



Research on the Driving Effect of Green Bond Issuance on Corporate Green Technology Innovation

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Abstract. Under the “Dual Carbon” goals, green technology innovation is crucial for corporate green transformation, yet its high investment and long cycles create financing constraints. Green bonds, as a key direct financing instrument in the green financial system, have unique institutional advantages. Using data of Chinese A-share listed firms from 2010 to 2023, this paper treats green bond issuance as a quasi-natural experiment and employs a staggered difference-in-differences model to examine its impact on green technology innovation and mechanisms. Findings show that green bond issuance significantly enhances corporate green innovation, robust to various tests. The effect operates through mitigating financing constraints and transmitting positive reputational signals. The driving effect is stronger in private firms, high-tech industries, and regions with stringent environmental regulations. The study provides empirical evidence for optimizing green finance policies.

Keywords: Green Bonds; Financing Constraints; Green Technology Innovation

1 Introduction

Under the "Dual Carbon" strategy, green technology innovation is the core lever for firms to achieve sustainable growth. However, its long cycles and high capital requirements subject firms to acute financing constraints, which traditional instruments cannot adequately address. Green bonds, as a cornerstone direct financing tool, leverage policy incentives and environmental orientation to provide low-cost funding for green projects.

Existing literature predominantly focuses on macro-level environmental effects or corporate financing efficiency, lacking microscopic analysis of transmission pathways through which green bonds influence green innovation. Moreover, exploration of heterogeneous effects under varying ownership, industry attributes, and environmental regulations is insufficient.

This paper takes "green bond issuance → mitigation of financing constraints → increase in green R&D → enhancement of green innovation" as the core logical framework. Using a staggered DID model and mediation tests, we systematically reveal the internal mechanisms and identify heterogeneous factors.

2 Literature Review

Green technology innovation is a key pathway for corporate green transformation, but its R&D characteristics create significant financing constraints¹. Traditional financing channels often fail to meet these needs. Green bonds, as direct financing instruments specifically supporting green projects, have gradually become important for breaking the financing bottleneck.

Existing research mainly revolves around macro-environmental effects of green finance^{2,3} and determinants of corporate green innovation⁴⁵. Studies on green bonds have explored their positive impacts on financing costs⁶ and environmental performance⁷, but most remain at correlation analysis, lacking causal identification of the "financing constraint mitigation → innovation output" chain.

In summary, existing studies have limitations: (1) macro perspective lacking micro-level analysis; (2) insufficient mechanism analysis; (3) deficient heterogeneity exploration. This paper attempts to fill these gaps.

3 Theoretical Analysis and Hypotheses Development

3.1 The Direct Impact of Green Bonds on Corporate Green Technology Innovation

Based on Financing Constraint Theory and Signaling Theory, green bonds may drive green innovation through dual pathways: direct mitigation of financing constraints and indirect reputational signaling.

Hypothesis 1 (H1): Green bond issuance promotes corporate green technology innovation.

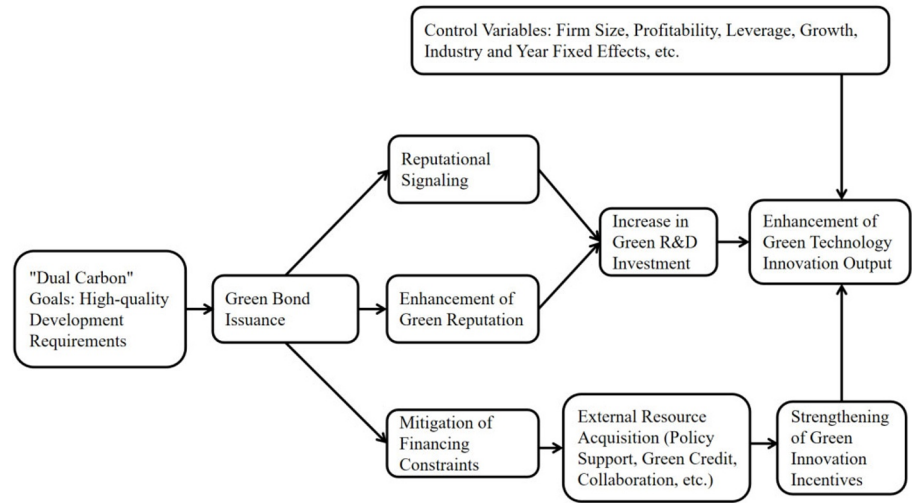


Fig. 1. Mechanism of Green Bonds Driving Green Innovation

3.2 Analysis of the Financing Constraint Mitigation Mechanism

Green bonds alleviate financing constraints through policy support (interest subsidies, tax preferences), maturity matching with long-term projects, and the earmarked-fund mechanism ensuring capital flows into green R&D. This increases green R&D investment, driving innovation output.

Hypothesis 2 (H2): Financing constraint mitigation mediates the effect of green bonds on green innovation.

3.3 Analysis of the Reputational Signaling and Innovation Incentive Mechanism

Issuing green bonds signals environmental responsibility to the market, enhancing corporate reputation⁸. This attracts external resources (preferential policies, technical collaborations) and strengthens intrinsic motivation for innovation, creating a “reputation-innovation” virtuous cycle.

Hypothesis 3 (H3): Reputational signaling mediates the effect of green bonds on green innovation.

Figure 1 illustrates the dual-path mechanism.

4 Methodology and Variables

4.1 Model Specification

We employ a staggered difference-in-differences model:

$$GPatent_{it} = \beta_0 + \beta_1 Treat_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (1)$$

Where $GPatent_{it}$ represents the level of green technology innovation for firm i in year t . $Treat_{it}$ is the core explanatory variable, taking a value of 1 if firm i issued green bonds for the first time in year t or thereafter, and 0 otherwise. X_{it} denotes a series of control variables. μ_i and λ_t represent firm-level fixed effects and year-level fixed effects, respectively. ϵ_{it} is the idiosyncratic error term. Standard errors are clustered at the firm level.

For mediation effects (following Wen et al., 2004⁹):

$$M_{it} = \alpha_0 + \alpha_1 Treat_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (2)$$

$$GPatent_{it} = \beta'_0 + \beta'_1 Treat_{it} + \beta'_2 M_{it} + \gamma X_{it} + \mu_i + \lambda_t + \eta_{it} \quad (3)$$

Where M_{it} represents the mediating variables: Financing Constraints (SA) and Reputational Signaling (Reputation). The existence of mediating effects is determined by examining the statistical significance of coefficients α_1 and β'_2 .

4.2 Variable Definitions

The specific definitions and measurement methodologies for all variables are detailed in Table 1.

Table 1. Variable Definitions and Measurements

Variable Category	Variable Name	Symbol	Definition and Measurement
Dependent	Green Innovation	GPatent	$\ln(1 + \text{green invention patent applications})$
Key Independent	Green Bond Issuance	Treat	1 if firm issued green bonds in or after year t
	Firm Size	Size	$\ln(\text{total assets})$
	Firm age	Age	$\ln(1 + \text{years since establishment})$
	Profitability	ROA	Net profit / total assets
	Leverage	Lev	Total liabilities / total assets
	Growth	Growth	Revenue growth rate.
Control	Ownership Structure	SOE	1 for state-owned enterprises
	Industry Competition	HHI	Herfindahl-Hirschman Index
	Regional Economic Development	GDP_pc	$\ln(\text{city GDP per capita})$
	Financing Constraints	SA	SA Index: $-0.737 \times \text{Size} + 0.043 \times \text{Size}^2 - 0.040 \times \text{Age}$
Mediating Variables	Reputational Signaling	Reputation	ESG comprehensive score (Huazheng)

4.3 Data Sources and Sample Selection

Sample: A-share listed firms, 2010–2023. Green bond data from Wind; financial data from CSMAR; green patents from CNRDS; ESG scores from Sino-Securities; city data from China City Statistical Yearbook. Exclude financial firms, ST/*ST, firms listed <1 year, and observations with missing key variables. Winsorize continuous variables at 1%. Final sample: 2,146 firms, 19,314 firm-year observations.

4.4 Descriptive Statistics

Table 2 presents descriptive statistics. GPatent has a mean of 0.852 (SD=1.174), indicating low green patent output with substantial variation. Treat averages 0.043, meaning 4.3% of observations are treated, reflecting gradual green bond market growth. SA averages -3.824 (SD=0.247), showing moderate variation in financing constraints. Reputation averages 72.34 (SD=5.62), indicating concentrated ESG performance. Other controls align with prior studies.

Table 2. Descriptive Statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max
GPatent	19314	0.852	1.174	0.000	5.238
Treat	19314	0.043	0.202	0.000	1.000
SA	19314	-3.824	0.247	-4.512	-3.012
Reputation	19314	72.34	5.62	55.23	88.50
Size	19314	22.451	1.353	19.823	26.307
Age	19314	2.935	0.328	1.792	3.689
ROA	19314	0.043	0.068	-0.215	0.236
Lev	19314	0.447	0.207	0.053	0.921
Growth	19314	0.161	0.393	-0.561	3.012
SOE	19314	0.358	0.479	0.000	1.000
HHI	19314	0.098	0.092	0.019	0.567
GDP_pc	19314	11.325	0.598	9.912	12.503

5 Empirical Analysis

5.1 Baseline Regression Results

Table 3 reports the staggered DID results. The Treat coefficient is consistently positive and significant at the 1% level, ranging from 0.147 to 0.168, confirming that green bond issuance significantly promotes green innovation (H1 supported). Based on Column (6), issuance increases green patent applications by approximately 15.3%. For controls, Size, ROA, and GDP_pc are significantly positive, while Lev is significantly negative. SOE is negative but insignificant.

Table 3. Regression Results of the Difference-in-Differences Model

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Treat	0.168*** (0.031)	0.165*** (0.031)	0.162*** (0.031)	0.158*** (0.030)	0.151*** (0.030)	0.153*** (0.030)
Size		0.215*** (0.012)	0.212*** (0.012)	0.208*** (0.012)	0.201*** (0.012)	0.199*** (0.012)
Age			-0.041* (0.022)	-0.039* (0.022)	-0.036 (0.022)	-0.035 (0.022)
ROA				0.372*** (0.091)	0.358*** (0.091)	0.355*** (0.091)
Lev					-0.087*** (0.032)	-0.089*** (0.032)
Growth					-0.012 (0.011)	-0.011 (0.011)
SOE					-0.023	-0.024

					(0.018)	(0.018)
					-0.087	-0.085
HIIHHI					(0.061)	(0.061)
GDP_pc						0.032**
						(0.014)
Constant	0.845***	-3.854***	-3.722***	-3.695***	-3.452***	-3.678***
	(0.002)	(0.257)	(0.261)	(0.261)	(0.265)	(0.281)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	19314	19314	19314	19314	19314	19314
R2	0.683	0.695	0.696	0.697	0.698	0.698

Notes: Robust standard errors are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The same applies below.

5.2 Robustness Checks

To ensure the reliability of the conclusions, a series of robustness checks were conducted, as summarized in Table 4.

Table 4. Robustness Check Results

Methodology	Coefficient of <i>Treat</i>	Significance
Excluding Concurrent Policy Interference	0.146***	1%
Placebo Test	0.002	N.S.
PSM-DID	0.149***	1%
Alternative Dependent Variable	0.137***	1%
Lagged Treatment Variable	0.142***	1%
Alternative Clustering	0.153***	1%

All tests support the robustness of the baseline findings, confirming that green bond issuance indeed fosters corporate green technology innovation.

5.3 Mechanism Testing

Green bond issuance significantly reduces financing constraints (Column 2) and improves reputation (Column 4). Both mediators significantly affect green innovation, with *Treat* coefficients decreasing after inclusion, confirming partial mediation. H2 and H3 are supported. Results are presented in Table 5.

Table 5. Results of Mechanism Testing

Variables	(1)	(2)	(3)	(4)	(5)
	GPatent	SA	GPatent	Reputation	GPatent
<i>Treat</i>	0.153***	-0.041***	0.138***	2.184***	0.126***
	(0.030)	(0.009)	(0.030)	(0.317)	(0.030)

SA	-0.366*** (0.027)				
Reputation	0.012*** (0.001)				
Control Variables	Yes	Yes	Yes	Yes	Yes
Firm/Year FE	Yes	Yes	Yes	Yes	Yes
Obs.	19314	19314	19314	19314	19314
R ²	0.698	0.712	0.705	0.745	0.708

5.4 Heterogeneity Analysis

The driving effect is stronger for private firms, high-tech industries, and regions with stringent environmental regulations. See Table 6 for detailed results.

Table 6. Heterogeneity Analysis Results

Variables	(1)SO Es	(2)POE s	(3)High-t ech	(4)Non-high -tech	(5)Strong- regulation	(6)Weak- regulation
Treat	0.098* (0.041)	0.187** (0.039)	0.198*** (0.038)	0.121*** (0.036)	0.176*** (0.035)	0.132*** (0.041)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm/Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	6925	12389	8952	10362	10218	9096
R ²	0.712	0.688	0.705	0.692	0.703	0.694

6 Conclusions and Policy Recommendations

6.1 Research Conclusions

Using staggered DID and mediation models, this paper finds that green bond issuance significantly promotes corporate green technology innovation ($\approx 15.3\%$ increase). The effect operates through mitigating financing constraints and enhancing reputational signals. Heterogeneity exists: stronger in private firms, high-tech industries, and regions with stringent environmental regulations.

6.2 Policy Recommendations

Based on the aforementioned conclusions, this paper proposes the following recommendations:

- (1) Expand green bond issuance scale and coverage, especially for private firms.

- (2) Strengthen supervision of proceeds to ensure they flow into green R&D.
- (3) Link green patent outputs to bond issuance evaluation to reinforce innovation incentives.
- (4) Implement differentiated support for high-tech industries and high-regulation regions.
- (5) Advance ESG disclosure to enhance reputational value of green bonds.

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