How green bonds promote firms' green collaborative innovation?

Article *in* Corporate Social Responsibility and Environmental Management · December 2023

DOI: 10.1002/csr.2688

CITATIONS
19

READS
407

3 authors, including:

Xuanshun Huang
Shenzhen University
1 PUBLICATION **19** CITATIONS

SEE PROFILE

Received: 12 May 2023 | Revised: 17 November 2023 | Accepted: 21 November 2023

DOI: 10.1002/csr.2688

RESEARCH ARTICLE

Corporate Social Responsibility and Environmental Management

WILEY

How green bonds promote firms' green collaborative innovation?

Jun Lian | Xuanshun Huang | Xia Wu

School of International Business and Management, Sichuan International Studies University, Chongqing, China

Correspondence
Xuanshun Huang, School of International Business and Management, Sichuan International Studies University, Chongqing, China.
Email: xuanshun@stu.sisu.edu.cn

Funding information
Chongqing Federation Social Science Planning Project, Grant/Award Number: 2021NDYB079; Humanities and Social Sciences Research Project of Chongqing Education Commission, Grant/Award Number: 23SKGH214; Key Projects of the Science and Technology Research Program of Chongqing Education Commission, Grant/Award Number: KJZDK202300902; SiChuan International Studies University Schoollevel Scientific Research Project, Grant/Award Numbers: sisu202043, sisu202134; Youth Project of Science and Technology Research Program of Chongqing Education Commission, Grant/Award Number: KJQN202000901

Abstract

As one of the most critical green financial tools, green bonds play an essential role in supporting the green collaborative innovation of enterprises. Using the data of China's nonfinancial listed companies from 2010 to 2020, the article examines the impact of green bonds on firms' green collaborative innovation. The results show that issuing green bonds can significantly promote the quantity and quality of firms' green collaborative innovation. The mechanism research shows that green bonds can improve the green independent innovation of enterprises, relieve their financing constraints, and enhance corporate reputation, thus promoting the green collaborative innovation of enterprises. Further research reveals that when enterprises obtain external reviews or repeatedly issue green bonds, their green collaborative innovation improves more significantly. This article indicates that China's green bond market has played a positive role in achieving environmental goals from the perspective of green collaborative innovation.

KEYWORDS
environmental performance, green bond, green collaborative innovation, green development, information asymmetry

1 | INTRODUCTION

Various industries are facing severe environmental pollution issues with the development of the economy and society. The Intergovernmental Panel on Climate Change (IPCC) stated in its report (IPCC, 2018) that mobilizing climate finance is crucial for limiting global warming to 1.5°C and preventing catastrophic climate change. However, available climate finance for promoting sustainable environmental development is severely insufficient, and this shortage of funds is particularly evident in developing countries (COP, 2021). The challenges brought by climate change seriously test the stability and contribution of the government and financial sector in transforming a polluted economy into a green one (Ning et al., 2022). In recent years, the importance of green bonds in climate and sustainable finance schemes has become increasingly prominent, as they represent a vital tool for mobilizing private financial resources to drive global pollution control and emissions reduction (Gianfrate & Peri, 2019). From 2008 to 2017, nearly $58 billion was raised from issuing green bonds globally, with these funds widely used for greenhouse gas emissions reductions equivalent to 108 million metric tons of CO_2 and investments in over 1500 GW of renewable energy capacity (Tolliver et al., 2019). For example, significant funding from green bonds supported the strengthening of Morocco's railway infrastructure, as well as the construction of the Wayra wind farm and Rubi solar photovoltaic plant in Peru, and two additional wind power plants in Kenya and Mongolia (Agliardi & Agliardi, 2019). These figures demonstrate that increasing capital flows into climate, sustainability, and clean production investments through green bonds, making them a critical financing tool for energy conservation, emissions reductions, and combating global warming trends.

Green innovation can effectively control the discharge of waste water, waste gas, and solid waste in the production process of enterprises, reduce the cost of emission reduction and improve the efficiency of resource utilization, which is an essential way for enterprises to solve environmental problems fundamentally (Pagnoni & Roche, 2015). Despite the abundance of research on the relationship between green

bonds and corporate green innovation (Wang et al., 2022; Zhang et al., 2022), existing literature mainly focuses on the perspective of independent innovation (Jiang et al., 2022), few studies pay attention to how green bonds affect the green collaborative innovation of enterprises. Collaborative innovation is an innovative activity based on the principles of "shared interests, shared risks, complementary resources, interactive functions, and interconnected platforms," which is a comprehensive and multilevel innovation model that integrates the strengths of collaborative entities to achieve a synergistic effect more remarkable than the sum of its parts (Li & Wang, 2022). Under the background of open innovation, collaborative innovation has become an essential way for enterprises to innovate. Green bonds can promote firms' green collaborative innovation through various ways, such as promoting the independent innovation of enterprises, alleviating their financing constraints faced in R&D activities, reducing their information asymmetry levels, and enhancing their corporate social reputation. However, existing studies lack a detailed exploration of this aspect, and our research aims to fill this gap.

Based on the data of nonfinancial listed companies in China from 2010 to 2020, we take the enterprises that have successfully issued green bonds as the treatment group and select the control group from the samples of enterprises that have not issued green bonds through PSM, and then construct DID model to test the influence of green bonds on green collaborative innovation of enterprises. The relevant data on green bonds were obtained from the Wind database, which is the largest and most comprehensive securities-oriented financial database in China. Our analysis shows that issuing green bonds can significantly promote firms' green collaborative innovation. Specifically, the total number of green patents and the number of green invention patents jointly applied by firms with other entities increased significantly after green bond issuance. We also conducted several robustness tests, including, but not limited to, remeasuring green bonds, remeasuring the dependent variable, the explained variables delayed by one period, using the Tobit model to reestimate the results. Furthermore, we conducted a placebo test, which supports the validity of our findings. The DID model assumes that the treatment and control groups had parallel trends before the policy shock. We confirmed this assumption and found that green bonds promote corporate green collaborative innovation dynamically and sustainably.

Subsequently, we investigated three potential channels through which green bonds affect enterprises' green collaborative innovation: (1) Technology advantages. The issuance of green bonds can improve firms' independent R&D capabilities, improve the quality of green products, and raise the standards of green products in the industry, thus forcing other enterprises in the supply chain to cooperate with them, share superior resources, and promote the green collaborative innovation. (2) Resource advantages. Issuing green bonds can signal the green development of enterprises to external stakeholders, thereby guiding green social capital, green banking capital, and green government capital to flow into the enterprises, bringing capital resources to enterprises, reducing their capital costs, optimizing their capital term structure, alleviating financing constraints faced by enterprises in collaborative innovation, such as difficulty and high costs of financing and a mismatch between short-term debt and long-term investment horizons, and thus promoting the green collaborative innovation. (3) Reputation advantages. Issuing green bonds not only improves the environmental quality of enterprises but also helps to enhance their image and social reputation, thereby improving the level of trust between enterprises and cooperating entities. On the one hand, it promotes the willingness of other organizations to cooperate and innovate with issuers. On the other hand, it improves the innovation efficiency between the issuer and the existing partners, thus promoting the green collaborative innovation of enterprises. We constructed a mediation effects model, and the research results showed that green bonds promote green collaborative innovation in enterprises through three channels: "Technology" channel, "Resource" channel, and "Reputation" channel.

Finally, we investigate the impact of green bonds on green collaborative innovation from the perspective of bond heterogeneity. Our findings reveal that issuing green bonds with external reviews or repeated issuance significantly improves the quantity and quality of jointly applied green patents. This result indicates that the green attributes of green bonds are crucial in driving firms' green collaborative innovation.

Our research extends and enriches the existing literature on green bonds. While prior studies mainly focus on the issuance pricing and premium of green bonds (Fatica et al., 2021; Immel et al., 2021; Larcker & Watts, 2020; Zerbib, 2019), investment efficiency in clean energy projects (Zhao et al., 2022), financial performance and enterprise value (Zhou & Cui, 2019), ESG performance (Flammer, 2021; Wang & Wang, 2022; Yeow & Ng, 2021), and stock market reactions (Baulkaran, 2019; Flammer, 2021; Li et al., 2020), there is limited research on how green bonds can promote green collaborative innovation. Against the backdrop of the rapid development of the green bond market, our study examines the impact of green bonds on collaborative green innovation among enterprises, thereby expanding the depth and breadth of research on green bonds.

Furthermore, our research enriches the relevant literature on the factors influencing collaborative innovation. Prior studies mainly explore the mechanism of collaborative innovation from the perspectives of absorptive capacity (Hong et al., 2019), blockchain application (Wan et al., 2022), supplier relationship (Patrucco et al., 2022), social capital (Al-Omoush et al., 2022), the trust between enterprises (Wan et al., 2022; Zhai et al., 2021), benefit distribution mechanism (Li et al., 2021), and knowledge management and sharing (Bai & Li, 2020). However, previous research on green collaborative innovation driving factors lack consideration of the role of green financial instruments. Our study expands the relevant research on the channels of impact on collaborative green innovation and provides a reference for the innovation-driven development strategy initiated by the Chinese government.

Moreover, our research sheds light on the impact pathway of green finance on the green investment behavior of real enterprises from the perspective of green bonds, thus opening up the black box of financial support for sustainable development and providing evidence and experience for market-oriented approaches to promoting ecological sustainability.

2 | RESEARCH BACKGROUND AND LITERATURE REVIEW

2.1 | Research background: Development of China's green bond market

In the past 40 years, China's economic growth has achieved remarkable results. However, the extensive development model of high energy consumption, high destruction, and high pollution has also made China's environmental problems more prominent. According to the report "Building China's Green Financial System" released by the United Nations, it is estimated that China's annual investment demand for green industries is about RMB 3 trillion, while government funds can only cover about 15%. China's green development strategy faces a huge funding gap. To fill the green funding gap through market-oriented means, the Chinese government has issued a series of policies and regulations since 2015 to promote the development of the green bond market vigorously.

Unlike the overseas focus on relying on international organizations or market forces to promote the development of the green bond market, the Chinese green bond market is dominated by policies and rules formulated by the public sector from top to bottom (Huang & Yue, 2020). In addition to regulating the issuance conditions, approval process, support scope, requirements for the use of raised funds, information disclosure rules, and third-party certification requirements of green bonds, the government also provides preferential policies from the issuance, investment, and underwriting ends to encourage the development of the green bond market. These measures mainly include:

1. Relaxing the entry threshold for green bonds so that more enterprises meet the issuance conditions;
2. Simplify the approval process for green bonds, and various approval departments have opened up "green channels" for green bonds to improve the efficiency of green bond registration;
3. Relax the scope of use of raised funds. In the early stages of the development of China's green bond market, the government allowed issuers to use some of the funds raised from green bonds to repay bank loans or supplement working capital. For example, the "Green Bond Issuance Guidelines" issued by the China Development and Reform Commission in 2015 clearly stated that enterprises are allowed to use no more than 50% of the funds raised from green bonds to repay bank loans and supplement working capital. It was not until 2022 that "China Green Bond Principles" issued by the China Green Standards Committee explicitly required that 100% of the funds raised by green bonds should be used for green projects such as green industries and green economic activities that meet the prescribed conditions;
4. Financial incentives, local governments in China support the development of the green bond market through various means such as investment subsidies, guarantee subsidies, and bond interest discounts.

China's green bond market started late, but has developed very rapidly thanks to government support. According to a report released by the Climate Bond Initiative, as of the end of 2021, China has cumulatively issued $327 billion in green bonds in domestic and international markets, becoming the second largest green bond issuer after the United States.

Although the government-led development model aligns with China's current primary national conditions and can quickly promote the development of China's green bond market, there are also many problems. For example, China's relaxation of the scope of use of raised funds may result in the funds raised by green bonds not being fully used for green projects or green industries, changing the original intention of green bonds to generate positive environmental benefits, thereby affecting the health of China's green bond market. Therefore, this article examines whether green bonds can have a positive impact from the perspective of green collaborative innovation, providing a basis for evaluating the development quality of China's green bond market.

2.2 | Literature review

2.2.1 | Research on green bonds

The emergence of green bonds originated from the public's attention to the natural environment and climate issues, carrying the public welfare goal and social responsibility of using financial resources to improve the Earth's environment and jointly build a civilized ecology. Since the issuance of the first climate-aware bond by the European Investment Bank in 2007, the International Capital Markets Association released the "Green Bond Principles" in 2014, and the Climate Bond Initiative launched the "Climate Bond Standards" in 2015. As a result, green bonds have gained widespread attention worldwide and opened a new market. The existing research on green bond-related fields is mainly focused on normative research. Scholars mainly focus on the essential theoretical aspects of defining the connotation of green bonds, the necessity of development, institutional design and optimization paths, implementation status, and greenwashing behavior (Criscuolo & Menon, 2015). Another empirical literature explores the impact of green bonds on issuers, mainly including two aspects: (1) Corporate reputation. Most scholars believe that green bonds have a signaling effect, which can transmit signals of sustainable development to the outside world and enhance corporate reputation, making them more likely to be favored by rational investors (Baulkaran, 2019; Tang & Zhang, 2020; Wang et al., 2020). (2) Cost of capital. There is no consensus on whether issuing green bonds can reduce the cost of project financing for enterprises. On the one hand, issuing green bonds manifests corporate social responsibility. Previous literature has shown that companies that perform better in corporate social responsibility (Bauer & Hann, 2010) or those with lower environmental risks (Chava, 2014; Sharfman & Fernando, 2008) can obtain lower borrowing costs, part of the empirical data validated this (Hachenberg & Schiereck, 2018; Zerbib, 2019). On the other hand, issuing green bonds means setting more restrictions on the investment decisions of enterprises, and environmental investment has

characteristics such as high risk and long cycle, thereby increasing financing costs (Flammer, 2021). A small amount of literature has explored the impact mechanism of green bond issuance price and found that factors such as the third-party certification, the issuer's financial condition, and liquidity risk can all affect the issuance price of green bonds (Hyun et al., 2020).

2.2.2 | Research on collaborative innovation

Innovation is the first driving force for development and the key to enhancing the core competitiveness of enterprises. However, in the increasingly fierce market competition environment, the limitations of enterprises relying solely on their resources for innovation are becoming increasingly prominent. Therefore, crossing organizational boundaries, seeking innovative resources from outside, and actively carrying out collaborative innovation has become the only way for enterprises to break through innovation bottlenecks (Jiao et al., 2019; Santoro et al., 2020). Collaborative innovation is a new type of innovative organizational model in which independent innovation entities from multiple organizations, institutions, or disciplinary fields, based on mutual knowledge sharing, technology promotion, and resource complementarity, jointly complete innovation activities by fully utilizing multiple factors such as talent, capital, and information to achieve limited innovation levels and create value beyond autonomous innovation (Kostopoulos et al., 2011;Murovec & Prodan, 2009). In collaborative innovation, different entities integrate their professional knowledge and skills through open communication, collaborative research and development, and joint creation, thereby achieving breakthroughs in solving complex problems, promoting technological progress, and launching innovative products or services. In practical applications, collaborative innovation can be reflected in forms such as collaborative innovation between scientific research institutions or enterprises, government, and research universities (Benhayoun et al., 2020; Yang et al., 2021), collaborative innovation between upstream and downstream enterprises or supply chains (Hong et al., 2019; Wang & Hu, 2020), and collaborative innovation across borders or regions (Wang & Zhang, 2019; Chen & Hung, 2014), intended to integrate different professional background knowledge in different fields, generate innovative solutions, and promote socioeconomic development.

In recent years, the global warming process has rapidly intensified due to the continuous deterioration of the ecological environment. The academic community is increasingly combining green development with collaborative innovation, proposing the concept of green collaborative innovation. Green collaborative innovation is a new innovative approach that balances high-quality economic growth and sustainable environmental development, utilizing professional background knowledge and relevant available resources in different fields to find solutions that can reduce the overuse of natural resources or improve the utilization of existing resources. There is relatively little research on the driving factors of green collaborative innovation, but relevant literature on the influencing factors of collaborative innovation can provide a reference for this article. Previous research mainly focuses on the following perspectives.

First, from the perspective of innovation resources, collaborative innovation is a high-risk, long-term project that requires a large amount of capital investment. Adequate cash flow can reduce the risk of innovation project interruption, ensure the smooth development of innovation projects, and thus enhance managers' willingness to engage in collaborative innovation (Meng & Zhang, 2022). Second, based on the perspective of trust, the trust relationship between collaborative entities can alleviate each other's concerns about opportunistic behavior, thereby reducing governance costs in the cooperation process. It is a prerequisite for achieving collaborative innovation and is conducive to the smooth development of collaborative innovation activities (Wan et al., 2022; Zhai et al., 2021). Third, based on the perspective of innovation capability, existing studies have shown that the innovation capability of enterprises themselves, such as their ability to absorb knowledge, can have a positive impact on collaborative innovation performance (Liu et al., 2021; Schulze & Brojerdi, 2012; Yang et al., 2021).

3 | HYPOTHESIS DEVELOPMENT

Green bonds are debt instruments that raise funds specifically for green sustainable development projects, aiming to generate positive environmental benefits. Previous research has shown that green bonds overall have played a role in reducing carbon dioxide emissions (Flammer, 2021), improving air quality (Wu, Tian, et al., 2022), and enhancing environmental performance (Yeow & Ng, 2021). As a crucial pillar of green development, green innovation is a key pathway to promoting economic green transformation and achieving environmental sustainability. With the deepening of open and collaborative concepts, collaborative innovation has become an important choice for enterprises' green innovation. Considering the advantages of technology, resources, and reputation brought by green bonds, we believe that green bonds can significantly improve enterprises' green collaborative innovation.

3.1 | Technology advantages

Prior studies have demonstrated that issuing green bonds can enhance a company's green technology innovation capabilities by raising the proportion of long-term loans, optimizing its capital structure, lowering its financing costs (Li et al., 2022), receiving government subsidies (Montmartin & Herrera, 2015; Liu et al., 2019), and being subject to strict environmental regulatory oversight (Porter & Linde, 1995). Improving the independent green innovation ability of green bond issuers will strengthen the willingness of upstream and downstream enterprises in the green supply chain to cooperate with green bond issuers, thus promoting the improvement of green collaborative innovation of issuers. There are two reasons, as follows.

First, when the green innovation of the core entity on the supply chain changes, it will prompt other entities on the supply chain to make corresponding adjustments to meet the requirements of the

core entity, driving the collaboration between the entities in the supply chain to achieve more environmentally friendly standards for inter-enterprise collaborative innovation. For example, when enterprises upgrade their green technology, their requirements for raw materials will also change. If enterprises find that the raw materials provided by suppliers do not meet the requirements after the technology upgrade, they will immediately stop those enterprises with poor environmental performance to provide services for them (Rao & Holt, 2005), thus forcing upstream suppliers to upgrade their technology and improve the quality of goods (Vachon & Klassen, 2008). Because green bond issuers often have high green innovation ability, enterprises with the same green innovation demand in the supply chain will actively seek cooperation from green bond issuers to promote existing product upgrading, new product development, and standard technology innovation.

Second, green innovation has the dual externalities of "green" and "innovation," so it often has the characteristics of high risk, high cost, and long cycle. Suppose enterprises only rely on their resources, in that case, it may not be easy to support the development of a green innovation activity fully, so they often seek cooperation from enterprises with technological leadership. With the improvement of the independent innovation of green bond issuers, the green technology advantages formed by their gradually solid R&D foundation will strongly attract the entities with similar green innovation needs in the supply chain to cooperate with them, actively disclose the available information to the green bond issuers, join cooperative R&D projects, actively share the innovation risks and R&D costs, and finally share the collaborative innovation dividend.

3.2 | Resource advantages

Himmelberg and Petersen (1994) argue that one of the most critical characteristics of R&D is the high adjustment cost. Much of R&D investment is spent on the salaries of scientists, engineers, and other professional and technical personnel. If the investment is reduced, it will inevitably lead to a decrease in the salaries of high-tech personnel and even trigger layoffs in enterprises (Hall, 2002). Losing R&D personnel may disrupt the inherent R&D path, leading to R&D interruptions. On the other hand, it may also lead to the leakage of the company's intellectual property to competitors, weakening the company's competitive advantage and reducing the value of the company's ongoing innovation projects (Loasby et al., 1983). Due to the high adjustment costs and the financing constraints most Chinese enterprises face, managers are hesitant to increase R&D investment easily. Green innovation has both "innovation" and "green" dual externality, and the risk is higher than ordinary innovation activities, so it faces a more serious capital bottleneck (Zhou et al., 2021). Previous studies have also shown that financing constraints are the main factor constraining green innovation in enterprises (Horbach et al., 2012). If the financing constraints of enterprises are alleviated, a fund buffer pool can be formed within the enterprise, external financing channels can be opened, and R&D smoothness can be effectively maintained, reducing managers' concerns about adjusting costs and promoting green collaborative innovation of the enterprise.

Previous studies have shown that green bonds can effectively alleviate the financing constraints of enterprises. On the one hand, green bonds, as a long-term direct financing method, can bring long-term financial resources to enterprises and alleviate the investment problem of mismatched terms that enterprises invest in long-term projects with short-term loans. Moreover, the financing scale of bonds is generally large, which can better meet the capital needs of enterprises. On the other hand, green bonds can transmit signals of green development of enterprises to investors, creditors, governments, and other stakeholders (Flammer, 2021), establish the ESG image of enterprises, improve their green reputation, and attract green social capital, green bank capital, and green government capital to flow into enterprises (Cheng et al., 2014), alleviate the financing problems faced by enterprises in green collaborative innovation, and then promote enterprises in green collaborative innovation.

3.3 | Reputation advantages

With the increasing awareness of ecological and environmental governance capabilities in the entire society, enterprises are motivated to seek environmental legitimacy to maintain their reputation. The green signals transmitted by core entities through green bonds not only improve the environmental quality of enterprises but also help to enhance their image and social reputation (Kim et al., 2019). Improving social reputation often enhances the credibility of enterprises. The social exchange theory believes that the trust relationship formed between enterprises is the foundation for achieving deep cooperation between both parties. Therefore, improving the reputation of enterprises is beneficial for enhancing the willingness of other organizations to cooperate with them. In addition, trust between organizations will positively affect collaboration efficiency and the acceptance of collaborative information and further promote resource sharing between both parties. It can be seen that the higher the level of trust between collaborating entities, the lower the occurrence of opportunistic behavior in the collaborative innovation process, and the better the performance of collaborative innovation.

In summary, this article proposes Hypothesis 1, and the mechanism of action is shown in Figure 1.

> **Hypothesis 1.** *Green bonds can significantly promote enterprises' green collaborative innovation.*

4 | SAMPLE SELECTION AND SUMMARY STATISTICS

4.1 | Sample selection

Our sample covers data from nonfinancial listed companies in China from 2010 to 2020. Because only the data of green collaborative innovation in 2020 and before can be obtained at present, the data in

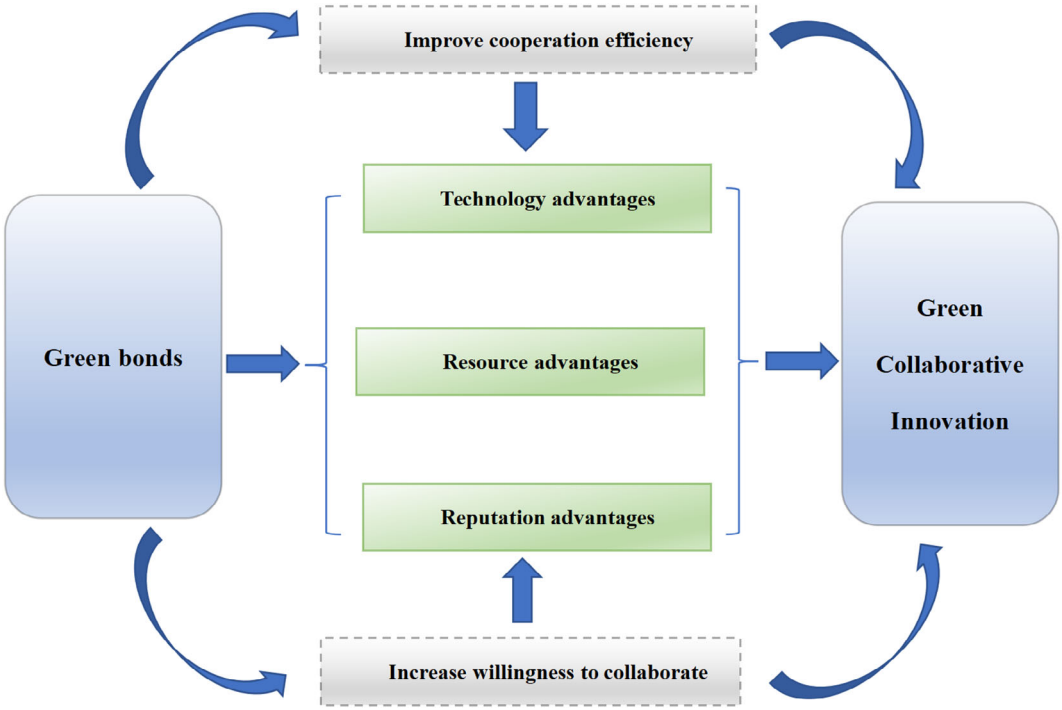

FIGURE 1 The channels of green bonds influencing firms' green collaborative innovation.

this paper is as of 2020. Since the green bond market in China started in 2015, in order to compare the green collaborative innovation of enterprises in the five years before and after the development of the green bond market, the data in this paper began in 2010). The green bond data was obtained from the Wind Green Bond database. We identified 63 listed companies that issued green bonds using their unified social credit code and then used the PSM one-to-one without replacement nearest neighbor matching method to select appropriate control groups from other companies in the same industry, using covariates such as Company Size (*Size*), Return on Equity (*Roe*), Enterprise Leverage (*Lev*), Cash Flow (*Cfo*), and Ownership Structure (*Soe*), while controlling for the industry. In the end, we obtained 63 pairs of target and control companies, totaling 1108 firm-year observations. The green collaborative innovation data came from the CNRDS platform, while other relevant data came from the CSMAR database. To reduce the influence of extreme values, we winsorzed all continuous variables at the 1st and 99th percentiles.

The prerequisite for the effectiveness of PSM is that there is no significant difference in observable variables between the treated and control groups after matching. Therefore, we conducted a matching balance test, as shown in Table 1:

1. Compared with before matching (*Unmatched*), the standardized bias (*%bias*) of all variables after matching (*Matched*) decreased significantly.
2. Except for Company Size (*Size*), the standardized bias (*%bias*) of other variables after matching (*Unmatched*) was less than 10%.
3. Except for Company Size (*Size*), the *t*-test results after matching (*Unmatched*) did not reject the null hypothesis that there was no systematic difference between the treated and control groups.

The above results indicate that the observable variables selected in this study were appropriate, and the matching method was appropriate as well.

4.2 | Variable measurement

4.2.1 | Measuring green collaborative innovation

Green collaborative innovation refers to a new organizational approach to green innovation in which green innovation entities cooperate and jointly develop. This approach can fully unleash the vitality of the "human resources, capital, information, and technology" elements among innovation entities, promote the effective convergence of innovation resources and elements, achieve mutual benefit through innovation, and thereby enhance enterprise value and core competitiveness. Existing research mainly adopts four methods to measure collaborative innovation: firstly, based on questionnaire survey data, measure collaborative innovation in enterprises from multiple dimensions (Jiao et al., 2019; Schulze & Brojerdi, 2012; Wang & Hu, 2020). Second, based on provincial data, the ratio of external R&D expenditure to total R&D expenditure is used to measure collaborative innovation (Shi et al., 2022); Third, based on enterprise data, using joint patent applications by enterprises to measure (Brockman et al., 2018; Huang, Xu, et al., 2023; Ji & Miao, 2020; Sena et al., 2022; Wan et al., 2022). Fourth, using text analysis, if the annual report contains statements about collaborative innovation between a company and its suppliers or customers, it is considered that the company has engaged in collaborative innovation with its suppliers or

TABLE 1 PSM balance test.

Variables	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p > |t|
Size	Unmatched	23.956	22.11	120.3		31.95	0.000
	Matched	23.956	23.69	17.3	85.6	2.49	0.013
Roe	Unmatched	0.0844	0.1181	−0.7		−0.12	0.904
	Matched	0.0844	0.0932	−0.2	74.0	−0.02	0.961
Lev	Unmatched	0.5952	0.4478	30.6		5.20	0.000
	Matched	0.5952	0.5762	3.9	87.1	0.38	0.707
Cfo	Unmatched	0.4732	0.0417	5.7		2.05	0.055
	Matched	0.4732	0.0444	2.9	49.3	0.45	0.653
Soe	Unmatched	0.6750	0.3667	64.9		14.78	0.000
	Matched	0.6750	0.6293	9.6	85.2	1.60	0.110

customers (Huang, Zhang, et al., 2023). Joint patent applications capture the output of enterprise collaborative innovation and are commonly used as a proxy for collaborative innovation in management and organizational literature. Therefore, we use the number of green patents jointly applied for by companies and other innovation entities to measure green collaborative innovation. In China, patents are divided into three types: invention patents, utility model patents, and design patents. Invention patents refer to new technical solutions proposed for products, methods, or improvements, primarily reflecting novelty, creativity, and utility. Utility model patents refer to new technical solutions proposed for the shape, structure, or combination of products that are applicable in practice. Design patents refer to new designs that are esthetically pleasing and applicable to industrial use, including the shape, pattern, or combination of a product, as well as the combination of color and shape or pattern. Compared with utility model and design patents, invention patents have stricter examination procedures, more complex procedures, higher costs, higher technical content, and better reflect the essence of innovation. Therefore, we use the total number of jointly applied green patents plus one, and then take the natural logarithm to characterize the quantity of collaborative innovation output by enterprises (*Patent1*). We use the total number of jointly applied green invention patents plus one, and then take the natural logarithm to measure the quality of collaborative innovation output by enterprises (*Patent2*).

4.2.2 | Measuring green bonds

The core explanatory variable of this study is the green bond ($Green_i \times Post_t$), where $Green_i$ is a virtual variable for the treatment and control groups. If enterprise *i* successfully issued a green bond during the sample period, it is assigned a value of 1, otherwise it is assigned a value of 0. $Post_t$ is a temporal dummy variable, where for the treatment group companies, if company *i* successfully issues a green bond for the first time at time *t*, then the values of $Post_t$ for *t* and all subsequent time periods are assigned a value of 1, otherwise they are assigned a value of 0; for the control group, $Post_t$ takes a value of 0 for all time periods.

4.2.3 | Measuring control variables

The level of green collaborative technological innovation in enterprises is driven by various factors, therefore we have included several important control variables in our model. First, based on resource-based theory, the willingness and risk-taking level of enterprises in collaborative innovation are influenced by their own characteristics and capabilities. Therefore, we control for variables that characterize the features and abilities of the enterprise, including size (*Size*), return on net assets (*Roe*), capital expenditures (*Expend*), cash flow (*Cfo*), ownership structure (*Soe*), and enterprise age (*Age*). Specifically, for the calculations, the enterprise size (*Size*) uses the natural logarithm of the enterprise's total assets at the end of the period; return on net assets *(Roe)* is calculated by dividing the enterprise's annual net profit by the total owner's equity at the end of the period; capital expenditures (*Expend*) are calculated by dividing the cash paid for fixed assets, intangible assets, and other long-term assets purchased by the enterprise during the year by the total assets at the end of the period; cash flow (*Cfo*) is calculated by dividing the net cash flow generated from the enterprise's operating activities during the year by the total assets at the end of the period; ownership structure (*Soe*) is a dummy variable, taking a value of 1 if the enterprise is state-owned, and 0 otherwise; enterprise age (*Age*) represents the time interval between the year the enterprise was registered and the year of the enterprise sample.

Second, based on stakeholder theory, the demands and governance capabilities of stakeholders such as creditors and enterprise executives also intervene in the green collaborative technological innovation decision-making of the enterprise. Therefore, this study includes variables such as leverage ratio (*Lev*) and executive shareholding ratio (*Exe*) in the control variable set. Among them, the leverage ratio (*Lev*) is calculated by dividing the enterprise's total liabilities at the end of the period by the total assets at the end of the period, and the executive shareholding ratio (*Exe*) is calculated by dividing the number of shares held by executives by the total shares outstanding.

Third, due to the externalities of environmental governance and technology, enterprises often lack the original impetus for green

TABLE 2 Descriptive statistics of the main variables.

Variable	Obs	Mean	Median	S.D.	Min	Max
Patent1	1108	0.520	0	1.102	0	4.779
Patent2	1108	0.376	0	0.879	0	4.094
Green × *Post*	1108	0.260	0	0.270	0	1
Size	1108	22.22	20.66	2.116	20.00	27.46
Roe	1108	0.075	0.077	0.068	−0.241	0.261
Lev	1108	0.420	0.422	0.230	0.045	0.846
Expend	1108	0.063	0.051	0.052	0	0.231
Cfo	1108	0.043	0.046	0.065	−0.150	0.205
Soe	1108	0.372	0	0.484	0	1
Age	1108	15.58	16	5.914	3	30
Subsidy	1108	9.063	14.00	8.506	0	21.34
Exe	1108	0.096	0.001	0.159	0	0.607
Regula	1108	21.389	34.778	15.274	1.776	235.475

technological innovation, so government intervention plays an important role in the decision-making of green collaborative innovation in enterprises. Based on this, this study controls for two factors that affect green collaborative innovation in enterprises, namely government subsidies (*Subsidy*) and environmental regulations (*Regula*). Among them, government subsidies (*Subsidy*) are calculated by taking the natural logarithm of the amount of government subsidies obtained by the enterprise plus one, and environmental regulations (*Regula*) are calculated by dividing the pollution control investment in each province by the industrial output value of that province and multiplying by 1000.

4.3 | Descriptive statistical analysis

Table 2 presents the descriptive statistics of the major variables. The standard deviations of the total number of joint green patent applications (*Patent1*) and the number of joint green invention patent applications (*Patent2*) are 1.102 and 0.879, respectively, indicating a significant difference in the level of green collaborative innovation among enterprises. Table 2 also shows that the mean of the number of joint green invention patent applications (*Patent2*) accounts for more than half of the mean of the total number of joint green patent applications (*Patent1*) (0.376/0.520). The descriptive statistics of other variables are basically consistent with the studies by (Wang & Zhou, 2022; Wang & Wang, 2021; Yang & Zhang, 2022), indicating that the research sample of this article is random. Table 3 reports the difference test of the green collaborative innovation of the treatment group before and after the issuance of green bonds. It can be seen that after the issuance of green bonds, the mean values of the total number of joint green patent applications (*Patent1*) and the number of joint green invention patent applications (*Patent2*) increased by 0.688 and 0.601, respectively, and passed the significance test, preliminarily supporting Hypothesis 1. However, since this result does not consider the impact of a series of accompanying factors on the level of collaborative green innovation of enterprises over time, we continue to use the DID model to provide a more rigorous proof of the results.

TABLE 3 Difference test of green collaborative innovation before and after green bond issuance by enterprises in the treatment group.

	Prerelease		After release		
Variables	Mean	S.D.	Mean	S.D.	*T*-test
Patent1	0.770	0.065	1.458	0.115	−0.688***
Patent2	0.528	0.050	1.129	1.304	−0.601***

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% levels, respectively.

5 | MAIN RESULTS

5.1 | Baseline regression

Considering the differences in the time nodes when enterprises issue green bonds, we follow the methodology proposed by (Beck et al., 2010) and (Yeow & Ng, 2021) to construct an asymptotic double difference model to test the impact of green bonds on firms' collaborative green innovation.

$$Patent_{i,t} = \alpha_0 + \alpha_1 Green_i \times Post_t + \sum \alpha_k Controls_{i,t} + \lambda_i + \delta_t + \varepsilon_{i,t}. \quad (1)$$

The variable $Patent_{i,t}$ is the dependent variable in this study, which represents the green collaborative innovation of firm *i* in year *t*. We measure this variable from two dimensions: the quantity (*Patent1*) and the quality (*Patent2*) of green technological innovation. $Green_i \times Post_t$ is the double difference term in the DID model, and the focus is on the coefficient $\alpha 1$ of $Green_i \times Post_t$. If $\alpha 1$ is significantly positive, it indicates that the issuance of green bonds can promote firms' green collaborative innovation. $Controls_{i,t}$ refers to the group of control

TABLE 4 PSM + DID test results.

Variables	(1) *Patent1*	(2) *Patent2*	(4) *Patent1*	(5) *Patent2*
Green × *Post*	0.575***	0.484***	0.535***	0.454***
	(4.20)	(4.13)	(3.90)	(3.81)
Size			0.131***	0.098***
			(5.76)	(5.59)
Roe			0.001***	0.001***
			(3.63)	(3.23)
Lev			0.007*	0.004
			(1.82)	(1.25)
Expend			−0.099	0.019
			(−0.63)	(0.15)
Cfo			0.019***	0.008***
			(2.75)	(3.37)
Soe			0.062*	0.037*
			(1.91)	(1.80)
Age			0.012***	0.015***
			(3.40)	(5.09)
Subsidy			0.002**	0.001**
			(2.02)	(2.31)
Exe			0.147*	0.158**
			(1.73)	(2.39)
Regula			0.038**	0.029**
			(2.55)	(2.41)
Constant	0.095***	0.052***	−2.891***	−2.243***
	(5.23)	(3.29)	(−6.06)	(−6.13)
Year and firm fixed effect	Yes	Yes	Yes	Yes
Observations	1108	1108	1108	1108
adj_R^2	0.690	0.679	0.694	0.682

Note: *, **, *** significant at 10, 5, and 1 percent levels, respectively; *t* values are reported in parentheses.

variables in the model. Additionally, Model (1) also controls for firm-specific fixed effects (λ_i) and annual fixed effects (δ_t).

Table 4 presents the impact of issuing green bonds on firms' green collaborative innovation. It can be observed that without the inclusion of control variables, the coefficients of *Green* × *Post* are 0.575 and 0.484, respectively, and both are significant at the 1% confidence level. After controlling for the variables, the results in columns (4) and (5) show that the coefficients of *Green* × *Post* are 0.535 (3.90) and 0.454 (3.81), respectively, indicating that the total number of green collaborative patent applications (*Patent1*) and the number of green collaborative invention patent applications (*Patent2*) for firms have significantly increased after issuing green bonds, confirming Hypothesis 1.

5.2 | Parallel trend test

We proceeded to construct Model (2) to examine the parallel trends in the DID model and investigate the dynamic marginal impact of green bonds on firms' green collaborative innovation. In Model (2), the variables *Before* (>3), *Before* (3), *Before* (2), *Before* (1), *Current*, *After* (1), *After* (2), and *After* (>2) represent the interaction between the dummy variables for the treatment group and the year dummy variables for the policy occurring more than three years ago, three years ago, two years ago, one year ago, the current year, and the policy occurring one, two, and more than two years after, respectively.

$$\begin{aligned} Patent_{i,t} = {} & \alpha_0 + \alpha_1 Before(>3) + \alpha_2 Before(3) + \alpha_3 Before(2) \\ & + \alpha_4 Before(1) + \alpha_5 Current + \alpha_6 After(1) + \alpha_7 After(2) \\ & + \alpha_8 After(>2) + \sum \alpha_j Controls_{i,t} + \varepsilon_{i,t}. \end{aligned} \tag{2}$$

Table 5 presents the results of the parallel trend test. The coefficients of *Before* (3), *Before* (2), and *Before* (1) are not statistically significant, whether the explained variable is the total number of green joint patent applications (*Patent1*) or the number of green joint invention patent applications (*Patent2*). The result suggests that in the absence

TABLE 5 Parallel trend and dynamic effect test results.

Variables	(1) *Patent1*	(2) *Patent2*
Before (3)	−0.082 (−1.12)	−0.056 (−1.05)
Before (2)	0.121 (0.35)	−0.098 (−0.83)
Before (1)	0.135 (1.33)	0.172 (0.48)
Current	0.161** (2.09)	0.222*** (3.08)
After (1)	0.211*** (2.30)	0.357** (2.00)
After (2)	0.421*** (2.82)	0.435*** (3.02)
Controls	Yes	Yes
Constant	−2.729*** (−5.75)	−2.096*** (−5.65)
Observations	1108	1108
adj_R^2	0.646	0.632

Note: *, **, *** significant at 10, 5, and 1 percent levels, respectively; *t* values are reported in parentheses.

of policy shocks, there is no significant difference in green collaborative innovation between the treatment and control groups, supporting the parallel trend hypothesis. The coefficients of *Current*, *After* (1), and *After* (2) are statistically significant with a confidence level of at least 5%, indicating that the promoting effect of issuing green bonds on firms' green collaborative innovation has dynamic sustainability.

5.3 | Robustness tests

5.3.1 | The policy shock of green bonds

Corporate decisions regarding whether to issue green bonds, invest in green innovation, and choose how to pursue green innovation are endogenous to the company's own decisions. To further alleviate endogeneity problems, we chose the issuance of the "Green Bond Issuance Guidelines" as an exogenous event to test the impact of green bonds on corporate green innovation collaboration. In December 2015, the National Development and Reform Commission of China issued the "Green Bond Issuance Guidelines," which provided an explanation of the concept, scope of support, issuance conditions, regulatory requirements, and support policies for green bonds, marking the official launch of the Chinese green bond market. In the same year, the People's Bank of China released the "Green Bond Support Project Catalogue (2015)," which limited the scope of support for green bonds. This paper takes 2015 as the policy shock year (*Post*), with a value of 1 for years after 2015 and 0 otherwise. We consider industries supported by the "Green Bond Support Project Catalogue" as the experimental group (*Green*), with a value of 1, and other industries as the control group, with a value of 0. We constructed a DID model to test the impact of green bonds on corporate green collaborative innovation. As shown in columns (1) and (2) of Table 6, we found that regardless of whether the explained variable was the total number of green joint patent applications (*Patent1*) or the number of green joint invention patent applications (*Patent2*), the coefficient of *Green* × *Post* was positively significant at the 1% level. The result indicates that after the issuance of the "Green Bond Issuance Guidelines," companies in the scope of green bond support showed better performance in green collaborative innovation. On the one hand, this may be because green bonds have guided green funds into companies, improving their financing environment, and promoting the improvement of green collaborative innovation. On the other hand, it may also be because the launch of the green bond market has inspired companies, and the new financing platform has given companies hope for financing, thereby increasing their investment in green innovation to seek better development. Regardless of which reason, it indicates that the development of the green bond market can play a role in promoting green collaborative innovation and promoting low-carbon and sustainable economic development.

5.3.2 | Replace the dependent variable

Referring to Huang et al. (2023), we use the method of text analysis to remeasure green collaborative innovation in enterprises. Specifically, if the annual report of an enterprise contains relevant statements about green collaborative innovation between the enterprise and other entities, it is considered that the enterprise has green collaborative innovation, and the value of *Patent* is 1, otherwise it is 0. The results are shown in Table 6, column (3), the coefficient of *Green* × *Post* is still significant, indicating that the research results in this article are robust.

5.3.3 | Explanatory variables lag by one period

Green joint patents represent explicit achievements of corporate low-carbon sustainable development, which to some extent can increase the probability of successful issuance of green bonds, thereby leading to a potential reverse causality problem. To mitigate this potential issue, following the approach of (Wu, Bu, et al., 2022), future one-period green collaborative innovation was used as the dependent variable in Model (1), as shown in Table 7, Column (1) and Column (2). The coefficients of *Green* × *Post* were 0.467 (3.29) and 0.399 (3.07), respectively, indicating that the issuance of green bonds significantly promotes the quantity and quality of green collaborative innovation in the subsequent period, verifying Hypothesis 1 and suggesting that the baseline regression results are robust.

5.3.4 | Tobit model

As the explained variables in this study are all truncated at zero, which could lead to bias in the OLS estimates, we reestimated the baseline regression using a Tobit model. The results, as shown in Table 7, Column (3) and Column (4), indicate that the coefficients of *Green* × *Post* are still significantly positive at the 1% level of confidence for both dependent variables, namely total green joint patent applications (*Patent1*) and green joint invention patent applications (*Patent2*). This provides further evidence for Hypothesis 1.

5.3.5 | Placebo test

We used a random sampling method to select 63 companies from the sample as the treatment group and used a one-to-one without replacement nearest neighbor matching method to select the control group from the remaining listed companies. We conducted a placebo test by constructing counterfactuals through 1000 repetitions. The results are shown in Figure 2, where the vertical dashed line represents the *t*-value estimated by the baseline regression model (*Model 1*). From Figure 2, it can be observed that for both the dependent variables, namely total green joint patent applications (*Patent1*) and green joint invention patent applications (*Patent2*), most of the *t*-values from the random sampling results are clustered around zero, with only a few estimates exceeding the *t*-value of the baseline regression result. The result suggests that the promotion effect of green bonds on green collaborative innovation in enterprises is not due to other unobservable factors.

5.4 | Mechanism analysis

According to the previous analysis, there are three channels through which green bonds affect enterprises' green collaborative innovation: the "Technology" channel, the "Resource" channel, and the "Reputation" channel. Next, we will test these channels. Drawing on the mediation test method proposed by (Baron & Kenny, 1986), we constructed models (3) and (4), in which the mediation variable (*Mediation*) includes three variables: enterprises' green independent innovation (*Innovation*), enterprises' financing constraint level (SA), and enterprises' reputation (*Reput*).

$$Mediation_{i,t} = \alpha_0 + \alpha_1 Green_i \times Post_t + \sum \alpha_k Controls_{i,t} + \lambda_i + \delta_t + \varepsilon_{i,t}. \quad (3)$$

$$Patent_{i,t} = \alpha_0 + \alpha_1 Green_i \times Post_t + \alpha_2 Mediation_{i,t} + \sum \alpha_k Controls_{i,t} + \lambda_i + \delta_t + \varepsilon_{i,t}. \quad (4)$$

5.4.1 | "Technology" channel

We adopted the firm's green independent innovation (*Innovation*) as a mediating variable to examine the "Technology" channel through which green bonds affect a firm's green collaborative innovation. The issuance of green bonds by firms can promote the enhancement of their green independent innovation, thereby changing the competition environment and green technology standards in the supply chain, forcing upstream and downstream firms to actively seek cooperation with innovative entities, and thus promoting their green collaborative innovation. Specifically, we used the natural logarithm of the total number of green patents independently applied for by firms plus one to measure their green independent innovation (*Innovation*). The green independent Innovation (*innovation*) is substituted into models (3) and (4) as a Mediation variable, and the empirical results are shown in Table 8. In column (1), the coefficient of *Green* × *Post* is 0.269 and significant at the 5% confidence level, indicating that the issuance of green bonds by firms can significantly promote the enhancement of their green independent innovation. Columns (2) and (3) report the estimation results of model (4). It can be seen that whether the explained variable is the total number of green joint patent applications (*Patent1*) or the total number of green joint invention

TABLE 6 Robustness test results I.

	Green bond policy impact		Replace the dependent variable
	(1)	(2)	(3)
Variables	*Patent1*	*Patent2*	*Patent*
Green × *Post*	0.397*** (5.24)	0.298*** (4.37)	0.463*** (6.38)
Controls	Yes	Yes	Yes
Constant	−12.235*** (−18.72)	−11.894*** (−16.37)	−5.879*** (−12.68)
Observations	30,726	30,726	1108
adj_R^2	0.568	0.601	0.524

Note: *, **, *** significant at 10, 5, and 1 percent levels, respectively; t values are reported in parentheses.

TABLE 7 Robustness test results II.

Variables	(1) *Patent1*	(2) *Patent2*	(3) *Patent1*	(4) *Patent2*
Green × *Post*	0.467*** (3.29)	0.399*** (3.07)	0.747*** (4.90)	0.647*** (4.43)
Controls	Yes	Yes	Yes	Yes
Constant	−2.466*** (−5.27)	−1.924*** (−5.16)	−23.981*** (−43.86)	−22.214*** (−39.87)
Observations	846	846	1108	1108
adj_*R*^{2}	0.652	0.646		
Pseudo R^2			0.128	0.646

Note: *, **, *** significant at 10, 5, and 1 percent levels, respectively; *t* values are reported in parentheses.

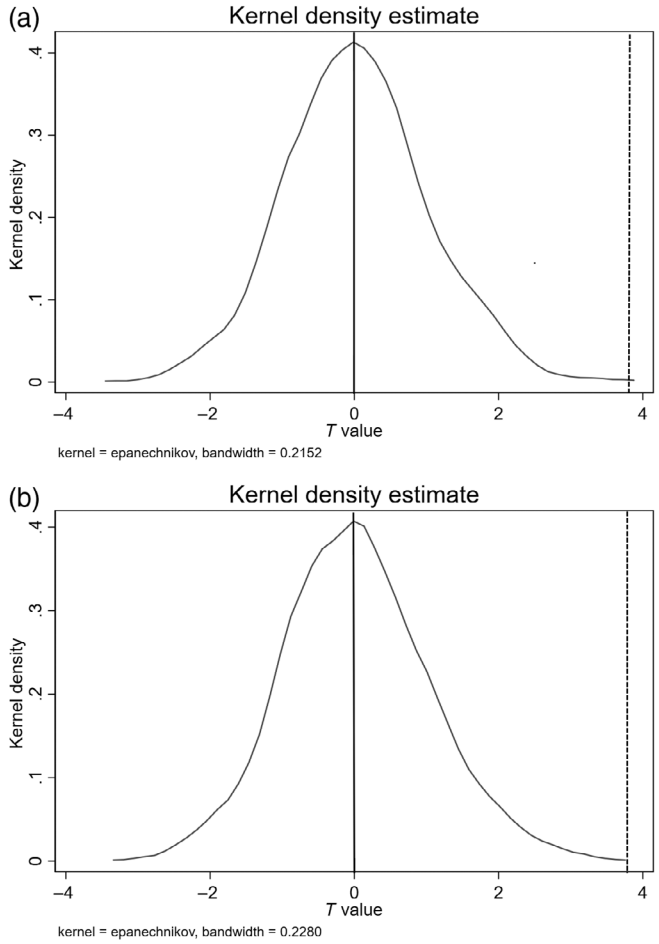

FIGURE 2 Placebo test results. (a) *Patent1*. (b) *Patent2*.

TABLE 8 "Technology" channel test.

Variables	(1) *Innovation*	(2) *Patent1*	(3) *Patent2*
Green × *Post*	0.269** (2.14)	0.517*** (3.89)	0.438*** (3.80)
Innovation		0.063*** (5.55)	0.056*** (5.76)
Bootstrap		0.017*** (5.23)	0.015*** (4.87)
Controls	Yes	Yes	Yes
Constant	−8.532*** (−11.32)	−2.229*** (−4.82)	−1.655*** (−4.64)
Observations	1108	1108	1108
adj_R^2	0.758	0.648	0.634

Note: *, **, *** significant at 10, 5, and 1 percent levels, respectively; *t* values are reported in parentheses.

patent applications (*Patent2*), the coefficients of Innovation are all significantly positive, indicating that the improvement of independent green innovation of enterprises is conducive to their collaborative green innovation. The above results show that the issuance of green bonds can promote firms' green independent innovation, thus promoting their green collaborative innovation, The "Technology" channel is verified.

TABLE 9 "Resource" channel test.

Variables	(1) SA	(2) *Patent1*	(3) *Patent2*
Green × *Post*	−0.081*** (−3.62)	0.507*** (3.73)	0.428*** (3.68)
SA		−0.140*** (−3.46)	−0.043*** (−3.59)
Bootstrap		0.011*** (4.05)	0.003*** (2.87)
Controls	Yes	Yes	Yes
Constant	−2.361*** (−8.76)	−8.231*** (−4.87)	−7.131*** (−4.75)
Observations	1108	1108	1108
adj_R^2	0.411	0.646	0.633

Note: *, **, *** significant at 10, 5, and 1 percent levels, respectively; *t* values are reported in parentheses.

5.4.2 | "Resource" channel

Green bonds can signal to the outside world that a company is committed to green and sustainable development, thereby directing social capital towards the company and alleviating financing constraints such as high costs, mismatches in maturities, and limited availability, which have long been obstacles to green collaborative innovation. To investigate the "Resource"channel through which green bonds promote green collaborative innovation, we use financing constraints (SA) as a mediator. Following the approach of Hadlock and Pierce (2010), we use the SA index to describe the degree of financing constraints faced by companies and calculate the logarithmic value of the absolute value of the SA index (SA). A higher SA value indicates a more severe financing constraint faced by the company. We use financing constraints (SA) as a mediator variable in models (3) and (4), and the results are shown in Table 9. Column (1) shows that *Green* × *Post* is significantly negatively correlated with SA, indicating that green bonds can significantly alleviate a company's financing constraints. Columns (2) and (3) report the estimation results of model (4), which show that whether the dependent variable is the total number of green joint patent applications (*Patent1*) or the number of green joint invention patent applications (*Patent2*), the coefficient of SA is significantly negative at the 1% confidence level, indicating that financing constraints faced by companies will have an adverse effect on their green collaborative innovation. These results demonstrate that issuing green bonds can alleviate a company's financing constraints, thereby promoting its green collaborative innovation and supporting the "Resource" channel.

5.4.3 | "Reputation" channel

Issuing green bonds can convey a signal of green and sustainable development to the outside world, enhance a company's green reputation, and enhance the trust relationship between the

TABLE 10 "Reputation" channel test.

Variables	(1) *Reput*	(2) *Patent1*	(3) *Patent2*
Green × *Post*	0.023** (2.00)	0.183*** (3.27)	0.169*** (3.21)
Reput		0.247** (2.27)	0.233* (1.90)
Bootstrap		0.005** (2.25)	0.004** (2.19)
Controls	Yes	Yes	Yes
Constant	4.579*** (8.36)	3.467*** (6.71)	5.011*** (8.72)
Observations	1108	1108	1108
adj_R^2	0.452	0.542	0.498

Note: *, **, *** significant at 10, 5, and 1 percent levels, respectively; *t* values are reported in parentheses.

company and its partners. On the one hand, it can attract external entities to cooperate and innovate with the company, and on the other hand, it also improves the communication and collaboration efficiency between the company and its existing partners, thereby promoting the improvement of the collaborative green innovation among enterprises. Based on this, we draw on the measurement methods of (Guan & Zhang, 2019), comprehensively consider the evaluation of corporate reputation by various stakeholders, select 12 corporate reputation indicators, and then use factor analysis scores to calculate the corporate reputation score. Finally, we divide the corporate reputation score into ten groups from low to high, with each group assigned a *Reput* of 1 to 10. The higher the value assigned, the better the reputation. These 12 indicators include: (1) the ranking of corporate assets, revenue, net profit, and value within the industry, reflecting the evaluation of corporate reputation by consumers and the general public; (2) the asset liability ratio, current ratio, and long-term debt ratio, reflecting the creditors' evaluation of the company's reputation; (3) from the perspective of shareholders, three indicators were selected: earnings per share, dividends per share, and whether they are audited by the four major international accounting firms; (4) two indicators, sustainable growth rate and independent director ratio, were selected from the perspective of the enterprise.

We substituted corporate reputation (*Reput*) as a mediator variable into models (3) and (4), and the results are shown in Table 10. From column (1), the coefficient of *Green* × *Post* is significantly positive, indicating that issuing green bonds by enterprises can improve their reputation. Columns (2) and (3) report the estimation results of model (4), and it can be seen that the coefficient of *Reput* is only significant at the 10% level when the dependent variable is the number of green joint invention patent applications (*Patent2*). We continue to perform nonparametric percentile bootstrap tests with bias correction on the model, and the results show that the bootstrap values are all significant at the 5% confidence level. The above results indicate that issuing green bonds by enterprises can enhance their reputation, thereby promoting the improvement of their collaborative green innovation level and verifying the "Reputation" channel.

6 | FURTHER ANALYSIS

So far, our research has shown that the issuance of green bonds by companies can promote the improvement of firms' green collaborative innovation. Therefore, we are interested in whether external review of green bonds can further promote the improvement of green collaborative innovation? Does the repeated issuance of green bonds have a significant impact on green collaborative innovation?

6.1 | External review

In the international market, independent intermediaries or third-party rating agencies are often employed to screen and certify the green projects in which green bonds are invested and evaluate the control system and compliance of the green bond issuance for green certification. External review can provide detailed explanations of the funds raised by green bonds, which possess both financial and environmental attributes, quantitatively demonstrating the expected environmental benefits and exerting certain supervision and restraint on the issuers. The issuance of green bonds that have been externally reviewed enhances the transparency of green bond information disclosure, sends a robust green signal to investors (Sun et al., 2022), establishes an excellent corporate green image, gains recognition from more environmentally friendly investors, enhances the green attributes of the bond issuance, and attracts more green capital investment. This, in turn, mitigates the financing constraints among the collaborative entities, increases the motivation of the collaborative enterprises to engage in collaborative R&D, and accelerates the process of collaborative achievement transformation. Therefore, we have reason to believe that external review will further promote firms' green collaborative innovation. Following (Flammer, 2021), if the green bonds issued by enterprises are subject to external review (*Certi*), the annual observation value of the company is assigned a value of 1; otherwise, it is assigned a value of 0. Subsequently, *Green* × *Post* × *Certi* is inserted into Model (1). The results in Table 11, columns (1) and (2) show that the coefficient of *Green* × *Post* × *Certi* is significantly positive at least at the 5% level whether the explained variable is the total number of green joint patent applications (*Patent1*) or the total number of green joint invention patent applications (*Patent2*), indicating that external review have a more substantial effect in promoting firms' green collaborative innovation.

6.2 | Repeated issuance of green bonds

Repeat bond issuance refers to enterprises that successfully issue green bonds more than once. For example, Donghua Energy Co., Ltd. issued a three-year green bond in 2017, raising 600 million RMB. The company issued a green bond again in 2018, successfully raising 600 million RMB; Similarly, China Jushi Co., Ltd. issued green bonds in 2018, 2019, and 2021, respectively, raising 200 million RMB,

TABLE 11 Heterogeneity test results.

	External review		Repeated issuance	
Variables	(1) *Patent1*	(2) *Patent2*	(3) *Patent1*	(4) *Patent2*
Green × *Post*	0.560*** (3.68)	0.491*** (3.75)	0.640*** (3.71)	0.514*** (3.43)
Green × *Post* × *Certi*	0.172** (2.31)	0.261*** (3.92)		
Green × *Post* × *Re-issue*			0.211* (1.83)	0.254** (2.29)
Controls	Yes	Yes	Yes	Yes
Constant	−2.891*** (−6.07)	−2.242*** (−6.13)	−5.778*** (−12.21)	−4.493*** (−11.06)
Observations	1108	1108	1108	1108
adj_R^2	0.644	0.631	0.537	0.511

Note: *, **, *** significant at 10, 5, and 1 percent levels, respectively; *t* values are reported in parentheses.

500 million RMB, and 500 million RMB, respectively. Repeated issuance of green bonds can reduce marginal issuance costs by leveraging the experience of collaborating with green bond underwriters and verifiers, lower information search costs, improve information disclosure levels, strengthen the green signal effect, expand social capital, enhance investor confidence, and boost market supply and demand (Hyun et al., 2021). Through repeated investment in environmentally friendly projects and leveraging the environmental performance reports and reputation tracking records established after previous green bond issuances, the cooperative entities can demonstrate a stronger environmental commitment signal to partners, thereby transmitting cooperation proposals at low cost to other high-quality entities with cooperative intentions. By utilizing the accumulated reputation advantage, they can benefit from additional premiums and credit spreads (Fatica et al., 2021). Under the dual relief of information asymmetry and capital constraints, the green bond issuance entity will engage in green collaborative innovation with more high-quality enterprises with a strong environmental protection willingness. Therefore, we believe that repeated green bond issuance has a significant impact on the level of collaborative innovation. We define enterprises that issue green bonds more than once as repeat bond issuance enterprises (*Re-issue*), assigning a value of 1, otherwise, a value of 0. *Green* × *Re-issue* is input into Model (1), and the results are shown in columns (3) and (4) of Table 11, with coefficients of 0.211 and 0.254, respectively, which are significant at least at the 10% level. This indicates that enterprises that repeat green bond issuance can promote both the quantity and quality improvement of green collaborative innovation.

7 | CONCLUSION

Since the industrial revolution, human activities have rapidly changed the natural environment, far exceeding the earth's self-recovery rate. This has resulted in a series of global environmental problems such as global warming, ozone depletion, species extinction, acid rain, and air pollution, which have put the entire planet in an unsustainable state. In the face of increasingly serious environmental issues, countries around the world have invested in sustainable development. However, green development requires a large amount of capital investment, and government funding can only cover a small part of it. Therefore, the financial sector's power is urgently needed to drive and incentivize more social capital to invest in the ecological industry, participate in environmental governance, and build a green home. As one of the most important green financial instruments, green bonds are an effective way to break through the shackles of funding and support the green development strategy. However, whether and how green bonds can play a positive role in promoting environmental sustainability development is still a question that has not been answered conclusively. In this context, we have studied how the issuance of green bonds by enterprises affects their green collaborative innovation. We found that the issuance of green bonds by enterprises can significantly promote their collaborative green innovation, and this improvement effect has dynamic sustainability.

Following that, we conducted a study on the three channels through which green bonds affect firms' green collaborative innovation of enterprises. The first channel is the "Technology" channel. We found that green bonds can significantly improve the green independent R&D capabilities of issuers, leading to an improvement in the technical standards of green products in the supply chain. This in turn encourages upstream and downstream enterprises in the supply chain to actively seek R&D cooperation with the issuer to consolidate their competitive position, thereby promoting the issuer's green collaborative innovation. The second channel is the "Resource" channel. We found that companies issuing green bonds can alleviate the financing constraints faced in the collaborative innovation process by obtaining sustained and stable green funding at low cost. This allows for advantages in resource agglomeration, thereby increasing the willingness for collaborative innovation and ultimately improving firms' green collaborative innovation. The third channel is the "Reputation" channel. We found that Issuing green bonds not only improves the environmental quality of enterprises but also helps to enhance their image and social reputation, thereby improving the level of trust between enterprises and cooperating entities. On the one hand, it promotes

the willingness of other organizations to cooperate and innovate with issuers. On the other hand, it improves the innovation efficiency between the issuer and the existing partners, thus promoting the green collaborative innovation of enterprises.

Finally, we also studied the impact of external review and repeated issuance of green bonds on the innovative driving effect of green bonds. We found that when an enterprise is subject to external review or issue green bonds repeatedly, their green collaborative innovation improves significantly. This indicates that the green attribute of green bonds is a key factor affecting green collaborative innovation. Research on this issue is beneficial for identifying the focal points of the healthy and orderly development of the green bond market.

8 | SUGGESTIONS

Green bonds are debt financing instruments that raise funds to support eligible green projects, green industries, or green economic activities. They aim to generate positive environmental benefits and are one of the most important green finance tools. This article suggests that vigorously developing the green bond market, improving the green bond market system, and ensuring the green attributes of green bonds are feasible ways to promote green collaborative innovation. Therefore, this article proposes policy recommendations on how to build a sustainable and healthy green bond market and promote corporate green collaborative innovation.

First, it is essential to establish a comprehensive green bond market system and implement supporting measures for green bond issuance. Initially, policies such as tax incentives, subsidies, and government guarantees for green bonds should be gradually improved and developed from a top-down perspective. This will enable the construction of a government-led policy support system for green bonds. Second, the operational norms and processes for green bonds should be improved, and the responsibilities and rights of all parties involved should be clearly defined. Financial institutions should be encouraged to actively engage in the green bond business, and companies should be encouraged to utilize green bond tools to raise funds. Lastly, a unified green bond institutional framework should be established to promote the overall institutional system construction of green bonds and international convergence, thereby encouraging overseas investors to actively participate in the domestic green bond market.

Second, a multilevel green bond market system should be constructed to expand green financial products that meet the needs of the issuing entities. Currently, green financial bonds occupy a large proportion of the green bond market, while other types of green bonds account for a relatively small proportion, resulting in an unbalanced development of the green bond market. Therefore, the market can be expanded by developing green asset securitization (Green ABS), green asset-backed notes (Green ABN), green revenue support securities, and other green financial products to increase investment choices for green investors and facilitate corporate financing, with a focus on developing the green asset-backed securities market.

Third, a transparent and open green bond market system should be established, and guidelines for green bond disclosure should be strengthened. Governments and regulatory agencies should require companies to regularly disclose the latest progress of green projects and their environmental benefits and increase the frequency of regular reporting. Encouraging third-party green certification of green bonds, and regulatory authorities should further improve the information disclosure standards of green bonds, establish a transparent tracking and evaluation system, coordinate multiple regulatory authorities, strengthen the supervisory role of third-party certification and evaluation institutions, and encourage social supervision while punishing "greenwashing" behaviors.

Fourth, a highly participatory green bond market system should be constructed, with targeted policy incentives. To enhance corporate and investor participation in green bonds, this article suggests that on the issuing end, the "green channel" should continue to play a role in fast-track approval. For the investment end, tax exemptions should be provided for green bond investment income, to increase investor enthusiasm. At the same time, green investment consumer groups should be cultivated, and green investment awareness should be encouraged. Multiple green bond issuers should be encouraged to enter the green bond market, and market-based means should be used to encourage investment in the green industry, stimulate corporate social responsibility, and achieve high-quality development in the real economy.

9 | CONTRIBUTION

This study has at least the following contributions: first, we creatively constructs a three-channel transmission mechanism for green bonds to promote green collaborative innovation and points out that the corporate green independent innovation, the level of resource financing constraints, and the corporate reputation are its key factors, which fills in the lack of existing research on the influence factors for promoting green collaborative innovation with the help of green financial tools, enriches the theoretical research on green collaborative innovation, and tries to answer the question of "How green bonds promote firms' green collaborative innovation?"; second, we identifies the role of the green attributes of green bonds in promoting green collaborative innovation, expands the research entry point of green financial instruments bonding green collaborative innovation, reveals the differences in the effectiveness of green collaborative innovation between listed companies issuing green bonds with different attributes, and provides reference basis and methods for enterprises to make reasonable decisions on the allocation of green bond resources with different attributes; third, we pays close attention to the green funding gap faced by the China's green bond market and the practical challenges of green collaborative innovation among existing enterprises. Our research proves the strong practical feasibility of green bonds in promoting green collaborative innovation; we provide useful reference for the Chinese government to improve the development of the green bond market and promote the integration of green collaborative innovation practices among enterprises.

9.1 | Limitations and future research

The limitations of this study are mainly manifested in several aspects that can be improved in future research. First, green collaborative innovation is not only a technological innovation brought by R&D investment but also involves management method innovation, strategic innovation, cooperation mode innovation, etc. However, the indicator of green joint invention patent applications used in this study to measure green collaborative innovation may not be comprehensive. Therefore, in the future, variable definitions of green collaborative innovation should be further optimized, and more comprehensive measurement indicators should be explored. Second, there are many mechanisms that affect green collaborative innovation after issuing green bonds. Due to the multidimensionality of research variables and data availability limitations, this study only selected three influencing factors for exploration. Subsequent research should analyze other factors to fully explain the inherent mechanism of issuing green bonds on green collaborative innovation. Third, this study did not consider alternative mechanisms for green bonds, that is, whether other green financial instruments can promote green collaborative innovation needs to be further verified. Therefore, future research can explore the impact of green funds, green insurance, green guarantees, and other perspectives on collaborative innovation.

FUNDING INFORMATION

Chongqing Federation Social Science Planning Project, 2021NDYB079. SiChuan International Studies University School-level Scientific Research Project, sisu202134. Key Projects of the Science and Technology Research Program of Chongqing Education Commission, KJZD-K202300902. SiChuan International Studies University School-level Scientific Research Project, sisu202043. Humanities and Social Sciences Research Project of Chongqing Education Commission, 23SKGH214. Youth Project of Science and Technology Research Program of Chongqing Education Commission, KJQN202000901.

ORCID

Xuanshun Huang https://orcid.org/0009-0008-1945-376X

REFERENCES

Agliardi, E., & Agliardi, R. (2019). Financing environmentally-sustainable projects with green bonds. *Environment and Development Economics*, *24*(6), 608–623.

Al-Omoush, K. S., Ribeiro-Navarrete, S., Lassala, C., & Skare, M. (2022). Networking and knowledge creation: Social capital and collaborative innovation in responding to the COVID-19 crisis. *Journal of Innovation & Knowledge*, *7*(2), 100181. https://doi.org/10.1016/j.jik.2022.100181

Bai, X., & Li, J. (2020). The best configuration of collaborative knowledge innovation management from the perspective of artificial intelligence. *Knowledge Management Research & Practice*, *18*, 1–13.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*(6), 1173–1182.

Bauer, R., & Hann, D. (2010). Corporate environmental management and credit risk. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1660470

Baulkaran, V. (2019). Stock market reaction to green bond issuance. *Journal of Asset Management*, *20*(5), 331–340.

Beck, T., Levine, R., & Levkov, A. (2010). Big bad banks? The winners and losers from bank deregulation in the United States. *The Journal of Finance*, *65*(5), 1637–1667.

Benhayoun, L., Le Dain, M.-A., Dominguez-Péry, C., & Lyons, A. C. (2020). SMEs embedded in collaborative innovation networks: How to measure their absorptive capacity? *Technological Forecasting and Social Change*, *159*, 120196. https://doi.org/10.1016/j.techfore.2020.120196

Brockman, P., Khurana, I. K., Zhong, R., & (Irene). (2018). Societal trust and open innovation. *Research Policy*, *47*(10), 2048–2065. https://doi.org/10.1016/j.respol.2018.07.010

Chava, S. (2014). Environmental externalities and cost of capital. *Management Science*, *60*(9), 2223–2247. https://doi.org/10.1287/mnsc.2013.1863

Chen, P.-C., & Hung, S.-W. (2014). Collaborative green innovation in emerging countries: A social capital perspective. *International Journal of Operations & Production Management*, *34*(3), 347–363. https://doi.org/10.1108/IJOPM-06-2012-0222

Cheng, B., Ioannou, I., & Serafeim, G. (2014). Corporate social responsibility and access to finance. *Strategic Management Journal*, *35*(1), 1–23.

Criscuolo, C., & Menon, C. (2015). Environmental policies and risk finance in the green sector: Cross-country evidence. *Energy Policy*, *83*, 38–56. https://doi.org/10.1016/j.enpol.2015.03.023

Fatica, S., Panzica, R., & Rancan, M. (2021). The pricing of green bonds: Are financial institutions special? *Journal of Financial Stability*, *54*, 100873.

Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, *142*(2), 499–516. https://doi.org/10.1016/j.jfineco.2021.01.010

Gianfrate, G., & Peri, M. (2019). The green advantage: Exploring the convenience of issuing green bonds. *Journal of Cleaner Production*, *219*, 127–135.

Guan, K. L., & Zhang, R. (2019). Corporate reputation and earnings management: Efficient contract theory or rent-seeking theory. *Accounting Research*, *2019*(1), 59–64. https://doi.org/10.3969/j.issn.1003-2886.2019.01.009

Hachenberg, B., & Schiereck, D. (2018). Are green bonds priced differently from. Conventional bonds? *Journal of Asset Management*, *19*(6), 371–383.

Hadlock, C. J., & Pierce, J. R. (2010). New evidence on measuring financial constraints: Moving beyond the KZ index. *Review of Financial Studies*, *23*(5), 1909–1940.

Hall, B. H. (2002). The financing of research and development. *Oxford Review of Economic Policy*, *18*(1), 35–51.

Himmelberg, C. P., & Petersen, B. C. (1994). R & D and internal finance: A panel study of small firms in high-tech industries. *The Review of Economics and Statistics*, *76*(1), 38.

Hong, J., Zheng, R., Deng, H., & Zhou, Y. (2019). Green supply chain collaborative innovation, absorptive capacity and innovation performance: Evidence from China. *Journal of Cleaner Production*, *241*, 118377.

Horbach, J., Rammer, C., & Rennings, K. (2012). Determinants of eco-innovations by type of environmental impact—The role of regulatory push/pull, technology push and market pull. *Ecological Economics*, *78*, 112–122.

Huang, H. B., Xu, C. H., & Sun, Y. N. (2023). Does the setting of R&D subsidiaries in business groups will facilitate collaborative innovation? *Business and Management Journal*, *45*(1), 125–143. https://doi.org/10.19616/j.cnki.bmj.2023.01.007

Huang, H. B., Zhang, Y. Y., & Sun, Y. N. (2023). Does supply network location promote collaborative innovation among enterprises? *Securities Market Herald*, *2023*(6), 3–14.

Huang, T., & Yue, Q. (2020). How the game changer was generated? An analysis on the legal rules and development of China's green bond

market. *International Environmental Agreements: Politics, Law and Economics*, *20*(1), 85–102. https://doi.org/10.1007/s10784-019-09460-9

Hyun, S., Park, D., & Tian, S. (2020). The price of going green: The role of greenness in green bond markets. *Accounting & Finance*, *60*(1), 73–95. https://doi.org/10.1111/acfi.12515

Hyun, S., Park, D., & Tian, S. (2021). Pricing of green labeling: A comparison of labeled and unlabeled green bonds. *Finance Research Letters*, *41*, 101816.

Immel, M., Hachenberg, B., Kiesel, F., & Schiereck, D. (2021). Green bonds: Shades of green and brown. *Journal of Asset Management*, *22*(2), 96–109.

Ji, H., & Miao, Z. (2020). Corporate social responsibility and collaborative innovation: The role of government support. *Journal of Cleaner Production*, *260*, 121028.

Jiang, S., Liu, X., Liu, Z., Shi, H., & Xu, H. (2022). Does green finance promote enterprises' green technology innovation in China? *Frontiers in Environmental Science*, *10*, 981013.

Jiao, H., Yang, J., Zhou, J., & Li, J. (2019). Commercial partnerships and collaborative innovation in China: The moderating effect of technological uncertainty and dynamic capabilities. *Journal of Knowledge Management*, *23*(7), 1429–1454.

Kim, H., Youn, S., & Lee, D. (2019). The effect of corporate social responsibility reputation on consumer support for cause-related marketing. *Total Quality Management & Business Excellence*, *30*(5–6), 682–707.

Kostopoulos, K., Papalexandris, A., Papachroni, M., & Ioannou, G. (2011). Absorptive capacity, innovation, and financial performance. *Journal of Business Research*, *64*(12), 1335–1343.

Larcker, D. F., & Watts, E. M. (2020). Where's the greenium? *Journal of Accounting and Economics*, *69*(2–3), 101312. https://doi.org/10.1016/j.jacceco.2020.101312

Li, C., & Wang, S. (2022). Digital optimization, Green R&D Collaboration, and green technological innovation in manufacturing enterprises. *Sustainability*, *14*(19), 12106.

Li, Q., Zhang, K., & Wang, L. (2022). Where's the green bond premium? Evidence from China. *Finance Research Letters*, *48*, 102950.

Li, Y., Huang, J., Guo, H., & Wang, Z. (2021). Research on incentive mechanism of benefit distribution in collaborative innovation of industry alliance. *MATEC Web of Conferences*, *336*, 9008.

Li, Z., Tang, Y., Wu, J., Zhang, J., & Lv, Q. (2020). The interest costs of green bonds: Credit ratings, corporate social responsibility, and certification. *Emerging Markets Finance and Trade*, *56*(12), 2679–2692.

Liu, D., Chen, T., Liu, X., & Yu, Y. (2019). Do more subsidies promote greater innovation? Evidence from the Chinese electronic manufacturing industry. *Economic Modelling*, *80*, 441–452.

Liu, H., Liu, Z., Lai, Y., & Li, L. (2021). Factors influencing collaborative innovation project performance: The case of China. *Sustainability*, *13*(13), 7380. https://doi.org/10.3390/su13137380

Loasby, B. J., Nelson, R. R., & Winter, S. G. (1983). An evolutionary theory of economic change. *The Economic Journal*, *93*(371), 652. https://doi.org/10.2307/2232409

Meng, F., & Zhang, W. (2022). Digital finance and regional green innovation: Evidence from Chinese cities. *Environmental Science and Pollution Research*, *29*(59), 89498–89521.

Montmartin, B., & Herrera, M. (2015). Internal and external effects of R&D subsidies and fiscal incentives: Empirical evidence using spatial dynamic panel models. *Research Policy*, *44*(5), 1065–1079.

Murovec, N., & Prodan, I. (2009). Absorptive capacity, its determinants, and influence on innovation output: Cross-cultural validation of the structural model. *Technovation*, *29*(12), 859–872. https://doi.org/10.1016/j.technovation.2009.05.010

Ning, Y., Cherian, J., Sial, M. S., Álvarez-Otero, S., Comite, U., & Zia-Ud-Din, M. (2022). Green bond as a new determinant of sustainable green financing, energy efficiency investment, and economic growth: A global perspective. *Environmental Science and Pollution Research*, *30*, 61324–61339.

Pagnoni, G. A., & Roche, S. (2015). *The renaissance of renewable energy* (1st ed.). Cambridge University Press. https://doi.org/10.1017/CBO9781139198363

Patrucco, A., Harland, C. M., Luzzini, D., & Frattini, F. (2022). Managing triadic supplier relationships in collaborative innovation projects: A relational view perspective. *Supply Chain Management: An International Journal*, *27*(7), 108–127. https://doi.org/10.1108/SCM-05-2021-0220

Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, *9*(4), 97–118.

Rao, P., & Holt, D. (2005). Do green supply chains lead to competitiveness and economic performance? *International Journal of Operations & Production Management*, *25*(9), 898–916.

Santoro, G., Bresciani, S., & Papa, A. (2020). Collaborative modes with cultural and creative industries and innovation performance: The moderating role of heterogeneous sources of knowledge and absorptive capacity. *Technovation*, *92–93*, 102040.

Schulze, A., & Brojerdi, G. J. C. (2012). The effect of the distance between partners' knowledge components on collaborative innovation. *European Management Review*, *9*(2), 85–98.

Sena, V., Marra, M., Demirbag, M., & Lubrano Lavadera, G. (2022). The impact of institutions on collaborative innovations and the role of equity-based entry modes. *British Journal of Management*, *33*(3), 1395–1411.

Sharfman, M. P., & Fernando, C. S. (2008). Environmental risk management and the cost of capital. *Strategic Management Journal*, *29*(6), 569–592. https://doi.org/10.1002/smj.678

Shi, J., Yu, L. P., & Du, W. (2022). Research on interaction mechanism between collaborative innovation and surprise innovation in high-tech enterprises. *Forum on Science and Technology in China*, *2022*(6), 111–122. https://doi.org/10.13580/j.cnki.fstc.2022.06.010

Sun, Z., Feng, J., Zhou, R., Yu, Y., & Deng, Y. (2022). Can labeled green bonds reduce financing cost in China? *Sustainability*, *14*(20), 13510.

Tang, D. Y., & Zhang, Y. (2020). Do shareholders benefit from green bonds? *Journal of Corporate Finance*, *61*, 101427. https://doi.org/10.1016/j.jcorpfin.2018.12.001

Tolliver, C., Keeley, A. R., & Managi, S. (2019). Green bonds for the Paris agreement and sustainable development goals. *Environmental Research Letters*, *14*(6), 64009.

Vachon, S., & Klassen, R. D. (2008). Environmental management and manufacturing performance: The role of collaboration in the supply chain. *International Journal of Production Economics*, *111*(2), 299–315.

Wan, Y., Gao, Y., & Hu, Y. (2022). Blockchain application and collaborative innovation in the manufacturing industry: Based on the perspective of social trust. *Technological Forecasting and Social Change*, *177*, 121540. https://doi.org/10.1016/j.techfore.2022.121540

Wang, C., & Hu, Q. (2020). Knowledge sharing in supply chain networks: Effects of collaborative innovation activities and capability on innovation performance. *Technovation*, *94–95*, 102010. https://doi.org/10.1016/j.technovation.2017.12.002

Wang, C., & Zhang, G. (2019). Examining the moderating effect of technology spillovers embedded in the intra- and inter-regional collaborative innovation networks of China. *Scientometrics*, *119*(2), 561–593.

Wang, J., Chen, X., Li, X., Yu, J., & Zhong, R. (2020). The market reaction to green bond issuance: Evidence from China. *Pacific-Basin Finance Journal*, *60*(1), 101294.

Wang, S., & Wang, D. (2022). Exploring the relationship between ESG performance and green bond issuance. *Frontiers in Public Health*, *10*, 897577.

Wang, T., Liu, X., & Wang, H. (2022). Green bonds, financing constraints, and green innovation. *Journal of Cleaner Production*, *381*, 135134. https://doi.org/10.1016/j.jclepro.2022.135134

Wang, X., & Wang, Y. (2021). Research on the green innovation promoted by green credit policies. *Journal of Management World*, *37*, 173–188. https://doi.org/10.19744/j.cnki.11-1235/f.2021.0085

Wang, Y. L., & Zhou, Y. H. (2022). Green finance development and enterprise innovation. *Journal of Finance and Economics*, *49*(1), 49–62. https://doi.org/10.16538/j.cnki.jfe.20220615.101

Wu, X., Bu, D., Lian, J., & Bao, Y. (2022). Green bond issuance and peer firms' green innovation. *Sustainability*, *14*(24), 17035.

Wu, Y. H., Tian, Y. N., & Chen, Y. Y. (2022). The spillover effect, mechanism and performance of green bond issuance. *Journal of Management World*, *38*(6), 176–193. https://doi.org/10.19744/j.cnki.11-1235/f.2022.0086

Yang, L. Y., & Zhang, Z. Y. (2022). The impact of green credit policy on corporate green innovation. *Studies in Science of Science*, *40*(2), 345–356. https://doi.org/10.16192/j.cnki.1003-2053.20210817.001

Yang, Z., Chen, H., Du, L., Lin, C., & Lu, W. (2021). How does alliance-based government-university-industry foster cleantech innovation in a green innovation ecosystem? *Journal of Cleaner Production*, *283*, 124559. https://doi.org/10.1016/j.jclepro.2020.124559

Yeow, K. E., & Ng, S.-H. (2021). The impact of green bonds on corporate environmental and financial performance. *Managerial Finance*, *47*(10), 1486–1510.

Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance*, *98*, 39–60.

Zhai, J., Xu, X., Xu, J., & Lyu, X. (2021). Research on green collaborative innovation mechanism of cloud manufacturing enterprises under government supervision. *Mathematical Problems in Engineering*, *2021*, 1–17. https://doi.org/10.1155/2021/8820791

Zhang, J., Yang, G., Ding, X., & Qin, J. (2022). Can green bonds empower green technology innovation of enterprises? *Environmental Science and Pollution Research*, *29*, 1–13.

Zhao, L., Chau, K. Y., Tran, T. K., Sadiq, M., Xuyen, N. T. M., & Phan, T. T. H. (2022). Enhancing green economic recovery through green bonds financing and energy efficiency investments. *Economic Analysis and Policy*, *76*, 488–501.

Zhou, M., Govindan, K., Xie, X., & Yan, L. (2021). How to drive green innovation in China's mining enterprises? Under the perspective of environmental legitimacy and green absorptive capacity. *Resources Policy*, *72*, 102038.

Zhou, X., & Cui, Y. (2019). Green bonds, corporate performance, and corporate social responsibility. *Sustainability*, *11*(23), 6881.

How to cite this article: Lian, J., Huang, X., & Wu, X. (2023). How green bonds promote firms' green collaborative innovation? *Corporate Social Responsibility and Environmental Management*, 1–18. https://doi.org/10.1002/csr.2688