The Impact of Green Bond Issuance on Corporate Green Innovation Performance

Haolun Han[1,*], Huilin Yang[2], Dong Li[3]

[1]Faculty of Liberal Arts and Professional Studies, York University, Toronto, Canada
[2]College of Finance, Nanjing Agricultural University, Nanjing, China
[3]Graduate School, Universitat Autònoma de Barcelona, Barcelona, Spain
*Corresponding author: HaolunHan2024@126.com

Abstract. Amid global climate change and environmental degradation, constructing a green financial system has become a worldwide consensus, with green bonds serving as a critical tool for promoting environmental protection and sustainable development. This paper selects 172 green bonds issued between 2011 and 2022 as samples and employs a difference-in-differences model to investigate the impact of green bond issuance on corporate green innovation performance. Empirical findings indicate that: firstly, the green bond issuance positively influences corporate green innovation performance. Secondly, media attention and corporate environmental information disclosure play a positive moderating role in this process. Thirdly, there are regional heterogeneity variations in how green bond issuance affects corporate green innovation performance. This research provides important theoretical foundations and practical references for green finance in supporting corporate sustainable development.

Keywords: Green Bonds; Green Innovation Performance; Media Attention; Environmental Information Disclosure.

1   Introduction

In China, there is a significant shortage of funds for investment in green technology sectors, and financing difficulties are one of the major issues faced by many green technology enterprises. To address this challenge, the People's Bank of China, along with six other ministries, jointly issued the "Guiding Opinions on Building a Green Financial System" in 2016. This guideline emphasizes the need to "establish and improve a green financial system, leveraging the capital market's role in optimizing resource allocation and serving the real economy," particularly by developing green financial products such as green bonds. The introduction of green bonds provides enterprises with a new financing avenue to support the funding needs of their green industrial projects, thereby holding significant policy and practical implications.

Bhutta et al. [1] regarded green bonds as alternatives to conventional bonds, positioning them as a financial tool for fulfilling environmental, social, and governance (ESG) objectives. Flammer [2] identified five advantages of green bonds: favorable announcement effects, improvements in long-term value and operational performance,

better environmental outcomes, a boost in green innovation, and increased holdings by long-term and environmentally focused investors. Overall, these results suggest that green bonds have proven to be an effective financial instrument, enabling companies to invest in projects that improve their environmental impact, thereby creating long-term value and attracting investors and customers who are sensitive to environmental issues.

The performance impact of corporate green innovation activities generally includes environmental performance, social performance, and financial performance. Corporate green innovation performance is the effective output of a company's green innovation activities and is influenced by various factors. Amore and Bennedsen [3] found that poorly managed companies produce fewer green patents compared to overall innovation, using changes in anti-takeover legislation in the United States. Economic development is also a dominant factor affecting the overall green innovation output in inland and coastal regions of China [4]. Some scholars believe that bank competition promotes corporate green innovation by reducing transaction costs and increasing the likelihood and number of corporate green patent applications [5].

Recently, scholars have started to examine the effects of green bond issuance on the performance of corporate green innovation. Lee et al. [6] argued that green bond policies directly promote green innovation and green space; Zhang et al. [7] also argued that issuing green bonds can significantly enhance a company's ability to innovate in green technology. Benlemlih et al. [8] demonstrated that the issuance of green bonds significantly improves a company's overall environmental performance and its capacity for innovative environmental technologies and processes, indirectly confirming the relationship between green bond issuance and corporate green innovation performance. However, few scholars have explored the role of corporate reputation in the mechanism by which green bond issuance affects corporate green innovation performance.

Therefore, this paper utilizes data from 172 green bonds issued by 111 listed companies between 2011 and 2022, employing a difference-in-differences (DID) model to attempt to reveal the impact of green bond issuance on corporate green innovation performance. The marginal contribution of this paper lies in its innovative use of corporate media attention and the degree of environmental information disclosure as moderating variables, exploring the role of corporate reputation in the mechanism by which green bond issuance affects corporate green innovation performance.

The structure of this paper is arranged as follows: The second section presents theoretical analysis and research hypotheses. The third section details the empirical research design. The fourth section is empirical result analyzes. The fifth section delves into the mechanism analysis. The sixth section provides further analysis. The seventh section summarizes the entire paper and provides policy recommendations.

2   Theoretical Analysis and Research Hypotheses

Khurram et al. [9] found that the green bond issuance positively impacts corporate green innovation levels, primarily by reducing the cost of obtaining funds and optimizing the debt structure of enterprises. Additionally, green bonds can enhance a

company's green reputation. The introduction of green bonds stimulates corporate green innovation, facilitating the seamless integration of green innovation with green finance. Corporate green performance also helps broaden the channels for commercial financing and equity financing, creating a positive feedback loop for the company's financing methods [10]. Based on this, we propose Hypothesis 1:

H1: The issuance of green bonds has a positive impact on corporate green innovation performance.

Tang et al. [11] confirmed that media attention significantly positively affects investment in green technology innovation. Further analysis shows that under the moderating effect of marketization, media attention also significantly influences the output of green technology innovation. Li et al. [12] suggested that higher media attention subject companies to broader public scrutiny during the innovation process, facilitating better integration of digital finance and green innovation. Xing et al. [13] demonstrated that a company's green image positively affects innovation performance under green credit constraints. Accordingly, we propose Hypothesis 2:

H2: Corporate media attention positively moderates the influence of green bond issuance on the performance of corporate green innovation.

Wang and Sun [14] found that ESG information disclosure can influence these companies' green innovation performance through cost effects, resource effects, and governance effects. Xiang et al. [15] posited that government direct subsidies can substantially enhance the environmental information disclosure of heavily polluting enterprises through a mediating effect, thereby improving their green innovation performance. As the issuance of green bonds increases corporate information disclosure and media exposure, it affects corporate green innovation performance. Therefore, we propose Hypothesis 3:

H3: Corporate environmental information disclosure positively moderates the impact of green bond issuance on corporate green innovation performance.

Huang et al. [16] found that compared to the eastern regions, the central and western regions are relatively weaker in terms of technology resource allocation, economic development model, and market maturity. Therefore, companies in these regions are more positively affected by green bonds in terms of technological competitiveness. Khurram et al. [9] pointed out that in underdeveloped financial regions, companies tend to rely on green bonds as a financing method, and in regions with stricter environmental regulations, companies have stronger motivations for green innovation. This effect exhibits regional heterogeneity characteristics in green financial pilot zones. Based on this, we propose Hypothesis 4:

H4: The impact of green bond issuance on corporate green innovation performance exhibits regional heterogeneity characteristics.

3   Empirical Research Design

3.1   Model Specification

To assess the impact of green bond issuance on corporate green innovation performance, this study constructs the baseline regression model outlined below, drawing on Khurram et al. [9]. The model constructed is specified as follows Eq (1):

$$GIP_{i,t} = \alpha_0 + \alpha_1 Treat_i \times Post_t + \alpha_2 X_{i,t} + \lambda_t + \eta_j + \varepsilon_{i,t} \tag{1}$$

$GIP_{i,t}$ represents the green innovation performance of firm i in year t. $Treat_i \times Post_t$ is the interaction term of the policy dummy variable and the time dummy variable. $X_{i,t}$ represents a series of control variables, specifically including firm size ($Size$), financial leverage ($Level$), profitability (ROA), operating cash flow ($Cashflow$), growth ability ($TobinQ$), number of employees ($Employee$), and years listed ($ListAge$). λ_t and η_j denote industry fixed effects and time fixed effects, respectively. $\varepsilon_{i,t}$ is the random error term that captures other potential factors affecting green innovation performance that vary over time.

The dependent variable, green innovation performance ($GIP_{i,t}$), measures the level of green technology innovation of a firm. Green technology refers to technologies that reduce pollution, decrease consumption, and improve the ecosystem. This study uses the number of green patent applications, log-transformed, to represent a firm's green innovation performance.

For explanatory variable ($Treat_i \times Post_t$), $Treat_i$ is a binary variable that equals 1 if the firm has issued green bonds, and 0 otherwise. $Post_t$ is a time dummy variable that uses the year when the firm first issued green bonds as the policy intervention time point. According to the "Guiding Opinions on Building a Green Financial System" jointly issued by the People's Bank of China and six other ministries in 2016, the model incorporates a one-year lag for policy impact, setting the starting year as 2017. Specifically, for firms that have issued green bonds, the dummy variable is set to 1 for the year of the first green bond issuance and all following years, and 0 for all prior years. For firms that have not issued green bonds, the dummy variable remains 0 for all years.

3.2   Data Sources

This paper collects data on "green" labeled bonds issued domestically by Chinese listed companies (excluding ST enterprises) and their subsidiaries from 2011 to 2022. After excluding green bonds with missing key variables, the final sample consists of 172 green bonds issued by 111 listed companies. Data on green innovation performance are sourced from the CNRDS database, while data on green bond issuance come from the CSMAR and CNRDS databases. Corporate data for control variables are also sourced from the CSMAR database.

4   Empirical Result Analysis

4.1   Baseline Regression Analysis

Based on the model specified earlier, the baseline regression results are displayed in Table 1. Column (1) shows the results without control variables, whereas Column (2) incorporates the control variables. The inclusion of control variables improves the model's R^2, indicating a better fit. The regression coefficient between the green bond issuance dummy variable and the green innovation performance of listed companies is positively correlated at the 95% confidence level, suggesting that issuing green bonds significantly enhances the level of green innovation performance in listed companies. Specifically, after issuing green bonds, corporate green innovation performance increases by 0.206 units. Green bonds provide companies with dedicated funding sources, alleviating financial constraints and enabling investment in green projects and technologies. This also sends a positive signal to the market about the company's commitment to sustainable development and environmental protection, enhancing market recognition and allowing companies to secure more funding, thereby further boosting their green innovation investments and performance. Thus, Hypothesis 1 is validated.

Table 1. Baseline Regression Results

Variables	(1) GIP	(2) GIP
Treat*Post	0.211***	0.206**
	(2.58)	(2.53)
Controls	NO	YES
Industry FE	YES	YES
Year FE	YES	YES
N	28,092	28,092
R^2	0.024	0.025

(Note: Parentheses indicate robust standard errors; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.)

4.2   Robustness Checks

The companies issuing green bonds are primarily distributed across seven industries: mining, manufacturing, electricity, heat, gas, and water production and supply, construction, wholesale and retail, transportation, storage and postal services, and water conservancy, environment, and public facility management. To comprehensively assess the impact of green bond issuance on corporate green innovation performance, this study restricts the sample to these seven industries for robustness checks. Table 2 illustrates the findings, where Column (1) displays the baseline regression results and Column (2) shows the results of the robustness check using a restricted sample. The coefficient continues to be significantly positive at the 95% confidence level, confirming the robustness of the baseline regression results and further supporting Hypothesis 1.

Table 2. Robustness Checks

Variables	(1) GIP	(2) GIP
Treat*Post	0.206**	0.158**
	(2.53)	(2.22)
Controls	YES	YES
Industry FE	YES	YES
Year FE	YES	YES
N	28,092	22,586
R^2	0.025	0.024

(Note: Parentheses indicate robust standard errors; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.)

4.3   Endogeneity Analysis

Table 3. Endogeneity Analysis

Variables	Unmatched Matched	Mean Control	Treated	t-test p>t	t-test t
Size	U	22.322	25.317	0.000	28.04
	M	25.349	25.317	0.845	-0.20
Level	U	0.413	0.694	0.000	18.07
	M	0.695	0.694	0.961	-0.05
ROA	U	0.044	0.029	0.000	-3.58
	M	0.029	0.029	0.852	-0.19
Cashflow	U	0.048	0.044	0.455	-0.75
	M	0.044	0.042	3.400	44.4
TobinQ	U	1.906	1.156	0.000	-9.64
	M	1.123	1.156	0.312	1.01
Employee	U	7.738	9.092	0.000	14.38
	M	9.201	9.092	0.477	-0.71
ListAge	U	2.009	2.310	0.000	4.78
	M	2.373	2.310	0.452	-0.75

The difference-in-differences (DID) model requires that the treatment group and control group exhibit common trends before the event. Therefore, this study first conducts a parallel trend test, preliminarily supporting the assertion that green bond issuance enhances corporate green innovation performance. To test whether the model is influenced by unobserved factors that change over time, a placebo test is conducted and passed. Finally, to eliminate or reduce sample self-selection bias, a multi-period PSM-DID model is employed for endogeneity analysis. In model (1), all control variables are used as covariates for propensity score matching, using a 1:5 nearest neighbor matching

method. Observations from bond-issuing firms are matched, and the matched sample is used for regression analysis. As shown in Table 3, pre-matching results are significant for all variables except cash flow, indicating significant differences between the treatment and control groups. After matching, the t-tests and p-values for the covariates are insignificant, suggesting that there are no significant differences between the treatment and control groups. This validates the effectiveness of the Propensity Score Matching (PSM) results.

5   Mechanism Analysis

To further explore the mechanism by which corporate green bond issuance affects green innovation performance, this study uses media attention (*Media*)and corporate environmental information disclosure (*EDI*) as moderating variables. This analysis investigates whether corporate reputation influences the impact of green bond issuance on green innovation performance. Following the methodology of Piñeiro-Chousa et al. [17], media attention is measured using internet news coverage of companies, with data sourced from the CNRDS database. Following the method proposed by Wang et al. [18], corporate environmental information disclosure is evaluated based on whether companies publish their annual reports, social responsibility reports, and environmental reports, and by scoring the comprehensiveness of the information provided in these disclosures. The scores are then logarithmically transformed to obtain the final indicator, reflecting the overall environmental information disclosure of companies. Data are sourced from the CSMAR database, company annual reports, social responsibility reports, and company websites. The following moderating effect models are constructed as follows Eq (2) and Eq (3):

$$GIP_{i,t} = \beta_0 + \beta_1 Media_{i,t} + \beta_2 Treat_i \times Post_t \times Media_{i,t} + \beta_3 X_{i,t} + \lambda_t + \eta_j + \varepsilon_{i,t} \tag{2}$$

$$GIP_{i,t} = \varphi_0 + \varphi_1 EDI_{i,t} + \varphi_2 Treat_i \times Post_t \times EDI_{i,t} + \varphi_3 X_{i,t} + \lambda_t + \eta_j + \varepsilon_{i,t} \tag{3}$$

As shown in Table 4, under the moderating effect of media attention, the positive effect of green bond issuance on green innovation performance becomes more significant, increasing by 0.022 units. The increase in media attention helps to promote the analysis of the impact of green bonds on green innovation performance, indicating that media attention can enhance corporate transparency through passive information disclosure—media exposure—thereby incentivizing companies to engage in innovative activities. Thus, Hypothesis 2 is validated.

After incorporating the corporate environmental information disclosure variable, the main effect significantly increases by 13.2% and is significant at the 99% confidence level. This indicates that environmental information disclosure significantly and positively influences the impact of green bond issuance on green innovation performance. Compared to media attention, proactive environmental information disclosure by companies, along with improved disclosure quality, is more effective in facilitating the internal flow of green funds within companies and aiding their green transformation. Thus, Hypothesis 3 is validated.

Table 4. Mechanism Analysis Results

Variables	(1) GIP	(2) GIP
Media	0.016**	
	(2.28)	
EDI		0.007
		(0.83)
Treat*Post*Media	0.022*	
	(1.80)	
Treat*Post*EDI		0.132***
		(2.90)
Controls	YES	YES
Industry FE	YES	YES
Year FE	YES	YES
N	27,233	25,520
R^2	0.024	0.026

(Note: Parentheses indicate robust standard errors; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.)

6   Further Analysis

To further explore whether the region in which the bond-issuing entity is located affects the impact of green bond issuance on green innovation performance, this study divides the 31 provinces involved in the sample into three regions: East, Central, and West.

Table 5 presents the regression results for the Eastern, Central, and Western regions. Column (1) shows the results for the Eastern region, Column (2) for the Central region, and Column (3) for the Western region. The results indicate that the impact of green bond issuance on corporate green innovation performance exhibits regional heterogeneity, with the effect being significant in the Eastern and Western regions at the 99% confidence level, with coefficients of 0.205 and 0.425, respectively. However, the effect is not significant in the Central region. The Eastern region has the largest sample size, and the Eastern and Western regions together account for the majority of the sample. In contrast, the number of companies in the Central region that finance through green bond issuance is relatively small. Therefore, Hypothesis 4 is validated.

Table 5. Further Analysis Results

Variables	(1) GIP	(2) GIP	(3) GIP
Treat*Post	0.205**	0.067*	0.425**
	(2.20)	(0.31)	(2.13)
Controls	YES	YES	YES
Industry FE	YES	YES	YES
Year FE	YES	YES	YES
N	20,726	3,159	4,198
R^2	0.031	0.041	0.049

(Note: Parentheses indicate robust standard errors; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.)

7   Conclusion

Based on the "Guiding Opinions on Building a Green Financial System" issued in 2016 as the policy variable, this paper selects data from 172 green bonds issued by Chinese listed companies between 2011 and 2022. Using a difference-in-differences model, the paper empirically investigates the impact of green bond issuance on corporate green innovation performance. The main conclusions are as follows: Firstly, issuing green bonds positively enhances corporate green innovation performance. Secondly, media attention and environmental information disclosure have moderating effects on this impact. Compared to media attention, the proactive disclosure of environmental information by companies has a more significant effect on the impact of green bond issuance on corporate green innovation performance. Thirdly, regional variations are evident in how green bond issuance affects corporate green innovation performance. Based on this, suggestions are put forward, such as issuing green bonds to reduce R&D costs and improve information transparency, actively disclosing information to enhance green innovation capabilities and central enterprises need to improve financing efficiency and strengthen green capital flows.

References

1. Bhutta, U.S., Tariq, A., Farrukh, M., et al. Green bonds for sustainable development: Review of literature on development and impact of green bonds. Technological Forecasting and Social Change, 175: 121378 (2022).
2. Flammer, C. Corporate green bonds. Academy of Management Global Proceedings, 2019 (2019): 136 (2019).
3. Amore, M.D., Bennedsen, M. Corporate governance and green innovation. Journal of Environmental Economics and Management, 75: 54-72 (2016).
4. Luo, Y., Salman, M., Lu, Z. Heterogeneous impacts of environmental regulations and foreign direct investment on green innovation across different regions in China. Science of the total environment, 759: 143744 (2021).
5. Wang, H., Qi, S., Zhou, C., et al. Green credit policy, government behavior and green innovation quality of enterprises. Journal of Cleaner Production, 331: 129834 (2022).
6. Lee, C.C., Wang, F., Chang, Y.F. net-zero emissions: Can green bond policy promote green innovation a·11nd green space? Energy Economics, 121: 106675 (2023).
7. Zhang, J., Yang, G., Ding, X., et al. Can green bonds empower green technology innovation of enterprises? Environmental Science and Pollution Research, 2022: 1-13 (2022).
8. Benlemlih, M., Jaballah, J., Kermiche, L. Does financing strategy accelerate corporate energy transition? Evidence from green bonds. Business Strategy and the Environment, 32(1): 878-889 (2023).
9. Khurram, M.U., Xie, W., Mirza, S.S., et al. Green bonds issuance, innovation performance, and corporate value: Empirical evidence from China. Heliyon, 9(4) (2023).
10. Tang, D.Y., Zhang, Y. Do shareholders benefit from green bonds? Journal of Corporate Finance, 61: 101427 (2020).
11. Tang, C., Xu, Y., Hao, Y., et al. What is the role of telecommunications infrastructure construction in green technology innovation? A firm-level analysis for China. Energy Economics, 103: 105576 (2021).

12. Li, Z., Huang, Z., Su, Y. New media environment, environmental regulation and corporate green technology innovation: Evidence from China. Energy Economics,119: 106545 (2023).
13. Xing, C., Zhang, Y., Tripe, D. Green credit policy and corporate access to bank loans in China: The role of environmental disclosure and green innovation. International Review of Financial Analysis, 77: 101838 (2021).
14. Wang, F., Sun, Z. Does the environmental regulation intensity and ESG performance have a substitution effect on the impact of enterprise green innovation: evidence from China. International Journal of Environmental Research and Public Health, 19(14): 8558 (2022).
15. Xiang, X., Liu, C., Yang, M., et al. Confession or justification: The effects of environmental disclosure on corporate green innovation in China. Corporate Social Responsibility and Environmental Management, 27(6): 2735-2750 (2020).
16. Huang, Y., Chen, C., Lei, L., et al. Impacts of green finance on green innovation: A spatial and nonlinear perspective. Journal of Cleaner Production, 365: 132548 (2022).
17. Piñeiro-Chousa, J., López-Cabarcos, M.Á., Caby, J., et al. The influence of investor sentiment on the green bond market. Technological Forecasting and Social Change, 162: 120351 (2021).
18. Wang, S., Chen, S.C., Ali, M.H., et al. Nexus of environmental, social, and governance performance in China-listed companies: Disclosure and green bond issuance. Business Strategy and the Environment, 33(3): 1647-1660 (2024).