

Natural Resource Asset Departure Audit and Green Innovation in Heavily Polluting Enterprises

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Abstract. This study treats the natural resource asset departure audit system as an exogenous quasi-natural experiment. Using data from heavily polluting listed enterprises between 2009 and 2019, a difference-in-differences (DID) approach is applied to examine the impact of the audit system on corporate green technology innovation. Empirical results indicate that the pilot implementation of this system has, to a certain extent, promoted green technology innovation among heavily polluting listed companies. This research provides empirical evidence for evaluating the effectiveness of the natural resource asset departure audit pilot and holds significant implications for a comprehensive understanding of the audit system.

Keywords: Natural resource asset departure audit; heavily polluting enterprises; green technology innovation.

1. Introduction

Since entering the new era, China's rapid economic development has been accompanied by extensive growth in high-pollution and high-emission industries, which has exerted a negative impact on environmental quality. Moreover, the current incentive mechanism for government officials in China primarily revolves around a political tournament model focused on economic growth, without incorporating indicators such as environmental quality and sustainable development into the performance appraisal system. As a result, many local government officials, driven by short-term economic performance considerations, may prioritize economic achievements at the expense of the environment during their tenure. Currently, issues related to sustainable economic development and environmental governance have attracted widespread attention. In November 2013, China first proposed the implementation of a natural resource asset departure audit for leading cadres. Pilot programs were launched in 17 regions across several provinces in 2014, and the scope of these pilots continued to expand between 2015 and 2017. Building on earlier pilot experiences, the audit system entered a phase of regularized implementation in 2018.

Compared to other environmental protection assessment mechanisms, this departure audit system exhibits the following distinctive features: (1) It audits the fulfillment of responsibilities by leading cadres in environmental protection work, highlighting their central role; (2) It focuses primarily on the protection of natural resource assets, including water, land, forests, wildlife, and other resources; (3) In addition to assessing the actual outcomes of environmental efforts, it emphasizes the development and implementation of institutional frameworks, such as environmental laws, regulations, policies, and standards; (4) It establishes clear mandatory indicators and evaluation tiers for assessing leading cadres, with each tier corresponding to specific benchmarks. As an institutional mechanism that combines both incentives and constraints, the system is bound to influence the decision-making of stakeholders. The implementation of this pilot policy has, to some extent, increased the pressure on local leading cadres to improve environmental governance. In particular, heavily polluting and high-emission enterprises have become key targets of government scrutiny. For these enterprises, maintaining existing production processes and technologies will make it difficult to meet regulatory requirements. To alleviate external regulatory and market pressures, companies have strong incentives to adopt green technology innovations to meet the expectations of stakeholders such

as the government and the market. In order to reduce political and environmental costs, enhance their social image, and maximize profits, heavily polluting enterprises are motivated to actively adopt innovative technologies to improve the efficiency of natural resource use.

2. Theoretical analysis and research hypotheses

The Natural Resource Asset Departure Audit system for leading cadres imposes binding environmental protection constraints. Initially introduced at the national level, the system defines its ultimate objectives, identifies accountable entities, and establishes mandatory assessment indicators alongside evaluation grading standards. Provinces are encouraged to adapt the framework according to local conditions, actively explore audit models, and develop specific implementation policies for pilot programs. These initiatives started in selected regions and gradually expanded, ultimately forming a comprehensive set of evaluation metrics aimed at supporting ecological civilization construction.

The impact of environmental performance audits on corporate green technology innovation can be categorized into two effects: the “compliance cost effect” and the “innovation compensation effect.” The compliance cost effect suggests that environmental audits impose additional pollution control and emission reduction costs on firms, which may lead to reduced R&D investment in the short term as companies seek to manage expenses. As a result, stringent environmental audits could temporarily hinder green technology innovation. In contrast, the innovation compensation effect argues that appropriately designed environmental audits can stimulate green technology innovation. Although such innovation involves high risks, improvements in production techniques and processes can enhance productivity and resource efficiency, fundamentally reducing pollution emissions and supporting environmental goals such as energy conservation, emission reduction, and waste recycling. Furthermore, green technology innovation helps companies build a positive environmental image, enhancing corporate value while promoting sustainable economic development—a win-win outcome.

According to the Porter Hypothesis, environmental regulation can spur green technology innovation in firms. By analyzing and evaluating the outcomes of environmental audits, companies can identify issues in resource use, environmental risks, and opportunities for improvement. This auditing process encourages enterprises to invest in and strive for green technology innovation, thereby reducing resource consumption, minimizing emissions, and improving environmental sustainability. When the Natural Resource Asset Departure Audit incorporates environmental and resource management into its evaluation criteria, firms are further motivated to adopt green technology innovations to meet audit requirements and enhance their performance in resource efficiency and environmental protection.

Drawing on stakeholder theory, the oversight imposed by the departure audit system creates pressure on local government officials to improve environmental governance. To pass institutional evaluations and maintain their administrative reputation, officials are likely to respond proactively by regulating and rectifying corporate environmental practices. Consequently, companies face increased environmental responsibilities, which drive them to pursue green technology innovation—adopting energy-saving, emission-reduction, and renewable energy technologies—to mitigate the negative environmental impact of industrial pollution and waste. This approach represents one of the most effective ways to address stakeholder environmental pressures. Given the mandatory assessment criteria of the Natural Resource Asset Departure Audit, firms are more inclined to engage in green technology innovation, develop environmentally friendly technologies, and reduce environmental costs through energy conservation, emission reduction, and low-carbon transformation.

Based on this analysis, the following hypothesis is proposed:

H: Compared to non-pilot cities, heavily polluting listed companies in pilot cities implementing the Natural Resource Asset Departure Audit system will engage in more green technology innovation.

3. Research design

3.1. Sample selection and data description

This study selects A-share listed companies in heavily polluting industries in China from 2009 to 2019 as the research sample to empirically examine the impact of the Natural Resource Asset Departure Audit system on corporate green technology innovation.

Information regarding the pilot implementation of the audit system was primarily collected from official government websites and relevant media reports. The pilot cities and their respective years of implementation were manually identified and cross-verified across multiple sources. According to the collected data, the first batch of pilot regions in 2014 included 17 cities, followed by an additional 154 regions in stages between 2015 and 2017. In total, 171 cities were involved in the pilot program from 2014 to 2017.

Green technology innovation by heavily polluting firms is measured using the number of green patent applications, with data sourced from the National Intellectual Property Administration. City-level characteristic data were obtained from provincial and municipal statistical yearbooks, while financial data were collected from the CSMAR database. The sample excludes the following firms: (1) those listed after 2014, (2) enterprises labeled as *ST, ST, or delisted, and (3) firms with missing values. To mitigate the influence of outliers, the final sample consists of 5,853 valid observations.

3.2. Variable Definitions

3.2.1. Explained Variable

Three indicators are used to measure corporate green technology innovation: total number of green patent applications; total number of green invention patent applications; total number of green utility model patent applications. To avoid taking the natural logarithm of zero, the total number of patent applications is incremented by 1 before applying the natural log transformation.

3.2.2. Explanatory Variable

Pilot cities refer to the 171 cities manually identified from official sources. The pilot year corresponds to the year in which each city initiated the audit trial. Two dummy variables, *Treat* and *Post*, are constructed and assigned values according to the following criteria. The interaction term *Treat*Post* = 1 indicates that a heavily polluting enterprise is located in a pilot city during the pilot period.

3.2.3. Control Variables

City-level controls include GDP per capita; Proportion of secondary industry; Regional industrial sulfur dioxide emissions. Firm-level controls include: Firm size; Return on assets (ROA); Cash flow ratio; Whether the firm incurred a loss (dummy); State-owned enterprise (SOE) status (dummy); CEO-Chair duality (dummy); Shareholding ratio of the largest shareholder; Tobin's Q; Firm age.

Definitions of the main variables used in this study are summarized in Table 1.

Table 1. Variable Definitions

Variable	Variable Definition
<i>LnPatent_T</i>	Natural logarithm of (total green patent applications + 1)
<i>LnPatent_i</i>	Natural logarithm of (green invention patent applications + 1)
<i>LnPatent_u</i>	Natural logarithm of (green utility model patent applications + 1)
<i>Treat*Post</i>	Equals 1 if the enterprise is in a pilot city during the pilot period; otherwise 0
<i>LnSO2</i>	Natural logarithm of industrial sulfur dioxide emissions in the city
<i>Lngdp</i>	Natural logarithm of GDP per capita in the city
<i>Industry</i>	Proportion of secondary industry in city's GDP (%)
<i>Size</i>	Natural logarithm of total assets at year-end
<i>ROA</i>	Net profit / average total assets
<i>Cashflow</i>	Net cash flow from operating activities / total assets
<i>Loss</i>	Equals 1 if net profit < 0; otherwise 0
<i>SOE</i>	Equals 1 for state-owned enterprises; otherwise 0
<i>Dual</i>	Equals 1 if the chairman also serves as CEO; otherwise 0
<i>Top1</i>	Number of shares held by the largest shareholder / total shares
<i>LnTobinQ</i>	Natural logarithm of (market value of assets / replacement cost + 1)
<i>Age</i>	Natural logarithm of the firm's age (years)

3.3. Model Design

The following regression model is constructed to examine the impact of the Natural Resource Asset Departure Audit on green technology innovation in heavily polluting enterprises:

$$\ln Patent_{T_{it}} / \ln Patent_{i_{it}} / \ln Patent_{u_{it}} = \beta_0 + \beta_1 Treat \times Post + \rho X_{it} + \delta_t + \alpha_i + \varepsilon_{it} \quad (1)$$

The coefficient β_1 reflects the net effect of the audit policy on corporate green innovation. Robust standard errors are clustered at the firm level.

4. Empirical Tests

4.1. Descriptive statistics

This study collects a total of 5,853 observations from heavily polluting listed enterprises between 2009 and 2019. Descriptive statistics of the relevant variables are presented in Table 2.

As shown in the results, the mean value of the total number of green patent applications ($\ln Patent_T$) for the sample enterprises is 0.768, with a standard deviation of 1.149. The mean value of the total number of green invention patent applications ($\ln Patent_i$) is 0.507, with a standard deviation of 0.944, while the mean value of the total number of green utility model patent applications ($\ln Patent_u$) is 0.496, with a standard deviation of 0.911. The mean value of the variable $Treat$ is 0.644, indicating that 64.4% of the sample enterprises are located in pilot regions implementing the Natural Resource Asset Departure Audit system for leading cadres, while 35.6% are in non-pilot regions. This distribution reflects the gradual expansion and maturation of the audit system over the study period.

Table 2. Descriptive statistics

Variable	N	Mean	Median	S.D.	Min	Max
$\ln Patent_T$	5853	0.768	0	1.149	0	7.728
$\ln Patent_i$	5853	0.507	0	0.944	0	7.615
$\ln Patent_u$	5853	0.496	0	0.911	0	5.841
$Treat$	5853	0.644	1	0.479	0	1
$Post$	5853	0.559	1	0.497	0	1
$Treat*Post$	5853	0.357	0	0.479	0	1
$Size$	5853	22.41	22.22	1.329	19.94	26.31
ROA	5853	0.043	0.036	0.065	-0.184	0.259
$Cashflow$	5853	0.058	0.056	0.070	-0.140	0.259
$Top1$	5853	0.370	0.355	0.154	0.091	0.797
$\ln TobinQ$	5853	1.032	0.943	0.331	0.540	2.197
Age	5853	2.352	2.565	0.703	0	3.258
$Loss$	5853	0.106	0	0.308	0	1
$Dual$	5853	0.187	0	0.390	0	1
$Industry$	5853	46.01	47.42	11.09	16.16	89.75
$\ln SO_2$	5853	10.48	10.70	1.223	6.886	13.07
$\ln gdp$	5853	11.06	11.11	0.609	8.704	13.06

4.2. Parallel Trend Test

A parallel trend test model was constructed by incorporating year dummy variables. For the treatment group, the difference between each year and the pilot implementation year was defined: the pilot year itself was coded as 0, the year before the pilot as -1, the year after as +1, and so forth. Thus, t years before the pilot were coded as -t, and t years after as +t. Due to limited data availability beyond five years after the pilot, observations from the fifth year onward were grouped into the fourth year.

As illustrated in Figure 1, the parallel trend test indicates that the estimated coefficients of the key variable were not statistically significant in the three years preceding the implementation of the policy. This suggests that there were no significant differences between the treatment and control groups prior to the pilot initiative. However, in the four years following the policy implementation, a clear and statistically significant divergence emerged between the treatment and control groups.

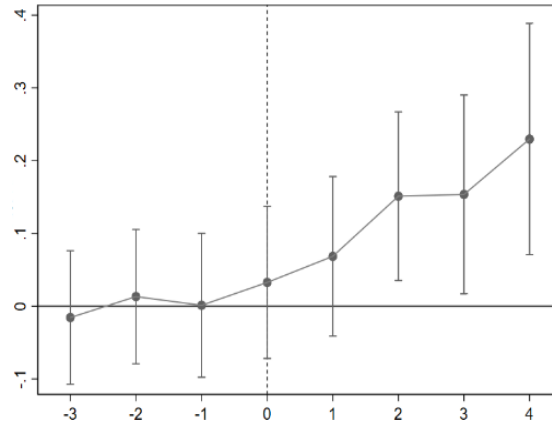


Fig 1. Parallel Trend Test

4.3. Regression Analysis

Table 3 presents the regression results. The findings indicate that, within the full sample of 5,853 observations, the interaction term $Treat \times Post$ exhibits a significantly positive correlation with both $LnPatent_T$ and $LnPatent_i$ at the 1% significance level, and a significantly positive correlation with $LnPatent_u$ at the 5% level. These results demonstrate that, compared to non-pilot regions, heavily polluting enterprises in pilot regions implementing the Natural Resource Asset Departure Audit system applied for a greater number of green patents. This difference is particularly evident in the total number of green patent applications and green invention patent applications, thereby supporting the hypothesis proposed in this study.

Table 3. Regression Analysis

Variable	$LnPatent_T$	$LnPatent_i$	$LnPatent_u$
<i>Treat * Post</i>	0.122*** (0.0386)	0.0839*** (0.0321)	0.0840** (0.0327)
<i>Size</i>	0.332*** (0.0287)	0.262*** (0.0238)	0.222*** (0.0243)
<i>ROA</i>	0.456* (0.264)	0.391* (0.219)	0.206 (0.224)
<i>Cashflow</i>	0.382** (0.176)	0.315** (0.147)	0.314** (0.149)
<i>SOE</i>	0.188** (0.0735)	0.121** (0.0611)	0.123** (0.0622)
<i>Top1</i>	-0.173 (0.160)	-0.176 (0.133)	0.0313 (0.135)
<i>LnTobinQ</i>	0.0615 (0.0420)	0.0600* (0.0349)	0.0557 (0.0356)
<i>Age</i>	-0.0547 (0.0440)	-0.0887** (0.0366)	-0.0321 (0.0373)
<i>Lngdp</i>	-0.111* (0.0623)	-0.0704 (0.0517)	-0.116** (0.0527)
<i>Loss</i>	0.0757* (0.0412)	0.0439 (0.0343)	0.0530 (0.0349)
<i>Dual</i>	0.00364 (0.0342)	0.0447 (0.0284)	-0.0540* (0.0290)
<i>Industry</i>	-0.00451 (0.00330)	-0.00418 (0.00274)	-0.00238 (0.00279)
<i>LnSO₂</i>	-0.0373* (0.0221)	-0.0494*** (0.0184)	-0.0446** (0.0187)
<i>Constant</i>	-5.107*** (0.911)	-3.914*** (0.757)	-2.896*** (0.772)
<i>Year & Firm</i>	Yes	Yes	Yes
<i>N</i>	5,853	5,853	5,853
<i>R²</i>	0.689	0.682	0.645

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are reported in parentheses. The same applies to the subsequent tables.

4.4. PSM-DID

Propensity Score Matching (PSM) is a methodological approach used to address endogeneity issues, particularly the "selection bias problem" in non-randomized experimental settings. Based on this, this study employs a PSM-DID model for robustness testing. The nearest neighbor matching method was applied with a matching ratio of 1:1 and a caliper of 0.05.

When two enterprises are nearly identical in all aspects except for whether they are located in a pilot city, any observed differences in their green technology innovation can be attributed to the implementation of the departure audit system. As shown in Table 4, the regression results from the difference-in-differences (DID) analysis conducted on the matched sample remain statistically significant, confirming the robustness of the findings presented in this study.

Table 4. PSM-DID

Variable	<i>LnPatent_T</i>	<i>LnPatent_i</i>	<i>LnPatent_u</i>
<i>Treat * Post</i>	0.101*** (0.0387)	0.0672** (0.0321)	0.0619* (0.0327)
<i>Size</i>	0.359*** (0.0289)	0.285*** (0.0239)	0.248*** (0.0244)
<i>ROA</i>	0.433 (0.264)	0.364* (0.219)	0.162 (0.223)
<i>Cashflow</i>	0.375** (0.176)	0.295** (0.146)	0.331** (0.149)
<i>Top1</i>	-0.222 (0.160)	-0.192 (0.132)	-0.0242 (0.135)
<i>LnTobinQ</i>	0.0665 (0.0422)	0.0665* (0.0350)	0.0654* (0.0356)
<i>Age</i>	-0.0501 (0.0440)	-0.0839** (0.0364)	-0.0366 (0.0371)
<i>Lngdp</i>	-0.0498 (0.0688)	-0.0263 (0.0570)	-0.0673 (0.0581)
<i>Loss</i>	0.0739* (0.0411)	0.0401 (0.0341)	0.0515 (0.0347)
<i>Dual</i>	0.00943 (0.0342)	0.0498* (0.0284)	-0.0505* (0.0289)
<i>Industry</i>	-0.00694** (0.00333)	-0.00618** (0.00276)	-0.00441 (0.00281)
<i>LnSO₂</i>	-0.0168 (0.0225)	-0.0328* (0.0186)	-0.0218 (0.0190)
<i>Constant</i>	-6.332*** (0.962)	-4.914*** (0.797)	-4.029*** (0.812)
<i>Year & Firm</i>	Yes	Yes	Yes
<i>N</i>	5,734	5,734	5,734
<i>R²</i>	0.678	0.666	0.635

5. Conclusion

This study leverages the exogenous policy shock of the Natural Resource Asset Departure Audit for leading cadres, treating it as a quasi-natural experiment. Using sample data from heavily polluting listed enterprises between 2009 and 2019, it designates firms in pilot cities as the treatment group and measures green technology innovation through the total number of green patent applications. The findings indicate that the audit system can, to a certain extent, increase the number of green patent applications by heavily polluting enterprises and enhance their green technology innovation.

The Natural Resource Asset Departure Audit entered a phase of regular auditing in 2018. To better leverage its supervisory and constraining functions, incentivize enterprises to engage in more green technology innovation, and support the construction of an ecological civilization, this study—based on the research conclusions—proposes recommendations focusing on four aspects: emphasizing regional differences, improving the audit system, enhancing information disclosure, and integrating big data technology.

First, attention should be paid to differences in natural resource endowments across regions. Tailored evaluation indicators should be developed according to each region's specific natural resources and environmental conditions, ensuring that audit results are assessed fairly, justly, and objectively. Second, the Natural Resource Asset Departure Audit system should be further refined. This includes establishing clear accountability definitions, detailing relevant evaluation criteria, and implementing timely accountability measures for issues identified during audits. Those responsible should be held accountable, and audit evaluation results should be recorded in the personal files of leading cadres to motivate government officials at all levels to earnestly fulfill their ecological and environmental responsibilities. Third, information disclosure regarding natural resource assets should be strengthened. Governments ought to establish public information platforms to provide convenient and efficient access for citizens, specify which types of natural resource asset information must be disclosed, and ensure the timeliness and accuracy of such disclosures. Fourth, big data and other internet technologies should be integrated into the departure audit process. By establishing databases and other means, relevant natural resource asset data can be systematically collected and presented in intuitive formats such as charts and maps, thereby enhancing the professionalism and accuracy of audit outcomes.

References

- [1] Albrizio, Silvia, Tomasz Kozluk, Vera Zipperer. Environmental policies and productivity growth: Evidence across industries and firms. *Journal of Environmental Economics and Management*, 2017,81: 209-226.
- [2] Cai, X., Zhu, B., Zhang, H., et al. Can direct environmental regulation promote green technology innovation in heavily polluting industries? Evidence from Chinese listed companies. *Science of the Total Environment*, 2020, 746:140810.
- [3] Eiadat Y, Kelly A, Roche F, Eyadat H. Green and competitive? An empirical test of the mediating role of environmental innovation strategy. *Journal of World business*, 2008, 43(02):131-145.
- [4] Guo, Mengmeng, Yicheng Kuai, et al. Stock market response to environmental policies: Evidence from heavily polluting firms in China. *Economic Modelling*, 2020, 86: 306-316.
- [5] Kneller, Richard, Edward Manderson. Environmental regulations and innovation activity in UK manufacturing industries. *Resource and Energy Economics*, 2012, 34(02): 211-235.
- [6] Li, C., Yao, Q., Wu, J., Wang, D. Financialization and risk taking of non-financial corporations empirical evidence from Chinese listed companies. *Journal of Applied Finance and Banking*, 2019,9(03), 79-107.
- [7] Xie R H, Yuan Y J, Huang J J. Different types of environmental regulations and heterogeneous influence on "green" productivity: Evidence from China. *Ecological Economics*, 2017, 132: 104-112.
- [8] Xie X, Huo J, Qi G, et al. Green process innovation and financial performance in emerging economies: Moderating effects of absorptive capacity and green subsidies. *IEEE Transactions on Engineering Management*, 2016, 63(01):101-112.
- [9] Xu, Jianzhong, Jun, Guan, Yan, Lin. The influencing factors of the relationship between corporate environmental performance and corporate financial performance: Based on a meta-analysis concerned with measuring and situational factors. *Chinese Journal of Management*, 2018, 5: 246–254.
- [10] Zhu, C., R. Liu, and H. Wang. Green innovation performance evaluation and promotion path of patent intensive industries. *Quantitative Economics and Technical Economics Research*, 2018, 35(04): 61-79.