Population, Resources & Environmental Economics (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/pree.2025.060109
ISSN 2616-2253 Vol. 6 Num. 1

Tax Incentives, Environmental Regulation and Corporate Green Technology Innovation: Evidence Based on a Quasi-natural Experiment

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Keywords: Tax incentives; accelerated depreciation policy for fixed assets; green technology innovation; environmental regulation

Abstract: Market failures hinder green technology innovation. This study investigates whether government tax policies incentivize enterprises to pursue green innovation. Leveraging a quasi-natural experiment based on the accelerated depreciation policy for fixed assets and using data from A-share listed firms (2011–2021), we employ a difference-in-differences approach to assess the policy's impact. The findings reveal that: (1) accelerated depreciation significantly enhances corporate green innovation; (2) the effect is more pronounced for state-owned enterprises than for private firms; (3) environmental regulation amplifies the positive impact of accelerated depreciation on green innovation; (4) the policy promotes green innovation through three mechanisms: alleviating financial constraints, increasing environmental investment, and mitigating managerial agency problems. Robustness checks, including parallel trend analysis, placebo tests, and alternative explanatory variables, confirm these results.

1. Introduction

Since China's reform and opening-up, rapid economic growth has been accompanied by excessive resource consumption and environmental degradation. To minimize production costs and maximize efficiency, enterprises have prioritized short-term profit growth at the expense of environmental sustainability. This extensive development model has led to severe pollution and ecological damage, necessitating urgent policy intervention. The 2022 Government Work Report underscores the need for policies that balance pollution reduction with economic incentives, promoting green and low-carbon development. Similarly, the 20th Party Congress Report highlights the imperative to develop green industries and accelerate the adoption of energy-saving technologies. As the role of green technological innovation in reconciling economic growth with environmental sustainability becomes increasingly evident, the transition from conventional technological innovation to green innovation is imperative. Given their dual role as economic agents and environmental stakeholders, enterprises play a crucial part in advancing national green development. However, green technology innovation is capital-intensive, entails significant uncertainty in returns, and is often characterized by long payback periods, discouraging firms from engaging in such investments[1].

A key question arises: how can corporate green technology innovation be effectively promoted? The literature suggests that, due to its strong positive externalities, market mechanisms alone are insufficient, necessitating government intervention to mitigate market failure. Policy instruments typically fall into two categories: regulatory measures and incentive-based mechanisms. From a regulatory perspective, Li & Tao (2022) demonstrate that environmental policies, such as carbon emissions trading mechanisms, can incentivize firms to engage in green innovation[2]. Similarly, Tian et al. (2022) show that transitioning from an environmental protection fee to an environmental protection tax has effectively encouraged polluting enterprises to invest in environmental protection, particularly in preventive environmental measures[3]. From an incentive-based perspective, governments commonly employ taxation and subsidies to stimulate innovation. While green subsidies have been shown to enhance the effectiveness of environmental policies[4], tax-based incentives, particularly those offering ex-ante benefits, tend to have a stronger impact[5]. Among these, accelerated depreciation policies serve as a fiscal incentive that enhances firms' responsiveness to national policies. In the context of China’s emphasis on "lucid waters and lush mountains as invaluable assets" and its commitment to a low-carbon economy, enterprises are expected to align their strategies with green technological advancements. This study, therefore, examines the role of tax incentives in fostering corporate green innovation.

Using data from A-share listed firms (2011–2021), this paper employs the accelerated depreciation policy for fixed assets, introduced by the Ministry of Finance and the State Administration of Taxation, as a quasi-natural experiment. A multi-period difference-in-differences (DID) approach is applied to assess the causal impact of tax incentives on green innovation. The results indicate that tax incentives significantly enhance corporate green innovation. Further, heterogeneity analysis reveals that the effect is stronger for state-owned enterprises (SOEs) and in regions with stringent environmental regulations. Notably, environmental regulation and accelerated depreciation policies exhibit a synergistic effect in promoting green innovation. Mechanism analysis suggests that this policy stimulates green innovation through three primary channels: alleviating financing constraints, increasing environmental investment, and mitigating managerial agency problems. Robustness checks, including parallel trend analysis, placebo tests, propensity score matching, and replacement of explanatory variables, confirm the validity of these findings.

This study contributes to the literature in several ways: (1) Policy Evaluation Perspective: By examining the impact of accelerated depreciation policies on green innovation at the firm level, this study provides empirical evidence on the effectiveness of tax incentives, offering insights for policymakers; (2) Causal Identification: The use of a quasi-natural experiment with exogenous policy shocks strengthens the causal inference between tax incentives and corporate green innovation; (3) Comprehensive Measurement of Innovation: Beyond conventional patent application and grant counts, this study incorporates patent citation frequency as an indicator of innovation quality, providing a more robust assessment of policy impact; (4) Expanded Mechanism Analysis: In addition to the commonly examined financing constraint alleviation mechanism, this study explores the roles of environmental investment and agency cost reduction, enriching the understanding of how tax incentives influence green innovation.

2. Institutional background and literature review

2.1 Institutional background

In recent years, the Chinese government has introduced multiple policies on accelerated depreciation for fixed assets to incentivize investment and drive industrial upgrading. This policy alleviates financial pressure on enterprises by reducing their initial tax burden, thereby enhancing corporate vitality and stabilizing economic growth.

The first major policy, Fiscal and Tax [2014]75, allowed firms in six industries—biopharmaceuticals, specialized equipment manufacturing, transportation equipment manufacturing (railways, ships, aerospace), electronics, instrumentation, and IT services—to shorten the depreciation period or adopt accelerated depreciation for fixed assets acquired after January 1, 2014. Additionally, small and micro enterprises in these sectors could fully deduct the cost of newly purchased instruments and equipment (≤ RMB 1 million) in the year of acquisition, eliminating the need for annual depreciation. For assets exceeding this threshold, firms were permitted to shorten the depreciation period or apply accelerated depreciation methods.

Subsequently, Fiscal and Tax [2015]106 further expanded the policy to cover four additional sectors: light industry, textiles, machinery, and automobiles. Later, Fiscal and Tax [2019]66 extended these benefits to all manufacturing industries, broadening the policy's applicability across the industrial landscape.

2.2 Literature Review

The literature relevant to this study primarily focuses on two aspects: tax incentives and corporate green technology innovation.

Since the introduction of the green development concept in China, extensive research has explored mechanisms to foster green technology innovation, accelerate the greening of economic activities, and drive industrial transformation. The determinants of green innovation can be analyzed from social, market, and governmental perspectives. From a social perspective, Yang et al. (2022) find that media, as an external stakeholder, can influence firms' environmental governance and technological innovation through pressure and demand feedback mechanisms[6]. From a market perspective, Xu et al. (2016) argue that green industries require substantial support from capital markets[7]. However, given their significant positive externalities and the discrepancy between private and social returns, private investors exhibit reluctance to enter the early stages of green investment. Therefore, policy interventions are necessary to guide capital into green industries[8]. From a governmental perspective, regulatory and incentive policies play a critical role in promoting green innovation. Xu and Cui (2020) show that low-carbon city pilot policies enhance corporate green innovation, particularly through energy-saving and alternative energy patents[9]. Compared to command-based environmental regulations, market-based mechanisms offer clearer incentives and penalties, making them more effective in encouraging firms to engage in green innovation and investment in green technology patents[10].

The relationship between taxation and corporate green innovation has been widely studied. Some scholars argue that environmental taxes encourage green innovation by imposing financial pressure on resource-intensive firms. Others, however, contend that such taxes may inhibit green R&D. Liu et al. (2022) find a threshold effect in the relationship between environmental protection tax and green investment, suggesting that at the current tax rate, firms experience cost pressures without sufficient incentives for green innovation[11]. While extensive literature exists on environmental regulation, taxation, and subsidies, the impact of accelerated depreciation for fixed assets on corporate green technology innovation remains unexplored. Current studies predominantly measure green innovation output through patent applications in low-carbon and renewable energy technologies, yet actual patent citations—indicating practical adoption—deserve greater attention.

The effect of tax incentives on corporate innovation has been extensively examined. A consensus exists that tax incentives significantly enhance corporate innovation by stimulating R&D investment and fixed asset expenditures[12]. Using a difference-in-differences approach, Lin and Liu (2022) find that tax incentives positively influence both the quantity and quality of innovation[5]. Han and Li (2022) argue that lower taxes increase firms' net benefits and internal cash holdings, thereby alleviating financial constraints and fostering innovation[13]. Wu and Li (2022) further show that tax incentives not only improve firms' financial conditions and R&D investments but also facilitate green transformation by reducing pollution while enhancing performance[14]. However, some scholars caution that poorly designed incentives may lead firms to engage in R&D cost manipulation rather than genuine innovation[15]. While previous studies have examined the relationship between tax incentives and corporate innovation, few have specifically investigated green technology innovation, leaving a gap in understanding how tax policies shape firms' green transformation strategies.

Despite extensive research on tax incentives and corporate innovation, no studies have established a causal link between accelerated depreciation policies and green technology innovation. Existing literature primarily relies on cross-sectional data and non-causal identification methods, limiting the ability to draw robust inferences. To address this gap, this study employs a quasi-natural experiment using China's accelerated depreciation policy and panel data from listed firms, applying a multi-period difference-in-differences (DID) approach to examine whether tax incentives can effectively promote corporate green innovation.

3. Theoretical analysis and hypothesis formulation

Green development is a fundamental aspect of ecological civilization and a key driver of technological and industrial transformation. Enterprises, as primary agents of technological innovation, play a crucial role in green technological advancements. Unlike conventional innovation, green innovation aims to reduce environmental pollution while generating economic and social benefits, aligning economic growth with environmental sustainability. As a fusion of technological progress and ecological responsibility, green technological innovation integrates industrial restructuring, traditional technological advancements, and environmental protection.

The policy of accelerated depreciation for fixed assets can stimulate corporate green technological innovation through multiple channels.

Firstly, the accelerated depreciation policy for fixed assets can ease the financial constraints of enterprises. Accelerated depreciation enables firms to allocate higher depreciation expenses upfront, reducing taxable income and alleviating financial burdens in the early stages of investment. Early-stage projects typically generate minimal revenue while requiring substantial fixed-asset investments, creating liquidity constraints. By deferring tax payments, accelerated depreciation improves internal cash flow, functioning as an interest-free loan that enhances firms' capacity to fund innovation. As projects mature and revenue increases, tax liabilities rise, but by then, firms are less financially constrained. Thus, this policy enables enterprises to align their income, taxes, and retained capital with their growth. Though accelerated depreciation does not alter the total tax burden over the asset's lifetime, it defers tax payments, giving companies the time value of money, effectively offering an interest-free loan. As retained capital increases and financing constraints ease, companies can optimize investment decisions, enhance equipment upgrades, and accelerate technological advancements.

Secondly, the accelerated depreciation policy for fixed assets serves as a significant driver for corporate investment in energy-efficient and environmentally friendly equipment. By enhancing the rate of return on investment, this policy increases the economic viability of projects that were previously deemed unprofitable, thereby encouraging firms to allocate more resources toward such investments. Empirical studies, both domestic and international, consistently demonstrate that tax incentives, such as accelerated depreciation, effectively stimulate corporate investment in fixed assets.

From the perspective of innovation costs, a firm's willingness to innovate hinges on the anticipated economic returns of innovation activities. Tax policies influence these decisions by altering the financial incentives for innovation. Specifically, direct tax incentives—such as reduced tax rates—

decrease the overall cost of innovation, thereby enabling firms to allocate greater resources to research and development. Given the high levels of risk and uncertainty inherent in innovation, external financial institutions, such as banks, often hesitate to fund such endeavors, compelling firms to rely on internal funds. Tax incentives not only reduce the marginal cost of innovation but also alleviate financial constraints by improving cash flow during innovation processes. These measures facilitate the accumulation of internal funds, thereby enhancing the firm's capacity for endogenous financing of innovation. Consequently, such policies create favorable conditions for small and medium-sized enterprises (SMEs) to upgrade equipment, advance technological research, and develop higher-value products with enhanced market competitiveness.

With increased financial resources, firms must decide whether to prioritize investments in green technology innovation—defined as technologies aimed at promoting environmental protection, energy efficiency, and low-carbon development. However, due to the substantial positive externalities associated with both green and innovative activities, firms as market actors often lack sufficient economic incentives to pursue green technology innovation voluntarily. External pressures, such as regulatory policies, often play a critical role in influencing corporate behavior in this regard. For instance, China's recent emphasis on high-quality development has been accompanied by a series of policy initiatives promoting environmental sustainability. A notable example is the introduction of the Environmental Protection Tax Law in 2018, which marked the China's first tax instrument explicitly targeting environmental protection. This development highlights the increasing importance of green development in China's policy agenda. In response, firms are incentivized to align their investment strategies with the government’s environmental priorities, including green technology innovation.

The accelerated depreciation policy for fixed assets not only improves the internal financial conditions of firms but also fosters a supportive external environment conducive to green technology innovation. Unlike conventional technological innovation, green innovation is characterized by greater complexity and higher initial investment barriers. Even firms with a clear interest in pursuing green innovation may face resource constraints in the early stages. The accelerated depreciation policy mitigates these challenges by improving firms’ financial flexibility and incentivizing R&D investment in green technologies. As an ex-ante tax incentive, this policy provides stability and predictability, which are critical for fostering long-term investments in green innovation, particularly given its strong positive externalities.

For example, the transformation of energy structures within manufacturing enterprises often requires replacing traditional equipment with technologies compatible with renewable energy sources. Such transformations are inherently capital-intensive, requiring significant investment in R&D and infrastructure optimization. The accelerated depreciation policy allows firms to expedite the depreciation of innovation-related equipment, thereby reducing the financial burden associated with these investments. By improving cash flow and providing material support, the policy creates favorable conditions for firms to engage in green technology innovation, thereby contributing to long-term sustainable development.

Thirdly, the accelerated depreciation policy for fixed assets can mitigate management’s short-sightedness and foster a long-term investment orientation. Green technology innovation typically requires substantial, long-term investments with uncertain and delayed financial returns. Consequently, management, whose performance is often evaluated based on short-term business outcomes, tends to avoid allocating resources to high-risk projects such as green technology innovation. This myopic behavior is one of the primary reasons why firms hesitate to engage in green innovation.

Tax incentives not only alleviate the financing constraints on innovation but also improve the external economic environment for corporate innovation activities. Internally, the accelerated depreciation policy, as a fiscal support mechanism, effectively reduces financial distress, optimizes firms' financial behavior, and increases their motivation to pursue R&D and innovation. These improvements enhance firms' core competitiveness, enabling them to undertake high-risk, high-reward projects. Empirical evidence suggests that tax incentives also positively influence managerial expectations. For example, Wu et al. (2021) found that firms encouraged by tax incentives often exhibit more positive and optimistic perspectives on future development in their corporate communications, such as annual reports[14].

Externally, the benefits of the accelerated depreciation policy extend to firms' reputational and relational environments. Improved financial performance and policy support can enhance public and stakeholder perceptions of a firm, thereby creating a more favorable external environment for green technology innovation. When internal and external expectations are poor, management tends to prioritize short-term production and financial decisions over long-term, high-externality investments. In contrast, a positive internal and external environment provides firms with the necessary tolerance for trial-and-error processes, which are critical for green technology innovation.

The accelerated depreciation policy addresses agency problems between management and shareholders by aligning managerial incentives with long-term value creation. By alleviating the pressure to prioritize immediate financial returns, the policy enables management to adopt a broader perspective that incorporates the economic, social, and environmental benefits of green technology innovation. This alignment not only reduces managerial myopia but also directs corporate decision-making toward sustainable development objectives. Consequently, the policy fosters a strategic focus on long-term investments, thereby promoting green technology innovation and supporting the overarching goals of sustainable corporate growth.

Based on the above analysis, we propose the following hypothesis:

H1: The policy of accelerated depreciation for fixed assets will promote green technological innovation in enterprises.

State-owned enterprises (SOEs) are fundamental to the national economy and the socialist system, bearing significant economic, political, and social responsibilities. Beyond moral and economic motives, they also assume unique social obligations driven by political objectives. Given their public ownership, SOEs inherently align economic and social benefits, necessitating accountability to stakeholders and the environment while ensuring sustainable development.

As key agents of national policy and environmental governance, SOEs play a crucial role in advancing the green development agenda. Their government affiliation subjects them to stricter oversight, including mandated environmental targets and rigorous inspections, compelling them to undertake greater social and environmental responsibilities. Consequently, SOEs allocate more resources to environmental protection. Moreover, policies such as accelerated depreciation for fixed assets and financial incentives create a favorable environment for green technology innovation. Compared to non-state-owned enterprises, which face resource constraints and slower policy adaptation, SOEs exhibit greater responsiveness to national directives and achieve more effective green innovation.

H2: Firm ownership moderates the impact of accelerated depreciation policies, with a more significant effect on promoting green technology innovation in state-owned enterprises.

4. Research Design

4.1 Data sources

This paper selects 3,246 A-share listed companies based on the Wind database as research subjects (2011-2021), among which data related to green patents are obtained from the China Research Data Service Platform (CNRDS). Before carrying out the empirical analysis, this paper processed the data as follows: (1) the reporting requirements of financial companies are different from those of general enterprises and therefore excluded; (2) ST and *ST companies were suspended due to operational problems and were also excluded from the sample, resulting in a total of 18,355 data.

4.2 Variable setting

4.2.1 Explained variables

The number of green patents of enterprises (Sum_number). Enterprise innovation is typically measured through R&D input and patent output, with the latter offering a more intuitive reflection of innovation performance due to the inherent risks and uncertainties of R&D activities. Following prior research, the number of patent applications, grants and citations are commonly used to assess innovation levels.

According to the *Patent Law of the People's Republic of China*, patents are categorized into invention patents, utility model patents, and design patents. As design patents have lower technical requirements and are easier to obtain, this study focuses on invention and utility model patents to evaluate enterprise innovation capability. Green patents refer specifically to green invention and utility model patents.

Thus, this study employs the number of green patents as the explanatory variable to measure green technology innovation. Given that patent citations better reflect the quality of innovation and R&D, robustness tests replace the original explanatory variable with the number of green patent citations, both domestic and international. Citation data are sourced from the China Stock Market & Accounting Research Database (CSMAR). To account for policy implementation lags and the long innovation cycle, all patent-related data are lagged by one period to better capture causal relationships.

4.2.2 Explanatory variables

The accelerated depreciation policy for fixed assets (Treat*Post). This policy was introduced in phases, taking effect on January 1, 2014, January 1, 2015, and January 1, 2019 across different industries, providing quasi-natural experimental conditions for tax incentive studies. Specifically, Treat = 1 if the enterprise belongs to an industry eligible for the policy; 0 otherwise. Post = 1 if the policy is in effect for the enterprise in a given year and beyond; 0 otherwise. Treat × Post is the core explanatory variable, capturing the differential impact of the policy on green technology innovation before and after implementation. The interaction term’s coefficient estimates this effect.

4.2.3 Control variables

To enhance regression estimation efficiency, the following control variables are included based on prior studies: Age, Growth, Qq, Size, Roe, Profit, Capital, BM, Lev, Mshare. The main variables and their definitions are shown in Table 1.

Table 1 Definitions of key variables

Type of Variable	Variables	Definitions
Explained Variables	*Sum_number*	The sum of green invention patent and green utility model patent
	I_number	The number of green innovation patents
	U_number	The number of green utility model patents
	Sum_patent	The total number of citations of green patents
Explanatory Variables	*Treat*	Industry. Whether the industry is in the key industry under the accelerated depreciation policy for fixed assets, set 1 for yes and 0 for no

	Post	Policy implementation time. Whether the industry implementing accelerated depreciation policies for fixed assets in the current year and afterwards, set 1 for yes and 0 for no
Control Variables	*Age*	Observation year - enterprise registration year
	Growth	Current operating income change / previous operating income
	R&D	Natural logarithm of R&D expenses
	Qq	Market value / total assets
	Size	Ln(total assets at the end of the year)
	Roe	Net profit/total assets
	Profit	Net profit of enterprise yearly (unit: 100 million yuan)
	Capital	Total assets at the end of the year (unit: 100 million yuan)
	BM	Net assets/company market value
	Lev	Total liabilities/total assets
	Mshare	Number of shares held by enterprise management (unit: 100 million shares)
Mechanism Variables	*State*	Virtual variable, set 0 for state-owned enterprises and 1 for non-state-owned enterprises
	Legal	Set 1 if the province started or has already established an environmental court in that year, set 0 otherwise
	SA	Calculate SA index based on company size and age
	E_investment	Environmental protection investment amount of the enterprise in observation year
	OER	Sum of enterprise management expenses and sales expenses/operating income

4.3 Model setting

To test the impact of accelerated depreciation policy for fixed assets on enterprises' green technology innovation, we set up model (1) for causal identification test:

$$Patent_{i,t+1} = a + \beta_1 Treat * Post + \beta_2 Control_{i,t} + \beta_3 Year + \beta_4 Company + \varepsilon_{i,t} \quad (1)$$

The core explanatory variable is $Patent_{i,t+1}$, which represents the level of green technology innovation of firm i in year t+1. The core explanatory variables is Treat*Post, which describes the impact of accelerated depreciation policy for fixed assets. The variable Control represents a series of control variables. To absorb the effects of unobservable factors that do not vary over time and unknown shocks over time, we also control for two-way fixed effects at the "individual (company) - time (year)" level.

5. Empirical Results and Economic Explanations

5.1 Descriptive Statistics

The descriptive statistics of the main variables are shown in Table 2.

Table 2 Descriptive statistics

	(1)	(2)	(3)	(4)	(5)
Variables	N	Mean	SD	Min	Max
Treat	18,355	0.710	0.454	0	1
Post	18,355	0.420	0.494	0	1
Sum_number	18,355	2.598	17.86	0	871
I_number	18,355	1.730	15.38	0	827
U_number	18,355	0.906	6.103	0	209

Sum_patent	14,140	19.13	103.7	0	3,402
Age	18,355	16.88	5.718	1	62
Growth	18,355	0.186	0.440	-4.144	9.570
Qq	18,355	2.079	2.230	0.153	122.2
Size	18,355	22.20	1.277	19.52	28.54
Roe	18,355	0.0760	0.101	-1.112	0.742
Profit	18,355	5.993	34.40	-170.5	1,460
Capital	18,355	163.8	837.1	0.459	24,884
BM	18,355	0.942	1.020	0.0199	8.061
Lev	18,355	0.511	0.827	-1.903	60.08
Mshare	18,355	0.638	1.471	0	33.44

5.2 Baseline regression

5.2.1 Testing Hypothesis 1

Table 3 Baseline regression results (I)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	*Sum_number*	*Sum_number*	*Sum_number*	*I_number*	*U_number*
*Treat*Post*	0.855***	1.295***	1.447***	1.310***	0.257*
	(0.257)	(0.201)	(0.276)	(0.292)	(0.134)
Size		1.097***	1.769***	1.682***	0.621***
		(0.389)	(0.312)	(0.336)	(0.131)
Profit		0.139***	-0.022	-0.008	0.006
		(0.053)	(0.032)	(0.035)	(0.012)
Capital		0.006***	0.005***	0.002	0.001
		(0.002)	(0.002)	(0.001)	(0.001)
Lev		0.434**	-0.040	-0.036	-0.008
		(0.169)	(0.168)	(0.157)	(0.026)
BM		-2.150***	-1.140***	-0.830***	-0.301***
		(0.327)	(0.216)	(0.175)	(0.069)
Roe		-6.156***	-0.389	0.248	0.396
		(2.111)	(1.163)	(1.305)	(0.492)
Growth		-0.531***	-0.422***	-0.373***	-0.132***
		(0.148)	(0.112)	(0.129)	(0.046)
Mshare		0.121	-0.016	0.011	-0.007
		(0.105)	(0.091)	(0.078)	(0.035)
Qq		-0.141***	0.038	-0.023	-0.015
		(0.044)	(0.032)	(0.032)	(0.012)
Constant	2.239***	-21.176**	-39.563***	-36.897***	-13.611***
	(0.189)	(8.294)	(6.923)	(7.285)	(2.909)
Company FE	NO	NO	YES	YES	YES
Year FE	NO	NO	YES	YES	YES
N	18,355	18,355	17,692	17,692	17,692
R-squared	0.001	0.291	0.825	0.689	0.647

Note: *, **, *** indicate that the statistics are significant at the 10%, 5%, and 1% levels respectively, and robust standard errors are in parentheses, so as follows.

Table 3 examines the impact of the accelerated depreciation policy for fixed assets on corporate green technology innovation. Column (1) presents the results of a univariate regression of the policy on the total number of green patents of listed firms; column (2) reports the results of the regression after adding the size , earnings characteristics and equity structure characteristics of listed companies as control variables; column (3) further incorporates time and firm fixed effects; columns (4) and (5) extend the analysis by separately considering the number of green invention patents and utility model patents, while controlling for individual and time fixed effects.

From an economic perspective, the regression results in Column (3) indicate that the implementation of the accelerated depreciation policy leads to an average increase of 1.447 in the number of green patents, equivalent to 55.70% of the mean number of green patents (2.598). This suggests that tax incentives significantly promote green patent output and serve as a key driver of high-quality corporate development, thus confirming Hypothesis H1.

Among the three patent types defined in the *Patent Law of the People's Republic of China*, invention patents undergo the most rigorous examination, have the longest approval process, and represent the highest technological quality. The results in Column (4) show that the regression coefficient of Treat*Post is 1.310, significant at the 1% level, indicating that the policy increases the number of green invention patents by an average of 1.310 for listed firms.

5.2.2 Testing Hypothesis 2

To examine the moderating effect of firm ownership, the sample is divided into state-owned enterprises (SOEs) and non-state-owned enterprises (NSOEs). NSOEs include private, foreign-funded, collective, and public enterprises. The variable State is assigned a value of 0 for SOEs and 1 for NSOEs. The regression results are presented in Table 4.

Table 4 Baseline regression results (II)

	(1)	(2)
VARIABLES	*Sum_number*	*Sum_number*
*State*Treat*Post*	1.589***	0.425**
	(0.411)	(0.209)
*Treat*Post*	2.402***	1.405***
	(0.441)	(0.375)
*State*Treat*	0.558	0.195
	(0.444)	(0.191)
State	1.011**	
	(0.417)	
Constant	-3.199	-3.545
	(3.099)	(4.440)
Controls	YES	YES
Company FE	NO	YES
Year FE	NO	YES
N	15,536	15,160
R-squared	0.323	0.886

The results in Column (1) indicate that the coefficient of Treat*Post*State is significantly positive at the 1% level, while State is significantly positive at the 5% level. This suggests that the accelerated depreciation policy for fixed assets effectively promotes green technology innovation in both SOEs and NSOEs.

Compared to NSOEs, SOEs play a more prominent role in implementing national policies due to their policy-driven mission in China’s transitional economy. They also benefit from greater innovation resources, stronger risk resilience, and closer government ties, enabling them to mobilize resources more effectively. Additionally, SOEs tend to have larger asset bases, making them more likely to benefit from the tax advantages of accelerated depreciation. Their alignment with national industrial policies and commitment to social responsibility and environmental sustainability further drive their engagement in green technology innovation.

In contrast, NSOEs often prioritize short-term financial performance due to their ownership structure and face greater resource constraints. As a result, their green technology innovation is less responsive to the accelerated depreciation policy.

5.3 Robustness test and endogeneity treatment

5.3.1 Parallel trend test

The validity of the difference-in-differences (DID) model relies on the common trend assumption, which requires that the outcome variables of the treatment and control groups exhibit a similar trend before policy implementation. To verify this assumption, we introduce multiple leads and lags of the policy shock and examine its time-series effects.

Figure 1 presents the estimated coefficients and 95% confidence intervals for the impact of accelerated depreciation on firms' green technology innovation, measured by the total number of green patents. The results show that all pre-policy coefficients are statistically insignificant, indicating no significant difference in green innovation levels among listed firms before the policy implementation. This suggests that the parallel trend assumption holds.

Given the lagged effect of policy implementation and the time required for firms to develop innovations, we incorporate a one-period lag in the explanatory variable to better capture the causal relationship. The findings confirm that the accelerated depreciation policy, as a tax incentive, has a strong and stable effect on promoting green technology innovation over time, aligning with the core theoretical expectations of this study.

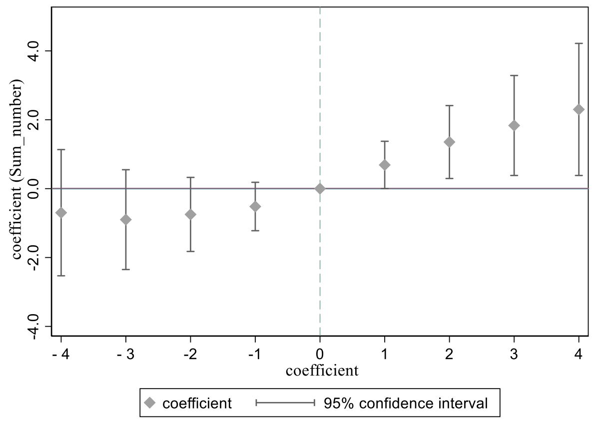

Figure 1 Parallel trend test

5.3.2 Placebo test

To further confirm that the improvement in firms' green technology innovation is driven by the accelerated depreciation policy rather than other unobservable factors, this study adopts the empirical method of Zhou Mao et al. (2018)[16]. Specifically, we perform a placebo test by randomly resampling 500 times based on Model (1) and re-estimating the interaction term Treat*Post. This approach examines whether the estimated coefficients and p-values significantly deviate from the baseline results.

The estimated coefficient of *Treat*Post* is given by:

$$\hat{\beta} = \beta + \gamma \frac{cov(did_{i,t}, \varepsilon_{i,t}|control)}{var(did_{i,t}|control)}$$

where *control* represents all the observable control variables included in the model, and γ captures the influence of unobservable factors. If γ = 0, the unobserved factors do not bias the estimation, ensuring that $\hat{\beta}$ remains unbiased.

Figure 2 presents the results of the placebo test, where the primary axis represents the regression coefficients and the secondary axis represents the p-values. The distribution of the 500 simulated $\hat{\beta}$ estimates is centered around zero and approximately follows a normal distribution. The vertical dashed line represents the baseline regression coefficient($\hat{\beta}$=1.447), while the horizontal dashed line represents the baseline p-value (p = 0.000). The true estimated coefficient lies outside the entire simulated distribution, and most of the p-values exceed the baseline threshold, indicating that randomly generated treatment assignments are unlikely to yield an estimate as large as 1.447.

These results confirm that $\gamma = 0$, implying that the benchmark regression estimate of $\hat{\beta}$ is unbiased. Thus, the placebo test supports the robustness of our findings and reinforces the conclusion that the accelerated depreciation policy significantly enhances firms' green technology innovation.

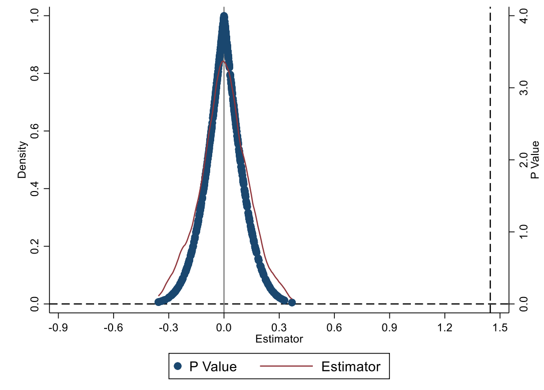

Figure 2 Placebo test

5.3.3 Propensity score matching(PSM)

The difference-in-differences (DID) model assumes that the treatment and control groups are randomly assigned. However, in practice, industries benefiting from the accelerated depreciation policy are not selected at random but through a systematic selection process influenced by multiple factors, which may also impact corporate innovation. Consequently, using the untreated group as a direct counterfactual for the treated group may lead to selection bias. To address this endogeneity concern, we employ propensity score matching (PSM) on a year-by-year basis as a robustness check.

First, we apply PSM to match firms in the treatment and control groups based on observable characteristics, minimizing differences between them and mitigating the influence of confounding factors. Second, we re-estimate the DID model using the matched sample. Specifically, we first perform a Probit regression using the control variables from Model (1) to estimate the probability of firms receiving the treatment (Treat). The predicted values from this regression serve as propensity scores for subsequent matching. We then apply nearest neighbor matching with a 1:2 matching ratio, ensuring that each treated firm is paired with two control firms with similar propensity scores.

Finally, we re-estimate the DID model using the matched sample. The results, presented in Table 5, indicate that the coefficient of Treat*Post remains significantly positive, further validating the robustness of our findings and confirming that the accelerated depreciation policy effectively promotes corporate green technology innovation.

Table 5 PSM-DID regression results

	(1)	(2)
	Sum_number	*Sum_number*
*Treat*Post*	0.836***	0.932***
	(0.141)	(0.142)
Constant	1.168***	2.145
	(0.036)	(3.007)
Control	NO	YES
Year FE	YES	YES
Company FE	YES	YES
Province FE	YES	YES
N	35,921	35,921
R-squared	0.664	0.670

5.3.4 Substitution of explanatory variables

To further verify the robustness of our findings, we conduct an additional test by substituting the explanatory variables. While the number of green patent applications serves as a key measure of green technology innovation, the number of green patent citations provides a complementary perspective, as it reflects the quality and impact of innovation rather than just its quantity. Accordingly, we replace the original explanatory variable with three alternative measures: Total number of green patent citations, number of domestic green patent citations and number of international green patent citations.

Table 6 presents the regression results. Column (1) reports the results for the total number of green patent citations without fixed effects, while Columns (2)–(4) incorporate city and time fixed effects and separately examine total citations, domestic citations, and international citations. The estimated coefficient of Treat*Post remains significantly positive at the 1% level across all specifications.

These results indicate that replacing the explanatory variable with citation-based measures, which provide a more precise assessment of innovation quality, does not change the main findings. Thus, our conclusions are robust and continue to support the core hypothesis that the accelerated depreciation policy effectively promotes corporate green technology innovation.

Table 6 Robustness test results

	(1)	(2)	(3)	(4)
VARIABLES	*Sum_patent*	*Sum_patent*	*Sum_Overseas*	*Sum_China*
*Treat*Post*	4.501**	23.877***	2.378***	21.499***
	(2.134)	(3.026)	(0.625)	(2.684)
Constant	32.833***	38.553***	0.717	37.836***
	(4.093)	(13.844)	(1.397)	(12.778)
Controls	YES	YES	YES	YES
City FE	NO	YES	YES	YES
Year FE	NO	YES	YES	YES
N	8,741	8,738	8,738	8,738
R-squared	0.246	0.289	0.076	0.304

6. Synergy of environmental regulation

Environmental regulation and the accelerated depreciation policy for fixed assets jointly influence firms' green technology innovation. Environmental regulation, as a key institutional mechanism for pollution control, imposes compliance requirements on firms. The implementation of such regulations increases environmental pressure on enterprises, shaping their innovation decisions. In China, the impact of environmental policies is first reflected in their signaling effect, as they indicate governmental commitment to pollution governance[17]. From the perspectives of organizational legitimacy and resource dependence, firms must align with regulatory constraints to secure scarce resources and policy advantages. Consequently, stricter environmental regulations incentivize firms to engage in green technology innovation.

Based on the study by Fan et al. (2019), we quantify environmental regulation by adopting the establishment of environmental courts at the prefecture level as a quasi-natural experiment[18]. Specifically, we define a dummy variable (Legal), which equals 1 if a province has established an environmental court at the intermediate people's court level in a given year and 0 otherwise. In our sample, provinces with environmental courts constitute the treatment group.

The regression results in Table 7 indicate that the presence of environmental courts significantly promotes corporate green technology innovation.

Table 7 Environmental regulation test results

	(1)	(2)
VARIABLES	*Sum_number*	*Sum_number*
*Legal*Treat*Post*	2.176***	2.137***
	(0.736)	(0.456)
*Treat*Post*	0.135	2.137***
	(0.354)	(0.456)
*Legal*Treat*	-0.906	-0.830
	(0.773)	(0.677)
Legal	-0.968**	-0.346
	(0.434)	(0.698)
Constant	-24.828***	-42.696***
	(2.676)	(7.301)
Controls	YES	YES
Province FE	NO	YES
Year FE	NO	YES
N	18,355	16,713
R-squared	0.293	0.311

7. Impact mechanism test

7.1 Financial optimization path

To examine the mechanism through which accelerated depreciation affects firms' green technology innovation, we focus on financing constraints as a mediating factor. Specifically, we employ the SA index (Hadlock & Pierce, 2010) to measure firms' financial constraints: $SA=-0.737*Size+0.043*Size^2-0.04*Age$[19], where Size is the logarithm of total assets and Age is the firm's age (calculated as the observation year minus the establishment year). A higher SA index indicates more severe financial constraints.

Table 8 shows that accelerated depreciation significantly alleviates financing constraints and enhances capital allocation efficiency. As a tax incentive, this policy functions similarly to short-term, interest-free financing, improving firms' financial conditions. In a relaxed financing environment, firms prioritize core business development over speculative financial investments. Given China's economic transition and strengthening regulatory environment, enterprises are increasingly inclined toward green development. With reduced financing constraints, firms can allocate more resources to technological upgrades and equipment modernization, rather than financial investments that crowd out industrial production, thereby fostering green technology innovation.

Table 8 Financial mechanism identification test: Financing constraints

	(1)	(2)
VARIABLES	SA	SA
*Treat*Post*	-0.009***	-0.015***
	(0.001)	(0.001)
Constant	-3.034***	-3.171***
	(0.017)	(0.020)
Controls	YES	YES
Company FE	NO	YES
Year FE	NO	YES
N	20,676	20,572
R-squared	0.853	0.982

7.2 Environmental protection investment path

Environmental protection investment serves as a short-term strategic response to regulatory pressure. Following Zhang et al. (2019), we quantify firms' environmental investment by summing expenditures related to environmental projects (e.g., desulfurization, wastewater treatment, dust removal, and energy conservation) reported under the construction-in-progress accounts of listed firms in heavily polluting industries[20]. To account for firm size differences, we standardize this investment by total assets and apply a logarithmic transformation.

Table 9 shows that accelerated depreciation significantly increases environmental investment among heavily polluting firms. This policy redistributes tax benefits over a firm’s growth cycle, aligning tax burden with revenue, improving cash flow, and easing financial constraints on capital allocation. Under stricter environmental regulations, heavy polluters face stronger incentives to enhance their core competitiveness by modernizing assets and increasing green investment. Accelerated depreciation not only raises environmental investment but also stimulates green patent output, achieving dual benefits at both input and innovation levels. This policy strengthens firms' R&D foundation and provides both financial support and technological impetus for green innovation.

Table 9 Environmental Investment Identification Test

	(1)	(2)
VARIABLES	*E_investment*	*E_investment*
*Treat*Post*	0.198***	0.352***
	(0.072)	(0.087)
Constant	-4.219***	0.064
	(0.952)	(1.996)
Controls	YES	YES
Company FE	NO	YES
Year FE	NO	YES
N	2,305	2,221
R-squared	0.332	0.822

7.3 Path to mitigate agency problems

Agency costs hinder firms’ innovation efficiency. Under the combined influence of environmental regulation and accelerated depreciation, managerial incentives shift toward environmental responsibility, fostering corporate green innovation. To test this mechanism, we follow Dai (2016) and measure agency costs using the operating expense ratio, defined as the sum of management and sales expenses divided by operating income[21]. A higher ratio indicates greater managerial consumption and higher agency costs.

Table 10 reports a significantly negative coefficient for Treat×Post, confirming that accelerated depreciation alleviates agency conflicts. By reducing agency costs, the policy enhances managerial focus on environmental objectives, ultimately improving firms' green innovation outcomes.

Table 10 Mitigating Management Proxy Issues

	(1)	(2)
VARIABLES	OER	OER
*Treat*Post*	-0.010***	-0.007**
	(0.003)	(0.003)
Constant	0.176***	0.281***
	(0.001)	(0.073)
Controls	NO	YES
Company FE	YES	YES
Year FE	YES	YES
N	15,695	15,695
R-squared	0.760	0.764

8. Conclusions

This study examines the impact of accelerated depreciation policy on corporate green technology innovation using panel data from A-share listed companies (2011–2021). Leveraging a quasi-natural experiment, we employ a fixed-effects model to analyze both the direct effects and underlying mechanisms of tax incentives on green innovation. The empirical findings indicate the following:

First, the accelerated depreciation policy for fixed assets not only significantly improves the level of green technology innovation measured by the number of green patents granted, but also promotes the quality of innovation measured by the number of patents cited, which can significantly promote green technology innovation of enterprises. This conclusion still holds after a series of robustness tests.

Second, the mechanism study shows that the accelerated depreciation policy of fixed assets can significantly improve the financial situation of enterprises, alleviate their financing constraints, enhance their green innovation R&D input and output capacity, and improve their external expectations. It enables heavy polluting enterprises to increase their environmental protection investment and promote their green development. It can alleviate the management agency problem, mitigate management's short-sighted behavior, and increase their long-term investment. At the same time, environmental regulation and accelerated depreciation policy for fixed assets have synergistic effects, which can better promote enterprises to carry out green technology innovation.

Third, the accelerated depreciation policy of fixed assets has a heterogeneous impact on enterprises' green technology innovation. From the enterprise dimension, state-owned enterprises benefit more from the accelerated depreciation policy of fixed assets and have stronger incentives for green technology innovation.

The recommendations of this paper are as follows. First, we should continue to implement the tax reduction policy to reduce the tax burden of enterprises. The policy of accelerated depreciation of fixed assets, as a universal incentive rather than a punitive measure, is conducive to the positive development of enterprises. Second, the government needs to actively guide enterprises to carry out green technology innovation. When the financing constraints faced by enterprises are eased, under the guidance of the general trend of green economic development, enterprises tend to have stronger subjective initiative and objective basis to carry out green technology innovation, which makes the tax incentive achieve a more agreeable policy effect. Third, the tax incentive policy should be improved to promote the comprehensive development of green technology innovation of enterprises according to local conditions. From the current difference of ownership of enterprise green technology innovation, the effect of tax incentive on enterprise green technology innovation is different, and further incentive measures should be made for green technology innovation of non-state enterprises.

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