Evaluating the Role of Environmental Policy in Driving Green Innovation in the Corporate Sector

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Abstract. Based on the implementation of the NEPL in 2015, this paper uses the DID model to explore the impact of the policy on the GTI of enterprises. The study finds that the NEPL has significantly promoted the GTI of heavy polluting enterprises, and this promotion effect is sustainable. Further analysis shows that enterprise R&D investment plays a significant intermediary role, which can improve the level of GTI of heavy polluting enterprises. In addition, the results of heterogeneity analysis show that the NEPL has a more significant promotion effect on non-state-owned enterprises. These research conclusions provide some enlightenment and suggestions for improving the research on the impact of the NEPL on the GTI of enterprises.

Keywords: Green Technology Innovation (GTI), R&D Investment, DID Model, New Environmental Protection Law (NEPL).

1. Introduction

China's strides in green development are commendable, but the pursuit of carbon peak and neutrality demands a rigorous industrial overhaul. Utilizing Green Technology Innovation (GTI) as a foundation, enterprises are expected to cultivate an exemplary development framework that fortifies the merits of green progress on the path to achieving carbon-related goals [1]. At the same time, on January 1, 2015, The People's Republic of China officially put into effect the Environmental Protection Law, which is henceforth referred to as the "New Environmental Protection Law." In order to deal with the serious environmental pollution problem, it absorbed the advanced experience of foreign environmental law and established a new structure of environmental protection forces. The legislative breakthrough of this paper is mainly reflected in the following three aspects: first, the implementation of regulatory mode transformation, focusing on solving current and preventing future environmental problems; The transformation of environmental protection law enforcement solves the problem that the environmental protection department has no right to enforce the law; Third, the requirements for information transparency and public participation have been raised.

Contrasting with Jiang Sanliang and Wu Haiqiang [2], who employed the citation count of corporate green patents as a measure of the quality of corporate green innovation, this paper adopts the total number of green invention patent applications as an index to determine the level of corporate green innovation. The potential peripheral contributions of this paper are delineated as: firstly, it assesses the GTI of enterprises with high pollution levels by the citation count of their GTI and subsequently investigates the influence of the NEPL on the GTI of these enterprises. Secondly, by selecting R&D investment as the mediating variable, the DID model can more truly and effectively reflect the positive effect of the implementation of the NEPL. Finally, based on the nature of enterprise ownership, this paper discusses the policy impact of the NEPL on soes and non-soes, which provides a new perspective for promoting soes to strengthen GTI and environmental protection.

2. Theoretical analysis and hypotheses

2.1. NEPL implementation and GTI of heavy polluting enterprises

By intensifying environmental legislation, the NEPL transforms the negative externalities of environmental pollution into an internalized cost for enterprises, mandating a change and improvement for businesses with substantial pollution emissions [3]. According to the research of Dong Jingrong et al, under the current policy intensity, both command-type environmental regulation tools and investment-type environmental regulation tools positively affect the investment in green innovation [4], It can promote the sustainable development, external effect and competitive advantage of enterprises [5].

In light of the prior evaluation, the First Proposition is introduced:

H1: The NEPL is conducive to promoting the GTI of heavy polluting enterprises.

2.2. GTI and enterprise R&D investment of heavy polluting enterprises

Green technology innovation capability is a key factor determining the core competitiveness of enterprises, among which R&D investment [6] is one of them. The R&D activities of heavily polluting enterprises often require high capital input, and the results are highly uncertain [7]. Based on the research of Lu Jieyue [8], we found that ESG performance of enterprises has a positive role in promoting green innovation, within this context, ESG performance is shown to influence green innovation via two primary pathways: easing the financial constraints and augmenting government financial support.

Given the deliberation above, the Second Conjecture is advanced:

H2: The GTI capability of enterprises is positively correlated with their R&D investment.

2.3. The impact of NEPL implementation on EPS heterogeneity

Zeng Huixiang [9] mentioned in his study that the NEPL can significantly inhibit the environmental negligence of listed companies with heavy pollution. However, in the study of Liu Jianjiang [3] et al., it is found that the NEPL has a significant transformation and upgrading effect on large and small, eastern and western regions and state-owned heavy polluting enterprises.

After the review above, the Third Hypothesis is put forward.:

H3: The NEPL has a more significant impact on state-owned enterprises.

3. Research design

3.1. Sample selection and data sources

Employing a dataset that captures the A-shares of China's industries with considerable ecological strain from the years 2012 to 2022, this paper probes into the NEPL's influence on the green innovation within these sectors. The demarcation of industries under analysis is in accordance with the scholarly definitions of Li Qingyuan and Xiao Zehua [10], and Qi Shaozhou [11], and aligned with the China Securities Regulatory Commission's 2012 classification benchmarks, the industries under scrutiny in this paper, identified by the codes B06, B07, B08, B09, C17, C19, C22, C25, C26, C28, C29, C30, C31, C32, and D44, have been meticulously chosen. Subsequently, the preliminary pool of subjects has undergone the following refinement process: (1) In order to ensure the financial health of the sample companies, the samples of companies with an asset-liability ratio of more than 100% are excluded. These firms may face higher financial risk and may behave differently from the average firm, which may bias the findings. (2) Eliminate the samples with missing data of important variables. Missing data may lead to inaccurate model estimation and affect the robustness of research conclusions. (3) Extreme values may have a significant impact on the results of statistical analysis. After the processing, there are 281 samples in total. Among them, the basic information and economic

characteristics of the enterprise are from the CSMAR database, and the data on corporate green patents which are come from the CNRDS database.

3.2. Definition of variables

(1) Explained variable: enterprises' GTI

Drawing on the research of Li and Xiao [10] and Qi [11], In this scholarly work, the metric for delineating the eco-innovation of corporations is the annual tally of their green patent applications. Initially, this choice surpasses carbon emission intensity as a benchmark, which is often subject to extrinsic influences, by offering a more precise portrayal of a company's innovative prowess. Subsequently, the count of patent applications is favored over the number of patents awarded, as it provides a measure that is both contemporaneously relevant and consistent.

(2) Explanatory variables: DID .

Where $Treat$ and $Post$ are the set group and time dummy variables respectively. If the enterprise is in heavy pollution industry, the value of $Treat$ is 1, which is the treatment group; Otherwise, the value of $Treat$ is 0 and it is the control group. Since the NEPL was formally implemented in 2015, the value of B is 0 before 2015; After 2015, $Post$ takes the value of 1. If the enterprise is in heavy pollution industry, and the value of $Treat \times Post$ is 1 after 2015; Otherwise, $Treat \times Post$ takes the value 0. If the coefficient of $Treat \times Post$ is Profoundly constructive, it indicates that compared with enterprises is less polluting sectors, There has been a significant enhancement in the green innovation of businesses operating in heavily polluting sectors, propelled by the NEPL. If the coefficient of $Treat \times Post$ is significantly negative, it indicates that compared with enterprises in non-heavy polluting industries, there is no considerable improvement in the GTI of enterprises in high-pollution industries post the NEPL's enactment.

(3) Variable of control

This study, in consultation with current literature, pinpoints four factors to be utilized as control variables: asset-liability ratio (Lev), return on assets (ROA), the number of employees ($\ln Labor$) and the size of the board of directors ($Board$). See Table 1 for the definition and description of variables.

Table 1. Definition of variables

Type of variable	Name of variable	Symbol of variable	Description of variables
Variable explained	Green innovation of enterprises	$\ln GI$	Number of green invention patent applications of enterprises
Explanatory variables	Whether it is a heavy polluting industry	$Treat$	$Treat$ =1 for heavy polluting firms, and $Treat$ =0 otherwise
	Whether the NEPL is implemented	$Post$	Sample years are defined as $Post$ =1 for 2015 and beyond, and $Post$ =0 otherwise
Mediating variable	R&d investment	rd	Current R&D expenditure of the enterprise
Variable of control	Asset-liability ratio	Lev	Total liabilities/total assets of the enterprise at the end of the period
	Return on assets	ROA	Net profit/total assets at the end of the year
	Number of employees	$\ln Labor$	Logarithm of the number of employees in the enterprise
	Size of the Board	$Board$	The natural log of the aggregate directorship

3.3. Model building

Firstly, this paper constructs the *DID* regression model (1) to test H1:

$$\ln GI_{i,t} = \beta_0 + \beta_1 Treat_{i,t} \times Post_{i,t} + \beta Controls_{i,t} + Year_t + \varepsilon_{i,t} \quad (1)$$

Where $\ln GI_{i,t}$ is the number of green patents applied by enterprise i in year t, $Post_{i,t}$ is whether it is a heavy polluting enterprise, whether the NEPL is implemented, $Controls_{i,t}$ is a series of control variables, $Year_t$ is the year fixed effect, the fixed effect model can effectively control the time effect and is suitable for panel data analysis. In this paper, robust standard errors are used to deal with the possible heteroscedasticity and serial correlation, thus improving the reliability of the estimation results. $\varepsilon_{i,t}$ is the error term, and the regression standard error is adjusted by clustering at the enterprise level.

Secondly, according to the above theoretical analysis, the NEPL may promote the GTI of enterprises in heavy polluting industries by increasing R&D investment. To this end, a mediating effect model is constructed, and models (2) to (3) are constructed on the basis of Model (1) to test H2:

$$rd_{i,t} = \beta_0 + \beta_1 Treat_{i,t} \times Post_{i,t} + \beta Controls_{i,t} + Year_t + \varepsilon_{i,t} \quad (2)$$

$$\ln GI_{i,t} = \beta_0 + \beta_1 Treat_{i,t} \times Post_{i,t} + \beta_2 rd_{i,t} + \beta Controls_{i,t} + Year_t + \varepsilon_{i,t} \quad (3)$$

Among them, current R&D expenditure (*rd*) is used to measure R&D investment, and other variables are consistent with Model (1).

4. Empirical results and analysis

4.1. Descriptive statistics

The key variable statistics are delineated in Table 2. It discloses an average of 0.912 for green patent filings, accompanied by a standard deviation of 0.165, which points to a consistent level of green patent applications across the majority of the enterprises in the sample. Additionally, the table signifies that a substantial 64% are categorized as heavy polluters, while the enactment of the NEPL is associated with 73% of the sample, as indicated by their respective mean values.

Table 2. Descriptive statistics.

Variables of interest	Average value	Median number of	Standard deviation	Minimum value	Maximum value
Standardization (Number of green patent applications)	0.912	1	0.165	0	1
Asset-liability ratio	0.446	0.449	0.192	0.0278	2.394
Return on assets A	0.050	0.049	0.080	-2.234	0.831
Treat	0.640	1	0.48	0	1
Post	0.730	1	0.445	0	1
Number of employees	8.234	8.149	1.321	4.745	13.253
Size of the Board	2.151	2.197	0.197	1.386	2.708
R&d investment	18.358	18.289	1.758	5.094	25.025

In order to avoid potential endogeneity problems, we conducted statistics on the correlation of the selected variables. Table 3 illustrates a low correlation among the variables, which adeptly addresses and keeps in check the potential endogeneity bias.

Table 3. Variable correlation analysis

	Normalized Y1	*DID*	Return on assets A	Asset-liability ratio	Number of employees	Size of the Board	Year
Normalized Y1	1.000						
DID	0.040	1.000					
Return on assets A	-0.055	0.030	1.000				
Asset-liability ratio	-0.198	0.037	-0.249	1.000			
Number of employees	-0.522	0.093	0.116	0.499	1.000		
Size of the Board	-0.212	0.069	0.057	0.182	0.279	1.000	
Year	-0.037	0.443	-0.050	0.047	0.082	-0.043	1.000

4.2. Analysis of benchmark regression results

To thoroughly investigate the influence of the NEPL on Green Technology Innovation (GTI), this paper employs a rigorous econometric approach using Model (1) for regression analysis. With a meticulous layout in Table 4, the benchmark results consider the year's fixed effects alongside those specific to each enterprise, thereby ensuring the sturdiness of the conclusions drawn. Upon close examination of Column (1), it becomes evident that the regression coefficient associated with the interaction term is not only statistically significant but also strongly positive, reaching a confidence level of 1%. This compelling evidence substantiates the assertion of Hypothesis H1, which posits that the NEPL, since its implementation, has had a markedly positive impact on the GTI of enterprises operating within heavily polluting industries. The significance of this finding underscores the effectiveness of the NEPL in driving sustainable innovation and the adoption of greener practices among firms that are traditionally associated with higher levels of environmental impact. Consequently, this research not only substantiates the empirical significance of regulatory structures in catalyzing technological progress but also imparts beneficial knowledge to policy architects and sector pioneers striving to enhance environmental durability via legal channels.

Table 4. Benchmark regression results of variables

Variables of interest	(1)
	$\ln GI$
DID	0.048***
	(0.061)
ROA	0.089**
	(0.043)
Lev	0.091***
	(0.017)
$\ln Labor$	-0.071***
	(0.002)
Board	-0.079***
	(0.013)
_cons	1.621***
	(0.031)
Year fixed effect	Yes
Industry fixed effects	Yes
Value of observation	3,090
R^2	0.298

The notations *, **, and *** mark the significance levels of 10%, 5%, and 1%, respectively; the parentheses contain the t-values for the standard errors, clustered at the enterprise level, a format that will persist for the remainder of the document.

4.3. Further regression analysis

Building upon the work of Wang et al. (2020), this research deploys a three-stage recursive model to ascertain the mediating role of R&D investment in the GTI of enterprises after the NEPL's enforcement. The coefficient, which is significantly positive at the 1% level, reflects the positive influence of the NEPL on companies' GTI. Column (2) displays the regression analysis with R&D input as the variable of interest, and Column (3) validates the mediating role of R&D investment in the green technological innovation of enterprises during the NEPL's implementation.

Table 5. Statistical Results of the Mediating Role Regression

Variables of interest	(1)	(2)	(3)
	$\ln GI$	rd	$\ln GI$
DID	0.048***	-0.510***	0.035***
	(0.006)	(0.054)	(0.006)
rd			-0.024***
			(0.002)
ROA	0.089**	1.553***	0.127**
	(0.043)	(0.385)	(0.043)
Lev	0.091***	-0.533***	0.078***
	(0.017)	(0.147)	(0.016)
$\ln Labor$	-0.071***	0.930***	-0.048***
	(0.002)	(0.021)	(0.003)
$Board$	-0.079***	-0.015	-0.079***
	(0.013)	(0.119)	(0.013)
$\_cons$	1.620***	10.456***	1.872***
	(0.031)	(0.270)	(0.036)
Year fixed effect	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
Value of observation	3,090	3,090	3,090
R^2	0.298	0.515	0.330

4.4. Analysis of heterogeneity

State-owned enterprises (SOEs) follow national policies and have more environmental and social responsibilities. Non-state-owned enterprises are more operationally flexible but have less access to official funding. The study divides samples into SOEs and non-SOEs for regression analysis using model (1), revealing coefficients of 0.026 for SOEs and 0.61 for non-SOEs. The 1% significant result for SOEs indicates that the NEPL better stimulates their green technology innovation (GTI), likely due to stricter post-NEPL ecological assessments, driving SOE innovation align with policies [12].

Table 6. Heterogeneity regression results

Variables of interest	(1)	(2)
	$\ln GI$	$\ln GI$
DID	0.026**	0.061***
	(0.012)	(0.007)
ROA	0.064	0.017
	(0.094)	(0.045)
Lev	0.111***	0.037*
	(0.026)	(0.021)
$\ln Labor$	-0.075***	-0.063***
	(0.004)	(0.003)
$Board$	-0.152***	-0.004
	(0.023)	(0.017)
$\_cons$	1.829***	1.414***
	(0.051)	(0.040)
Year fixed effect	Yes	Yes
Industry fixed effects	Yes	Yes
Value of observation	1,265	1,826
R^2	0.338	0.256

4.5. Robustness test

(1) Parallel trend test: Figure 1 shows a policy effect decline two years post-implementation, possibly due to a lack of specific measures. A rebound four years later indicates a delayed corporate response, supporting Hypothesis H1.

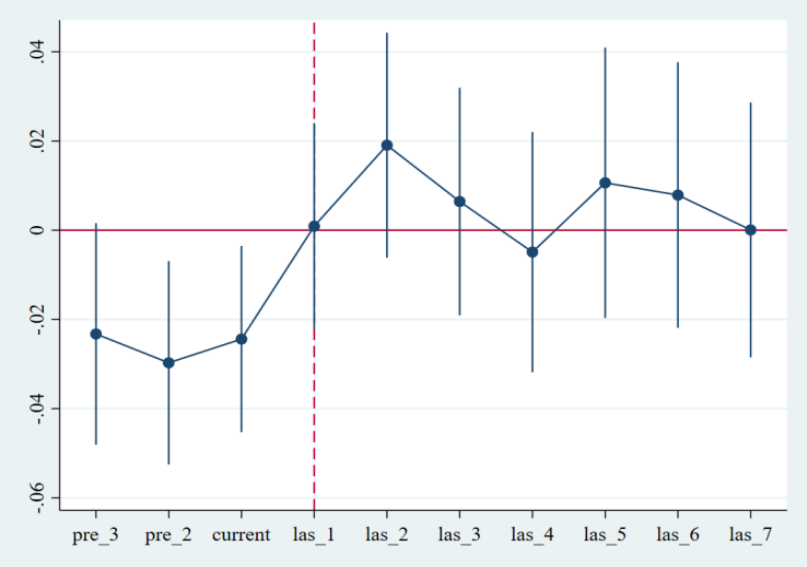

Figure 1. All firms are tested for parallel trends

(2) Dynamic testing was conducted post-NEPL implementation, with analysis by year. The stable 1% coefficient in Table 7's Column (1) after 2015 suggests significant improvements in the quantity, quality, and efficiency of GTI output from heavily polluting firms following NEPL.

Table 7. Test of dynamics

Year	(1)
	$\ln GI$
2013	0.003
	(0.017)
2014	-0.001
	(0.017)
2015	-0.027**
	(0.012)
2016	-0.036**
	(0.012)
2017	-0.033**
	(0.012)
2018	-0.040***
	(0.010)
2019	-0.042***
	(0.012)
2020	-0.044***
	(0.012)
2021	-0.029**
	(0.012)
2022	-0.012
	(0.012)
_cons	1.620***
	(0.031)
Year fixed effect	Yes
Industry fixed effects	Yes
Value of observation	3,090
R^2	0.298

5. Empirical Conclusions and Suggested Policies

5.1. Study Finale

This study explores NEPL's effect on green innovation in high-pollution firms. It reveals that NEPL substantially boosts their green innovation. Further analysis indicates that higher R&D spending by these firms significantly fosters green innovation. Moreover, heterogeneity analysis suggests a stronger NEPL impact on state-owned enterprises (SOEs).

5.2. Policy suggestions and implications

This paper offers three key suggestions: First, acknowledging the NEPL's limitations as a foundational law, it cannot cover all environmental aspects in detail. Second, it's crucial to maximize the NEPL's policy impact by focusing on pollution prevention principles while addressing the need for more concrete measures. Third, recognizing R&D investment's positive role as a mediator in NEPL implementation, further research is needed on its intermediary effect between government subsidies and innovation performance [13].

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