthgp	Numerical variable referring to the increase compared with the previous year.
External variable	Provpenalty	Numerical variable referring to the total cases of punishment issued by the environmental authorities in a province yearly.
Firms' parameters	shrholder1	Numerical variable for the share percentage that the top shareholder owns.
	Controller	Dummy variable for firms' actual controllers; 1 refers to related stated-owned firms, including local state-owned enterprises, the local state-owned asset administration bureau, central-state-owned enterprises, and universities; 0 refers to individuals, foreign capital, and workers' unions.
	Lnsize	Numerical variable for the size of the firm according to the natural log of total assets.
	Liability	Numerical variable referring to the total liability divided by the total assets.
Penalties	ReturnOA	Numerical variable referring to the net income divided by the total assets.
	punishTime	Numerical variable referring to the number of times that firms have been punished by the environmental authorities.
	punishAmount	Numerical variable referring to the amounts of penalty fines from the environmental authorities (unit: 10,000 RMB).
	lnpunishAmount	Numerical variable referring to the natural log of penalty fines.
	punishIntensity	Numerical variable for cumulative scoring for different types of penalties.

Table 2. Categories and levels of corporate environmental penalties.

Categories	Labels (Scoring for Severity)	
Warning, rectification before a certain deadline	1	
Fines (units: 10,000 RMB)	Fines < 5	1
	$5 \leq \text{Fines} < 20$	2
	$20 \leq \text{Fines} < 40$	3
	$40 \leq \text{Fines} < 60$	4
	$60 \leq \text{Fines}$	6
Seal up, seize, and confiscate illegal gains	6	
Order to restrict production	6	
Order for the suspension of production for rectification	12	
Administrative detention for environmental crime	12	

Notes: There are different types of environmental penalties, including warnings, fines, rectifications, and suspensions of production; the severity scoring assessment was conducted according to the guidelines for the analysis of enterprises' environmental credit. Meanwhile, the specific scoring for the index of penalties and hierarchy of authority deployed is slightly different [11], but the same framework is used overall.

Table 3. Descriptive analysis for observations.

Variable	Obs	Mean	Std. Dev.	Min	Max
HiPollution	19.255	0.8568	0.3502	0	1
Penalty	19.255	0.3138	0.4641	0	1
greenPatent	19.255	2.060	1.160	0	728
lngreenPatent	5.409	1.127	1.128	0	6.590
lngreenPatent1	19.255	0.423	0.8285	0	6.592
Growthgp	19.255	0.4205	6.407	−406	360
Provpenalty	19.255	1165	2.595	0	17,106
shrholder1	19.255	0.3699	0.1603	0.0029	0.8999
Controller	19.255	0.5131	0.4998	0	1
lnsize	19.255	2.189	1.415	12	29
LiabilityA	19.255	0.5646	7.525	0.00056	1.013
ReturnOA	19.255	0.0309	0.4212	−48.316	8.449
punishTime	6.043	3.144	620	0	77
punishAmount	6.043	133.33	1016	0	17,036.14
lnpunishAmount	5.457	2.867	1.686	−0.223	9.743
punishIntensity	6.043	5.264	4.952	1	24

Notes: For some variables that are asymmetric, such as greenPatent and punishAmount, it takes the logarithm values, and the histogram and kdensity distributions for these variables are presented in Figure 1.

Table 4. The correlations among the variables.

No.	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1	HiPollution	1												
2	Penalty	−0.60 *	1											
3	greenPatent	−0.07 *	0.07 *	1										
4	growthgp	−0.03 *	0.02 *	0.57 *	1									
5	provpenalty	−0.07 *	0.03 *	0.07 *	0.02	1								
6	shrholder1	0.03 *	0.05 *	0.04 *	0.02	−0.09 *	1							
7	controller	0.02 *	0.07 *	0.04 *	0.02	−0.23 *	0.26 *	1						
8	lnsize	0.06 *	0.28 *	0.10 *	0.12 *	0.19 *	0.1813 *		1					
9	liabilityR								−0.06 *	1				
10	ReturnOA	0.05 *							0.06 *	−0.09 *	1			
11	punishTime	0.12 *		0.06 *	0.03	−0.05 *	0.17 *	0.13 *	0.28 *			1		
12	punishAmount	−0.03		0.09 *		−0.03 *	0.06 *		0.07 *			0.12 *	1	
13	punishInte~y	0.09 *					−0.04 *		0.08 *	0.25 *				1

Note: * $p < 0.05$, and the correlations among different variables are presented in Table 4.

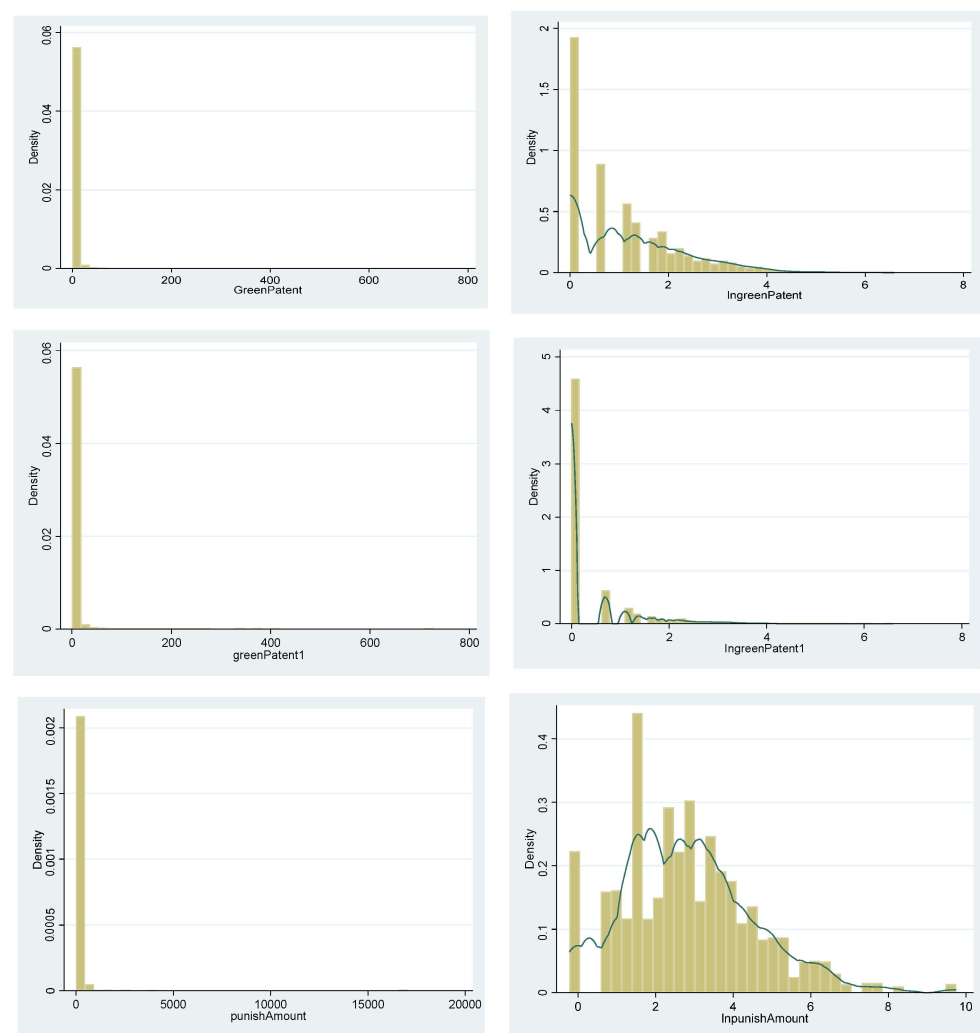


Figure 1. The histogram and kdensity distributions for the variables: greenPatent, lngreenPatent ((Top), (left) vs. (right)); greenPatent1, lngreenPatent1 ((middle), (left) vs. (right)); punishAmount and lnpunishAmount ((bottom), (left) vs. (right)). Note: In the (left) panel, asymmetry is indicated; the specific models were tested with the logarithm values. Alternatively, the Poisson regression can be deployed.

4. Empirical Results and Findings

4.1. Hypothesis 1

Regarding Hypothesis 1 (H1), environmental penalties led to greater green innovation—specifically, a greater number of times that a penalty was issued by the authorities, larger amounts of penalty fines, and a higher penalty intensity led to greater green innovation.

In the test, as shown in Table 5 in the format of a panel dataset, the coefficients for the number of penalties and the intensity of penalties were not statistically significantly associated with the dependent variables, indicating that the specific hypotheses (H1a and H1c) could not be supported. Only the amounts of penalty fines were statistically significantly associated with green innovation, thus supporting the hypothesis that the greater the environmental penalties, the greater the green innovation (H1b). In comparison with previous research on the identification of factors affecting investment in environmental innovations, the propensity results were affected by the internal variables, such as firms' environmental awareness and capabilities, while for the external variables, the propensity was also affected by norms and regulations, but the monetary and fiscal incentives were not found to be significant [16]. The external variable of regulations was found to be significant, but this observation relied on perception data. Meanwhile, theoretically, environmental

regulations promoted enterprises' green innovation, and there was a decreasing effect ranging from penalties to subsidies in a tripartite evolutionary game model [19]. Additionally, when $\log(\text{greenPatents}+1)$ was used to avoid the asymmetry, this conclusion was also supported in Table 6.

Table 5. The test results for Hypothesis 1.

	Model 1	Model 2	Model 3	Model 4
Yearprior > 0 (All Samples after Punishments)				
punishTime	−0.110 (0.10)			−0.162 (0.10)
punishAmount		0.002 (0.00)		0.002 * (0.00)
punishIntensity			0.029 (0.12)	0.004 (0.12)
HiPollution	−3.756 ** (1.21)	−3.961 *** (1.20)	−3.934 ** (1.21)	−3.780 ** (1.22)
ProvPenalty	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)
ShrHolder1	1.335 (4.14)	1.493 (4.14)	1.086 (4.14)	2.037 (4.16)
Controller	−1.365 (1.34)	−1.374 (1.34)	−1.372 (1.34)	−1.372 (1.34)
lnSize	8.535 *** (0.49)	8.318 *** (0.47)	8.393 *** (0.47)	8.515 *** (0.49)
Liability	0.219 (0.16)	0.207 (0.16)	0.212 (0.16)	0.215 (0.16)
ReturnOA	−5.886 (4.38)	−5.602 (4.37)	−5.697 (4.38)	−5.919 (4.38)
Constant	−183.5 *** (10.67)	−179.1 *** (10.36)	−180.6 *** (10.37)	−183.3 *** (10.72)
R ²	0.162	0.163	0.162	0.164
df_r	1943	1943	1943	1943
Bic	18,342	18,340	18,343	18,352

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6. The test results for Hypothesis 1 with the logarithm value of lngreenPatent1.

Ingreenpantents1	Model 1	Model 2	Model 3	Model 4
Yearprior ≥ 0 (All Samples after the Punishments)				
punishTime	0.005 (0.00)			−0.001 (0.00)
lnpunishAmount		0.068 *** (0.01)		0.059 *** (0.02)
punishIntensity			0.014 ** (0.00)	0.009 (0.01)
HiPollution	−0.094 * (0.05)	−0.128 ** (0.05)	−0.108 * (0.05)	−0.132 ** (0.05)
ProvPenalty	0.000 *** (0.00)	0.000 ** (0.00)	0.000 *** (0.00)	0.000 ** (0.00)
ShrHolder1	−0.328 * (0.16)	−0.125 (0.17)	−0.294 (0.16)	−0.119 (0.17)
Controller	−0.057 (0.05)	−0.052 (0.05)	−0.059 (0.05)	−0.051 (0.05)
lnSize	0.441 *** (0.02)	0.441 *** (0.02)	0.450 *** (0.02)	0.444 *** (0.02)
liabilityR	0.010 (0.01)	0.008 (0.01)	0.011 (0.01)	0.009 (0.01)
ReturnOA	−0.186 (0.17)	−0.229 (0.19)	−0.213 (0.17)	−0.237 (0.19)
constant	−8.903 *** (0.41)	−9.093 *** (0.42)	−9.161 *** (0.40)	−9.191 *** (0.43)
R ²	0.263	0.284	0.266	0.285
df_r	1943	1755	1943	1753
bic	5630	5049	5623	5061

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; it is consistent with the previous testing.

Meanwhile, environmental penalties can increase audit fees and environmental administration [11]. A positive relationship was found between environmental management and financial performance [35]. High-emission firms face shorter loan maturities, higher interest rates [36], and green credit guidelines for the promotion of corporate green technology [37]. This research supported the hypothesis that penalties have a certain effect related to public reputation, credit, and finance; meanwhile, certain variables lead to green technology. However, these studies primarily deployed perceived data. In order to further investigate the effect of penalties on green innovation, a study was conducted from the longitudinal perspective according to Formula (3) instead of only a panel dataset.

From the longitudinal perspective, as shown in Table 7, according to Formula (3), the effect of penalties faded over time. This indicated that parameters, including the number of times that punishments were issued and the penalty amounts, were statistically significant in the year in which the penalties were imposed and one year after the punishment. However, from the second year, the effect faded, and the variables were no longer statistically significant. Meanwhile, the logarithm values deployed in the empirical studies also support the above conclusion being presented in Table 8. Accordingly, firms did not seek green innovation as the solution for environmental penalties in the long-term perspective. This was consistent with research in the fields of emission trading behaviors in the EU [38], corporate environmentalism in managerial delegation, and abatement subsidy policies for Pareto-improving alignment [39]. European companies translate their carbon reduction strategies into carbon targets according to their CEOs' short-term and long-term compensation [40]. Firms switch to producing green patents when committing environmental violations with high legal costs in the long run [28].

Table 7. A comparison of the effects of penalties imposed in different years.

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Year of Penalty Imposed = 0		1 Year after Penalty = 1		2 Years after Penalty = 2		3 Years after Penalty = 3		4 Years after Penalty = 4	
HiPollution	−1.133 (1.31)	−0.777 (1.29)	−1.343 (1.21)	0.049 (1.53)	−0.500 (1.55)	−1.490 (1.24)	−2.299 (1.68)	−2.327 (1.72)	−4.548 * (2.27)	−4.217 (2.34)
ProvPenalty	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	−0.000 (0.00)	−0.000 (0.00)	−0.000 (0.00)	−0.000 (0.00)
ShrHolder1	7.320 (4.55)	9.688 * (4.47)	2.878 (4.38)	10.070 (5.33)	6.340 (5.41)	2.391 (4.45)	5.502 (5.87)	5.147 (5.96)	−9.056 (7.94)	−9.709 (8.08)
Controller	0.233 (1.48)	0.099 (1.44)	0.462 (1.35)	−0.220 (1.71)	0.050 (1.76)	0.434 (1.36)	−1.854 (1.93)	−2.021 (1.95)	0.800 (2.52)	0.641 (2.56)
lnSize	5.233 *** (0.59)	5.167 *** (0.59)	2.684 *** (0.55)	6.118 *** (0.70)	6.003 *** (0.70)	2.573 *** (0.57)	4.726 *** (0.76)	4.678 *** (0.79)	6.005 *** (0.85)	6.071 *** (0.89)
liabilityR	−8.561 * (3.97)	−8.243 * (3.87)	2.682 (3.45)	−8.064 (4.36)	−8.640 (4.46)	2.676 (3.46)	−0.410 (4.89)	−0.572 (4.93)	0.721 (0.75)	0.783 (0.76)
ReturnOA	−25.412 * (12.30)	−25.254 * (12.12)	2.197 (8.75)	−7.052 (9.36)	−5.875 (9.59)	2.869 (8.80)	−17.639 (9.45)	−17.861 (9.59)	−1.283 (4.80)	−0.992 (4.87)
punishTime		−0.230 * (0.12)		−0.350 ** (0.13)		0.112 (0.12)		0.094 (0.16)		0.008 (0.20)
punishAmount		0.003 *** (0.00)		0.004 *** (0.00)		−0.001 (0.00)		−0.002 (0.00)		−0.002 (0.00)
punishIntensity		0.045 (0.13)		−0.002 (0.15)		0.050 (0.12)		0.055 (0.18)		−0.038 (0.23)
constant	−110.5 *** (12.04)	−110.1 *** (12.12)	−57.6 *** (11.57)	−131.8 *** (14.62)	−128.1 *** (14.72)	−55.4 *** (12.10)	−99.7 *** (15.81)	−98.7 *** (16.55)	−124.6 *** (18.79)	−125.5 *** (19.78)
R ²	0.222	0.268	0.117	0.255	0.206	0.120	0.176	0.178	0.228	0.230
df_r	382.0	379.0	328.0	364.0	367.0	325.0	270.0	267.0	213.0	210.0
bic	3.124.6	3.119.1	2.601.9	3.115.3	3.121.6	2.618.2	2.290.2	2.306.4	1.903.5	1.919.1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Therefore, according to the previous two tests, the conclusion that environmental penalties cannot lead to greater green innovation from a long-term perspective, except for the penalty fine amount could be, while from a short-term perspective, there was a spontaneous and instinctive conditioned effect on green innovation, but the effect quickly faded away. Accordingly, regarding the characteristics of green innovation, there was a non-obvious direct economic effect and long investment cycle—the double externality of environmental and innovation externality—giving rise to double market failure and causing investment in green innovation to be less active than expected.

Table 8. A comparison of the effects of penalties imposed in different years with logarithm values.

IngreenPatent	Model 1	Model 2	Model 3	Model 4	Model 5
	Year of Penalty Imposed = 0	1 Year after Penalty	2 Year after Penalty	3 Year after Penalty	4 Year after Penalty
HiPollution	−0.372 * (0.17)	−0.012 (0.17)	−0.178 (0.17)	−0.194 (0.19)	−0.322 (0.23)
ProvPenalty	−0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	−0.000 (0.00)
ShrHolder1	0.575 (0.57)	1.266 * (0.58)	0.798 (0.63)	0.266 (0.62)	−0.228 (0.81)
Controller	0.251 (0.18)	−0.004 (0.18)	0.045 (0.18)	−0.033 (0.21)	−0.214 (0.24)
lnSize	0.429 *** (0.07)	0.441 *** (0.07)	0.253 ** (0.08)	0.388 *** (0.08)	0.524 *** (0.09)
liabilityR	−0.177 (0.56)	−0.192 (0.48)	0.472 (0.48)	0.363 (0.58)	0.047 (0.10)
ReturnOA	−0.980 (1.48)	0.771 (0.81)	2.073 (1.57)	−2.088 (1.37)	0.086 (0.96)
punishTime	−0.024 * (0.01)	−0.017 (0.02)	0.012 (0.02)	0.001 (0.02)	−0.009 (0.01)
lnpunishAmount	0.041 (0.06)	0.089 (0.06)	0.073 (0.06)	0.012 (0.07)	−0.016 (0.08)
punishIntensity	0.033 (0.02)	0.003 (0.02)	0.008 (0.02)	0.008 (0.02)	0.001 (0.02)
constant	−8.752 *** (1.50)	−9.391 *** (1.54)	−5.362 ** (1.64)	−7.745 *** (1.66)	−9.962 *** (2.06)
R ²	0.334	0.319	0.222	0.275	0.354
df_r	153	161	159	133	90
bic	508	545	548	466	336

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.2. Hypothesis 2

Regarding Hypothesis 2, there was a spillover of the deterrence effect from external penalties; the greater the number of penalty cases in a province, the greater the green innovation.

As shown by the results of the tests in Table 9, the coefficients of external penalties were statistically significant, except for the sample in Model 4, but the coefficients were subtle and tiny. Meanwhile, the percentages of the top shareholders and the actual controllers were statistically significant, which was consistent with findings regarding the monitoring of the board of directors and managerial incentives [41]. A robust linear and positive relationship was found between board gender diversity and carbon performance [42]; in addition, there was a positive relationship with the presence of independent directors and a negative relationship with local shareholders [43]. A gradual increase in the Climate Compliance Index despite disparities across sectors and management areas was imposed by external pressure [44], thus improving corporate environmental management in supply chains [45]. Therefore, overall, external penalties exerted a certain deterrence effect on green innovation, but with the subtlety of the coefficients, this effect was intertwined with the actual controllers and shareholders.

Table 9. A comparison of the regression analyses among different groups of samples.

	Model 1	Model 2	Model 3	Model 4
	All Samples	All Samples	Yearprior < 0	Yearprior ≥ 0
HiPollution	−1.659 *** (0.29)	−2.143 *** (0.23)	−0.904 ** (0.28)	−3.780 ** (1.22)
Penalty	0.601 ** (0.22)			
ProvPenalty	0.000 *** (0.00)	0.000 *** (0.00)	0.000 * (0.00)	0.000 (0.00)
ShrHolder1	−0.479 (0.53)	−0.408 (0.53)	4.269 *** (0.92)	2.037 (4.16)
Controller	−0.162 (0.17)	−0.123 (0.17)	−0.955 ** (0.31)	−1.372 (1.34)
lnSize	2.289 *** (0.06)	2.295 *** (0.06)	2.761 *** (0.11)	8.515 *** (0.49)
Liability	0.026 * (0.01)	0.026 * (0.01)	0.183 ** (0.06)	0.215 (0.16)
ReturnOA	−0.318 (0.19)	−0.324 (0.19)	−1.922 ** (0.71)	−5.919 (4.38)
punishTime				−0.162 (0.10)
punishAmount				0.002 * (0.00)
punishIntensity				0.004 (0.12)
Constant	−46.729 *** (1.29)	−46.308 *** (1.28)	−59.200 *** (2.37)	−183.354 *** (10.72)
R ²	0.085	0.085	0.146	0.164
df_r	19,246	19,247	4083	1941
Bic	147.418	147.416	29.395	18.352

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Parameters such as the concentration of environmental violations in different provinces were endogenous variables of the deterrence effect of external penalties, so a further test was conducted with different scales of penalties using the division of the median, as shown in Table 10. More specifically, in terms of the divisions of the penalties imposed in the specific provinces, in the sample group that was less than the median, the dummy parameters of high-pollution industries and penalties were statistically significant at the levels of 1 and 5%, respectively. Meanwhile, the variation in the punishment amount imposed by the authority was statistically significant at the level of 10%. However, for the sample group that was greater than the median, these variables were not statistically significant. Therefore, external penalties had a deterrence effect overall, particularly for the group that was smaller than the median. In terms of the group with greater external penalties, this effect was not statistically significant, and this finding was interpreted as firms being used to the penalties issued by the environmental authorities.

Meanwhile, the solutions deployed by firms to mitigate the effects of penalties were different. Corporations are likely to utilize political donations as a business strategy to ease regulatory actions [46], take carbon credits to offset their own emissions [47], and purchase abatement goods from an eco-industry within a duopolistic framework [39].

Additionally, in the regional heterogeneity analysis, under different environmental regulations for green innovation and pollutant emissions and under various external pressures, 61.2% of heavily polluting enterprises chose conservative environmental behavior [48]. Other research—for example, studies on coping with increasingly severe environmental regulatory pressure, end-of-pipe technologies, and clean technologies [49], sustainable development in the Indian coal mining industry [50], the influencing factors of emissions in various provinces [51], and manufacturers' preference to cooperate with a medium-

rich retailer for an emission-dependent supply chain [52]—supported the findings of the heterogeneity analysis.

Table 10. Heterogeneity analysis in terms of external punishments.

	Model 1	Model 2	Model 3	Model 4
	Provpenalty < 5022 (Median)	Provpenalty < 5022 and Yearprior ≥ 0	Provpenalty ≥ 5022	Provpenalty ≥ 5022 and Yearprior ≥ 0
HiPollution	−1.577 *** (0.30)	−4.546 ** (1.47)	−1.689 (1.11)	−1.550 (2.04)
Penalty	0.619 ** (0.22)		0.961 (0.95)	
ProvPenalty	0.001 *** (0.00)	0.001 (0.00)	−0.000 (0.00)	−0.000 (0.00)
ShrHolder1	−0.544 (0.54)	−1.523 (5.11)	3.629 (2.25)	12.688 (6.55)
Controller	−0.114 (0.18)	−1.261 (1.59)	0.628 (0.85)	−0.473 (2.48)
lnSize	2.112 *** (0.06)	8.875 *** (0.58)	3.819 *** (0.28)	7.682 *** (0.91)
Liability	0.024 * (0.01)	0.230 (0.17)	−1.031 (1.04)	−7.537 (5.38)
ReturnOA	−0.284 (0.19)	−6.980 (5.28)	−4.658 (3.30)	−13.501 (9.33)
punishTime		−0.189 (0.11)		0.181 (0.28)
punishAmount		0.002 * (0.00)		0.002 (0.01)
punishIntensity		0.028 (0.15)		−0.071 (0.20)
Constant	−43.119 *** (1.33)	−190.883 *** (12.74)	−80.448 *** (6.24)	−165.380 *** (19.62)
R ²	0.081	0.164	0.139	0.189
df_r	17,582	1494	1655	436
Bic	134.004	14.317	13.288	4.038

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.3. Endogeneity and Heterogeneity Analysis

Importantly, regarding endogeneity issues, firstly, in the design of the sample data, two sets were deployed, namely, heavily polluting listed firms and punished firms, in order to avoid endogeneity. Secondly, issues such as simultaneity, dependent variables, and green patents were statistically associated with the dummy variables of HiPollution and lnSize. Other variables, such as ShrHolder1, Controller, Liability, and ReturnOA, were not associated with green patents and vice versa. Meanwhile, the variable lnSize was statistically associated, so there may have been a heterogeneity problem, and further segmentation was necessary.

As shown in Table 11, in terms of the divisions according to the enterprise size, the dummy variable of high pollution and the percentage of shareholders were both statistically significant. Meanwhile, their coefficients were negative, demonstrating that the higher the percentage of the top shareholder, the fewer green patents and innovations for both larger and smaller enterprises. However, regarding the variables for punishment, the number of punishments was statistically significant for both larger and smaller enterprises at the levels of 1% and 5%, respectively, while the coefficients were the opposite. For the group of smaller enterprises, the increase in the term of the number of punishments was associated with an increase in green innovation, while the contrary was found for larger enterprises.

Table 11. A comparison using heterogeneity analysis based on the size of the companies.

	Model 1	Model 2	Model 3	Model 4
	Insize < 22 (Median)	Insize < 22 and Yearprior ≥ 0	Insize ≥ 22	Insize ≥ 22 and Yearprior ≥ 0
HiPollution	−0.257 ** (0.09)	−0.209 (0.55)	−2.587 *** (0.48)	−4.811 ** (1.51)
Penalty	0.085 (0.07)		1.491 *** (0.36)	
ProvPenalty	0.000 *** (0.00)	0.000 (0.00)	0.000 *** (0.00)	0.000 (0.00)
ShrHolder1	−0.340 * (0.17)	2.172 (2.05)	−1.986 * (0.86)	−5.615 (5.09)
Controller	−0.266 *** (0.05)	−0.414 (0.65)	−0.522 (0.30)	−2.276 (1.66)
lnSize	0.236 *** (0.04)	0.706 (0.67)	4.885 *** (0.14)	14.265 *** (0.77)
Liability	0.002 (0.00)	−0.052 (0.04)	−4.026 *** (0.74)	−9.833 * (4.32)
ReturnOA	−0.015 (0.04)	−1.053 (1.28)	−1.744 * (0.85)	−6.161 (8.03)
punishTime		0.790 *** (0.20)		−0.297 ** (0.11)
punishAmount		0.003 (0.00)		0.002 * (0.00)
punishIntensity		0.041 (0.05)		−0.119 (0.15)
Constant	−4.112 *** (0.80)	−15.919 (13.83)	−103.639 *** (3.03)	−308.166 *** (16.58)
R ²	0.021	0.077	0.119	0.218
df_r	8299	411	10,938	1519
Bic	36.511	2.681	89.270	14.642

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The size of the enterprise affects the transmission mechanism of penalties. When subcontractors are deployed by large enterprises, the technological investments in green innovation are often larger and have a long operation cycle; firms deploy the option of subcontractors to meet the demands of regulations, and greenwashing can hardly be detected by other stakeholders [6]. Meanwhile, as a substitute for financial liabilities, environmental liabilities are more pronounced for larger firms [53]; there was a significant U-shaped relationship between China's energy efficiency index and environmental regulation according to a provincial-level analysis [54]. Moreover, the parameters of different industries are also important for the mechanisms of the imposed penalties; for example, as shown by the driving factors of green innovation in the sports goods manufacturing industry, competition and strict environmental policy can promote green innovation [32].

5. Discussion, Conclusions, Policy Implications, Limitations, and Further Research

5.1. Discussion

This study aimed to investigate the transmission mechanism between environmental penalties and green innovation using an empirical econometric model and two sets of samples, namely, heavily polluting listed firms and punished firms. Regarding Hypothesis H1, except for penalty fine amounts, environmental penalties cannot lead to greater green innovation from the long-term perspective, while from the short-term perspective, they have a spontaneous conditioned effect on green innovation, but this effect fades away quickly. Meanwhile, this research divided the dataset according to two patterns for the data analysis, namely, panel data and time-series data, thus digging into the effect mechanism from a longitudinal perspective. Consistently, penalties have a more significant influence at

the early stage [12], emphasizing the different effects at different stages. Meanwhile, there is an adverse effect [10] that is positively associated with green innovation [14]. Accordingly, it cannot be simply concluded that there are positive or negative associations with green innovation; as shown by a rigorous comparison with previous studies, the whole process should be overseen, the effects at different stages should be studied, and the positive effect that fades away quickly in the second year should be found.

Regarding the second hypothesis, the coefficients of external penalties were statistically significantly associated with green innovation due to the intertwined effects of actual controllers and shareholders, which was consistent with the conclusion that the stronger the regional environmental regulation, the greater the positive impact [11]. Meanwhile, it was also statistically significant for the interaction terms with internal and external variables, such as firms' environmental awareness, company staff, capabilities [16], board reforms, the effect on corporate social responsibility, and indirect momentum for green innovation [33]; there was a negative association with the proportion of family ownership [6], the size of the company, sector affiliation [38], corporate environmentalism in a managerial delegation and abatement subsidy policy [39], and CEOs' short-term and long-term compensation [40].

5.2. Main Conclusions

The main conclusions of this study are threefold. Firstly, among the three parameters, the number of penalties and the intensity of penalties were not statistically significantly associated with green innovation, indicating that the hypothesis that the greater the environmental penalties, the greater the green innovation could not be supported. However, the penalty fine amount was statistically significantly associated with green innovation, indicating that only the hypothesis that the greater the environmental penalty amount, the greater the green innovation could be supported. Secondly, from the longitudinal perspective, there was only one spontaneous conditioned effect on the green patents, but the effect quickly faded away after the second year, indicating that firms did not seek green innovation as a solution for environmental penalties from this perspective. Thirdly, external penalties were significantly statistically associated with green innovation due to the intertwined effects of actual controllers and shareholders, but with a very subtle coefficient. Meanwhile, taking the median as the benchmark for the group division, the group that was smaller than the median was statistically significant. However, in the group with higher external penalties, this was not statistically significant, leading to the interpretation that firms are used to the penalties issued by environmental authorities.

5.3. Policy Implications

Firstly, regarding policies, an appropriate mix of regulations and stimuli should be proposed. In terms of the transmission mechanism, this research indicated that penalties have a short and spontaneous effect on green innovation from the longitudinal perspective; they can only exert an effect on behaviors related to tackling challenges in the short term, but motivation is lacking for the long term. Accordingly, there should be separate and independent support for green innovation and research, striking a balance between the stick and the carrot. Secondly, regarding the object of supporting policies, they cannot only refer to the final achievement of green patents but must also consider the procedures of innovation and the use of green materials in the development of green technology and innovation [33,38,39]. Thirdly, as there is an external deterrence effect, public communication and the improvement of environmental awareness are important for further green development [14,16].

5.4. Limitations and Future Research

Firstly, this research did not consider the issues of relocation of production as spatial leakages to offset penalties. Secondly, this framework of research and data did not address causal relationships; therefore, the Difference-in-Difference (DID) and Difference-in-Difference in Difference (DDD) methods can be deployed to study cross-time differences,

thus eliminating the time-invariant unobserved group features between the effects of treatments on a controlled group in a quasi-natural experiment.

$$Y_{i,t} = \alpha_0 + \alpha_1 du + \alpha_2 dt + \alpha_3 du * dt + \varepsilon_{i,t} \quad (4)$$

In Formula (4), du is a grouping dummy variable. If individual i is affected by the implementation of a policy, then individual i belongs to the treatment group, and the corresponding du value is 1. If individual i is not affected by the implementation of a policy, then that individual belongs to the control group, and the corresponding du value is 0. Meanwhile, dt is a dummy variable for policy implementation; when the value of dt is 0, this refers to the status before the policy implementation, and 1 refers to the status after the policy implementation. $du \cdot dt$ is the interaction term between the dummy variables of the grouping and policy implementation, and the coefficient α_3 reflects the net effect of policy implementation.

In the model setting of the DID method, as shown in Table 12, there are two key conditions. Firstly, there must be a pilot policy impact to divide the treatment group and control group. Secondly, there must be a set of panel data for at least two years, namely, one year before and one year after the policy implementation.

Table 12. The framework for the Difference-in-Difference method.

Group	Before the Policy (Penalty)	After the Policy (Penalty)	Difference
Treatment Group	$\alpha_0 + \alpha_1$	$\alpha_0 + \alpha_1 + \alpha_2 + \alpha_3$	$\alpha_2 + \alpha_3$
Control Group	α_0	$\alpha_0 + \alpha_2$	α_2
Difference	α_1	$\alpha_1 + \alpha_3$	α_3 (D-in-D)

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