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Green Bond Issuance and the Spillover Effect of Green Technology Innovation from the Perspective of Market Attention: Evidence from China

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Abstract: As the green bond market in China develops and its institutional structure improves, the green bond has emerged as a pivotal element within the broader framework of the green financial system. We focus on bond issuers in China's A-shares from the years 2010 to 2021 and explore green bond issuance and the spillover effect of green technology innovation under the market attention perspective. Findings are that: (1) Green bond issuance can produce the spillover effect in the industry and significantly enhance peer enterprises' green technology innovation. (2) From the viewpoint of market attention, analyst attention can significantly enhance the spillover effect of green bond issuance within the industry. The same is true for media attention and investor attention. (3) Further research shows that within the same industry, the spillover effect is more pronounced for state-owned enterprises, large-scale enterprises, and enterprises in regions with higher levels of green financial development. For the booming development of China's green bond market and the sustainable development of enterprises, this paper provides theoretical and practical foundations.

Keywords: green bond; spillover effect; green technology innovation; market attention; sustainable development

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1. Introduction

Green finance refers to financial services primarily designed for activities that enhance environmental conservation, address climate change, and promote efficient resource utilization. Given this context, enhancing energy efficiency, refining the energy framework, and advancing low-carbon, sustainable growth are essential [1]. Developing green finance is a necessary guarantee for promoting sustainable development [2]. Green bond, as a useful financing tool to cope with environmental issues [3], meets the requirements of "green" and satisfies the standards of "finance". Government, banks, enterprises, and other institutions issue this "star" tool within the green financial system.

Due to the continuous guidance of the "dual carbon" goal, China's market for a green bond is steadily growing. The People's Bank of China released the "Notice on the Issuance of Green Financial Bonds in the Inter bank Bond Market" and the "Directory of Green Bond Support Projects" on 22 December 2015, which directed the issuance of green financial bonds, set up green bond standards and policies comprehensively, and officially initiated China's green bond market. China's green bond issuance has seen a steady yearly rise from 2016 to 2022, resulting in the broadening of the market's scope. The market is set to flourish by late 2023, with the cumulative issuance of green bonds expected to hit approximately RMB 3.6 trillion. Guided by the "dual carbon" goal, the market keeps growing. Using data from the statistics of the iFinD database, we plot Figure 1 to show the green bond issuance in China.

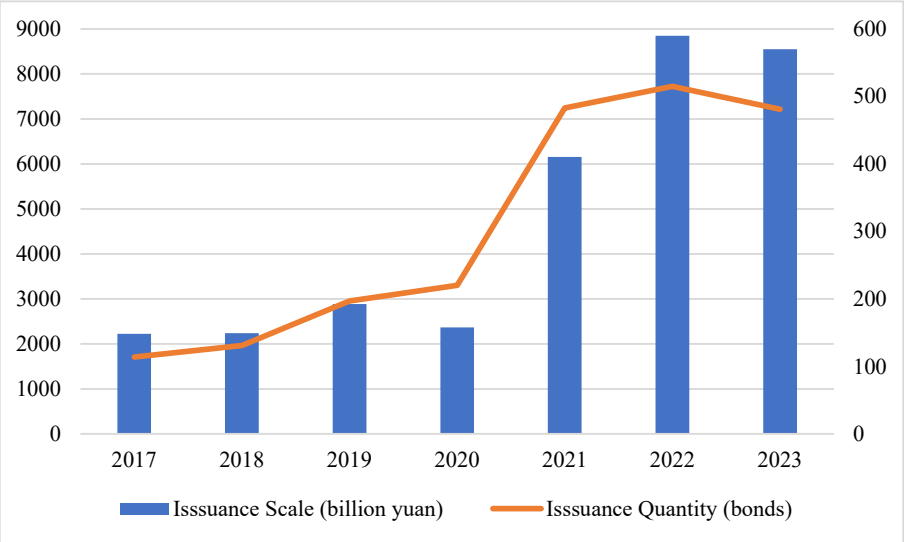

Figure 1. Green bond issuance in China from 2017 to 2023.

Current research on green bonds primarily examines the financial impacts of green bond issuance. Green bonds, unlike regular bonds, serve the dual purpose of debt financing and signaling environmental sustainability to the market [4,5]. Analyzing bonds reveals that China's green bond pricing premium is significantly higher than the premium for traditional bonds and surpasses that of international green bonds noted in earlier research works. The premium is especially notable for new corporate green bonds issued by enterprises and underwriters with high social responsibility [6]. From the perspective of bond issuers, it is determined that green bond, serving as a funding mechanism, possesses both "environmental" and "financial" qualities [7], and their issuance encourages enterprises' green innovation [8–10]. First, the expense of financing through green bonds is less compared to regular bonds [11–13], the financing constraints of enterprises have been alleviated [14], financing costs have been reduced, and financing channels have been improved [15]. Therefore, the internal capital allocation of enterprises has been more fully utilized [7] to promote green innovation. Second, issuing green bonds has improved information transparency [16,17], and alleviated enterprises' agency costs [8], which is more conducive to their green innovation activities. Third, green bond issuance is more conducive to technological innovation when the area where the enterprise is situated has robust environmental management, as well as when the financial marketization index is higher [7,14].

While existing studies are of great significance to research on green bond issuance enhancing enterprises' green innovation, they fail to examine whether it generates the spillover effect; that is, whether the signals transmitted by green bond issuance can be used as a reference for peer enterprises, thus affecting the overall industry. There is a lack of exploration with respect to the impact of external pressure such as market attention, namely analyst attention, media attention, and investor attention, on the spillover effect of green bond issuance for green technology innovation in the industry.

To fill this gap, we test whether green bond issuance produces the spillover effect. Furthermore, we aim to evaluate the role of market attention, an external pressure, on the spillover effect while issuing green bonds. Results are that green bond issuance can produce spillover effect and significantly enhance peer enterprises' green technology innovation. Analyst attention, media attention, and investor attention play positive moderating roles. The spillover effect of green bond issuance is more pronounced in state-owned enterprises, large-scale enterprises, and enterprises located in areas with higher levels of green financial development.

Our marginal contributions: (1) We build on existing studies that analyze market responses to green bond issuance and examine whether it generates the spillover effect and facilitates peer enterprises' green technology innovation. (2) We exam the influence of market attention, including the moderating roles of analyst, media, and investor attention. (3) The varying influence of green bond issuance on enterprises within the same sector is further examined based on different enterprise and region characteristics.

Figure 2 is the flowchart of this study.

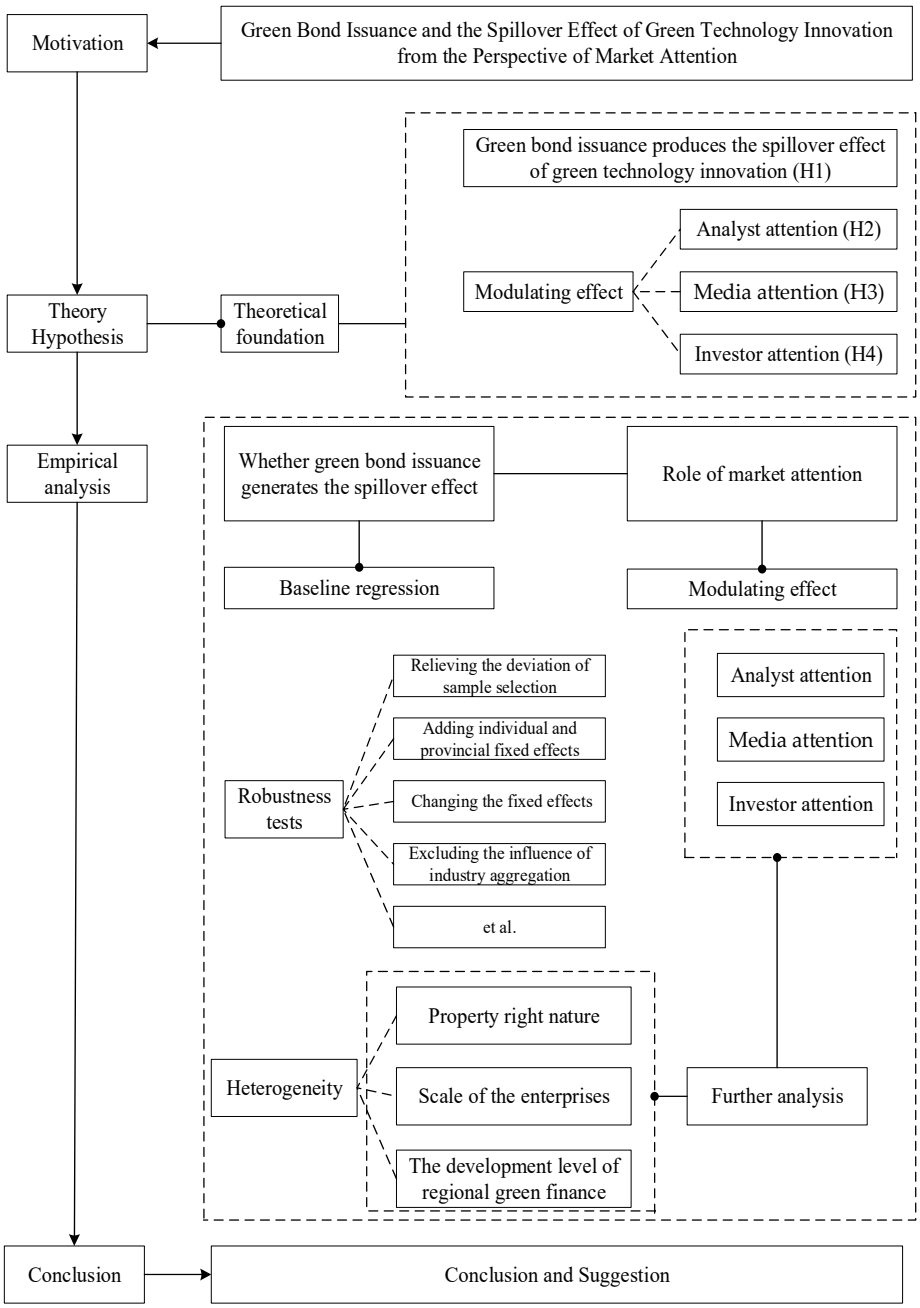

Figure 2. The flowchart.

2. Theoretical Analysis and Research Hypotheses

2.1. Green Bond Issuance, Spillover Effect, and Green Technology Innovation

Green bonds, as a bond instrument, use proceeds to support or refinance green projects [18]. Green bonds, in contrast to regular bonds, possess the characteristics of bond financing and eco-friendliness [19]. Therefore, this paper proposes that the signals transmitted following green bond issuance by enterprises may spread within the industry and promote enterprises in the same industry, thereby actively implementing green technology innovation. This ultimately contributes to sustainable development [20]. The rationale can be explained as follows:

Bond issuers may benefit from issuing green bonds. Green technological advancements contribute to enhancing environmental standards [21], and enterprises may establish technical barriers and forge core competitiveness, as well as improve resource utilization efficiency [22]. For enterprises to attain sustainable growth and enhance their competitive edge, the innovation of eco-friendly technology is essential [14]. Innovating in green technology holds substantial strategic importance for the sustainable growth of businesses, yet it also faces challenges like significant risks and extended research and development periods [23]. Enterprises can encourage green technological advancements by releasing green bonds [8]. First, when enterprises issue green bonds, they open up new external funding avenues, enhancing internal cash flow [7]. Second, due to government support for green projects, enterprises receive government subsidies for green bonds, resulting in lower financing costs compared to general credit bonds [24]. External funding and reduced borrowing expenses ease the capital distribution for enterprises, thereby fostering their technological advancements [25].

Moreover, the spillover effect describes the tendency of decision-makers to mimic or analyze the decisions of their peers within a context of informational uncertainty [26]. On one side, enterprises are adopting eco-friendly technological advancements to meet external environmental demands and ensure sustainable growth [27]. First, when enterprises effectively launch green bonds, it offers a blueprint for peer enterprises to explore new funding avenues, thereby boosting their interest in securing financing through green bond issuance. Green bonds' funds are intended to back eco-friendly initiatives, including green innovation. Peer enterprises bring about green technological innovation in order to issue green bonds and obtain new financing channels. Second, considering technological spillover effects, these advancements and ideas can serve as a reference for peer enterprises, fostering overall technological upgrades. Additionally, green bonds channel investments towards eco-friendly initiatives within the sector, fostering the growth of such projects. This also elevates environmental compliance awareness among peer enterprises, thereby boosting their motivation to pursue green technological advancements. Driven by the need to issue green bonds for new funding opportunities or influenced by technological spillovers and the push for environmental credibility, peer enterprises will opt for green technological innovations, balancing economic efficiency with sustainable growth.

On the other hand, green bonds emit a trustworthy "green" signal, and enterprises issuing these bonds demonstrate their commitment to social responsibility. This will help enterprises build a sustainable reputation for energy efficiency and reduced emissions, attract eco-friendly investors, and drive their innovation in green technology. Starting from the signaling theory, the implementation of green technological innovations by bond-issuing enterprises serves to demonstrate their willingness to comply with environmental regulations in an active and proactive manner. Furthermore, it contributes to the shaping of a positive social image, which in turn reflects their fulfillment of social responsibility. When enterprises in the industry issue green bonds for green technology innovation, investors with green preferences will subjectively increase their attention to the industry as a whole, and thus other enterprises in the industry will step up to improve their own green technology innovation for reputational reasons in the presence of external monitoring. Stemming from peer learning theory [28], enterprises are likely to mimic the manufacturing and operational behaviors of industry peers. Peer enterprises may take the initiative to

make strategic decisions conducive to environmental protection and low financing costs. As enterprises issue green bonds, indicating a dedication to eco-friendly tech advancements, it is probable that additional enterprises will follow suit.

The business scope and other aspects of enterprises within the same industry are relatively similar. Therefore, the profit mode of peer enterprises may be consistent, and the change of credit risk will show strong synchronism. Based on the dynamic competition theory, peer enterprises have spillover effects due to their interactive competitive relationships [29]. The issuance of green bonds by enterprises provides it with competitive advantages in terms of green technology innovation. Consequently, other enterprises in the same industry will respond promptly in order to reduce the barriers to competition. Nevertheless, those who issue debt will leverage the financing advantages of green bonds to gain further access to green innovation resources in the market, thereby alleviating the competitive pressures coming from enterprises in the same industry. The management of enterprises that issue green bonds and those that do not engage in repeated dynamic games due to competitive pressures to construct business models that compete with enterprises in the same industry. This promotes the improvement of the level of green technology innovation in the entire industry. And, it is common practice among enterprises to emulate the production and business decisions of their peers, particularly those at the vanguard of their respective industries [30,31]. As a result, enterprises in the same industry will also take the initiative to create green technology innovation.

Then, we propose Hypothesis 1.

H1. *Green bond issuance can produce spillover effect and enhance peer enterprises' green technology innovation.*

2.2. The Role of Market Attention

Green bond issuance produces strong information disclosure and transmits a "green signal" to the market [32]. Enterprises or investors will react accordingly, with market participants playing crucial roles in this development [5]. As the nation actively pushes its goals for "dual carbon", alongside the growth of eco-friendly and low-carbon sectors, enterprises are increasingly focusing on green technology innovation, drawing heightened market interest [33]. An enterprise's R&D investment can attract the attention of ordinary investors who pay attention to an enterprise's innovation and put external pressure on an enterprise's innovation [34–36]. Based on the reputation theory, reputation can be regarded as a valuable asset of an enterprise, which will bring in the inflow of economic resources to the enterprise [37]. Heightened external supervision prompts the enterprise to pay greater attention to its image and make judicious management decisions [38]. Therefore, if Hypothesis 1 is established, we will delve deeper into how analyst, media, and investor attention influence the spillover effect of green bond issuance on peer enterprises' green technology innovation.

2.2.1. Analyst Attention

"Analyst attention" refers to the ability of analysts to make use of their own professional capabilities and the advantageous channels of their brokerage enterprises to conduct in-depth and comprehensive mining of information on listed enterprises and provide relevant forecasts and recommendations to the outside world in the form of easy-to-understand research reports for the reference of stakeholders. Analysts play a supervisory and information intermediary role in the capital market, by directing their attention to influence enterprises' innovation behavior on which they exert pressure [34]. First, as an important part of the capital market, analysts' external governance functions can have an important impact on technological innovation [39]. Analysts, in contrast to regular investors, possess superior professional knowledge and enhanced data processing skills [40], as well as a larger number of information source channels through which they can obtain information relevant to the inner operations of an enterprise [41]. Analysts use their expertise and

information processing abilities to analyze and summarize the information obtained, and pass it to on investors in a manner that is concise and easy to understand [42], which allows investors to "supervise" enterprise managers and avoid hindering the technological innovation of enterprises due to their own interests [43].

Second, analysts' evaluations of an enterprise can not only place direct pressure on the enterprise itself but can also exert indirect pressure on the investor side by transmitting information to the investor [44]. When enterprises issue green bonds to advance their green technology innovation to gain competitive advantages [8], peer enterprises will also pursue green technology advancements due to analyst scrutiny and the associated pressure. Therefore, under the pressures arising from analyst attention, peer enterprises are more inclined to pursue green technology innovation to remain competitive as other enterprises issuing green bonds enhance green tech capabilities.

H2. *Analyst attention strengthens the impact of green bond issuance on the spillover effect of green technology innovation in the industry.*

2.2.2. Media Attention

Due to the rising influence of online media, its significance in the financial market is growing [45,46]. "Media attention" is defined as the number of times an enterprise is covered by the media, which means that the more media coverage an enterprise receives, the more media attention it receives. And, it typically denotes the extent of news coverage and interest directed towards enterprises in the area [47]. On the one hand, according to the principles of effective oversight, transparent media can facilitate the unrestricted exchange of information within a market economy, diminish information imbalances [48,49], and enhance its regulatory function [50,51]. The return on investment for green technology innovation is significantly longer compared to general innovation efforts [52], and owing to its high risk characteristics, the enterprise's business activities may be impacted by information asymmetry, which creates a potential opportunity for opportunistic behavior among executives. When subject to media attention, managers will consciously avoid opportunistic behavior in order to manage their reputation, thereby increasing an enterprise's green technology innovation activities. The media's high attention and the public's surging external pressure on environmental protection have prompted companies in the same industry to raise environmental awareness and keep pace with industry leaders [49]. On the other hand, the role of the media as an integral part of cultural communication should not be underestimated; not only does it have an impact on behavioral decisions, but it also changes the symmetry of market information [53]. The media, to a certain extent, take the government policy as the guiding standard, respond to the government's call, emphasize the positive role of enterprise environmental protection behavior, form the concept of environmental protection between corporate organization and the public, and create a cultural type of mandatory informal pressure on enterprises [54]. There are enterprises that issue green bonds to promote their green technology innovations in an effort to gain competitive advantages in the industry and transmit a "green signal". Media attention means that enterprises in the same industry will be subject to greater pressure and will be more motivated to promote an environmentally friendly image and respond to the green signal in the industry, thus boosting their capacity for green technology innovation. Therefore, under media pressure, peer enterprises are also more likely to pursue green technology innovation to remain competitive as other enterprises enhance green innovation through the issuance of green bonds.

H3. *Media attention strengthens the impact of green bond issuance on the spillover effect of green technology innovation in the industry.*

2.2.3. Investor Attention

Institutional economics divided public opinion into informal institutions [55]. Negative environmental news related to an enterprise is likely to induce boycotting by investors; public opinion often criticizes enterprises that harm the environment, prompting regulators to impose penalties. In response to external pressure, enterprises are likely to maybe focus more on the implementation of green, low-carbon, and sustainable development goals, and to promote an environmentally friendly corporate image [56]. "Investor attention" is used to describe the extent to which investors are seeking information. As enterprises within the sector issue green bonds to advance their green technology and gain a competitive edge, they send a "green signal" that attracts investor interest. This, in turn, encourages these enterprises to improve their eco-friendly technology development to establish a sustainable enterprise image. From the perspective of legitimacy theory, enterprises will seek recognition in the social environment and avoid punishment [57]. Legitimacy theory is based on the contract between enterprises and society. Society is viewed as giving enterprises the right to exist, in the hope that enterprises can meet stakeholders' expectations and requirements. When an enterprise transmits an "environmentally friendly signal" by issuing green bonds and improving its green technology innovations, supervision by investors can force peer enterprises to take active green environmental protection actions, thereby realizing green technology innovation [58].

H4. *Investor attention strengthens the impact of green bond issuance on the spillover effect of green technology innovation in the industry.*

The theoretical framework is shown in Figure 3.

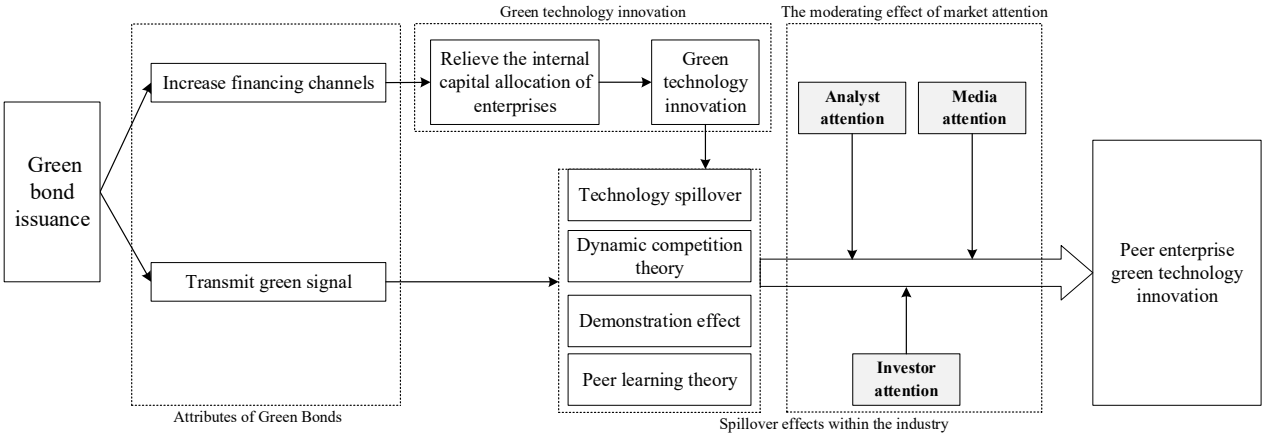

Figure 3. Theoretical framework.

3. Research Design

3.1. Sample

We took the dataset from China's A-share listed enterprises that issue bonds in the period 2010 to 2021. The sample in this study was filtered based on specific criteria: (1) Excluded enterprise samples that were ST or *ST (enterprises under special treatment by the exchange). (2) Excluded enterprises in the financial sector. (3) Excluded enterprises listed for less than one year. (4) Excluded enterprises lacking essential financial data. (5) Performed 1% and 99% tail reduction processing on the data. We ultimately obtained 11,428 "firm-year" observations. The enterprise green innovation data, the number of news reports, and the network search index were sourced from the CNRDS database, and the other data were sourced from the CSMAR Database.

3.2. Variable

3.2.1. Explained Variable

Green technology innovation (*GTI*). Patents are a measure of an enterprise's degree of innovation and an accurate indicator of the output of innovative activities. It takes three to five years for a patent to be granted before a decision is accepted, which hinders an accurate assessment of an enterprise's innovation for the year [59]. Therefore, we referred to Ma et al. (2021) [60] and Li and Xiao (2020) [61] and used green patent applications to reflect the level of green technology innovation of enterprises in the current period. *GTI* is specified as the number of independent applications for green inventions by enterprises in that year plus one and take the natural logarithm.

3.2.2. Explanatory Variable

Whether the industry issued green bonds (*Green* × *Post*). We referred to the study conducted by Wu et al. (2022) [12]. *Green* × *Post* takes the value of 1 when the industry issues green bonds and is in a year in which green bonds have already been issued, otherwise it takes the value of 0. The term "*Green*" is a dummy variable for whether there are enterprises in the industry that have issued green bonds. The term "*Post*" indicates whether it is in the year of the first green bond issuance in the industry and in subsequent years.

3.2.3. Moderating Variables

Analyst attention (*Analyst*), Media attention (*Media*), and Investor attention (*Investor*). Referring to the research of Liu and Tian (2021) and Wang et al. (2018) [62,63], the natural logarithm of the count of analyst trackers plus 1 serves as an indicator of analyst attention. Referring to Wang et al. (2022) [64], the natural logarithm is taken as a measurement index of media attention after adding 1 to the frequency of the enterprise's mentions in financial news. Because Chinese domestic investors mainly use the Baidu search engine, we refer to Zhou et al. (2017) [36] and use the Baidu search index as a measure of investor attention, which is specifically expressed as the Baidu search index plus 1 natural logarithm.

3.2.4. Control Variables

Control variables (*Controls*): detailed explanations can be found in Table 1.

Table 1. Variable definition.

Variable Symbol	Variable Definition
GTI	ln (the number of independent applications for green inventions in that year + 1)
Green × *Post*	takes the value of 1 when the industry issues green bonds and is in a year in which green bonds have already been issued, otherwise takes the value of 0
Analyst	the number of analysts' attention in the year plus 1 takes the natural logarithm
Media	the natural logarithm is taken after the number of times the enterprise was reported by financial news plus 1
Investor	the number of the Baidu search index of the enterprise in that year plus 1 natural logarithm
Rd	the percentage of enterprise R&D expenditure to total assets
Size	the natural logarithm of enterprise total assets scale
Lev	net profit divided by average balance of shareholders' equity
Roa	net profit divided by average balance of total assets
Fixed	ratio of net fixed assets to total assets
Growth	(current year's operating income/previous year's operating income) − 1
Board	natural logarithm of the number of board members
Indep	independent directors divided by the number of directors
Dual	the chairman and the general manager are the same person 1, otherwise 0
Top	the number of shares held by the top five shareholders/the total number of shares
TobinQ	(stock price × number of tradable shares + net assets per share × number of non-tradable shares + book value of liability)/total book assets
Big4	the company was audited as 1 by the Big Four (PWC, Deloitte, KPMG, Ernst & Young), otherwise it was 0

Table 1. *Cont.*

Variable Symbol	Variable Definition
Opinion	if the company's financial report of the year is issued a standard audit opinion, the value is 1, otherwise it is 0
Year	year dummy variable
Industry	industry dummy variable

3.3. Basic Model

Equation (1) is developed to verify whether green bond issuance promotes the spillover effect of green technology innovation.

$$GTI_{i,t} = \beta_0 + \beta_1 Green \times Post_{i,t} + \beta_i Controls_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (1)$$

$\varepsilon_{i,t}$ represents the random perturbation term. If β_1 is significantly positive, then Hypothesis 1 is verified.

4. Empirical Results

4.1. Descriptive Statistics

In Table 2, for the explained variable (*GTI*), the mean value is 0.9273, and the median is 0.6931. This indicates varying degrees of *GTI* among bond issuers. The average value for the explanatory variable (*Green* × *Post*) is 0.1160, indicating that 11.60% of enterprises in the same sector will be influenced by the release of green bonds. In addition, the maximum value of VIF was 2.090, and no serious collinearity problem was detected.

Table 2. Statistical results of main variables.

VarName	Obs	Mean	SD	Min	Median	Max
GTI	11,428	0.9273	1.2067	0.0000	0.6931	5.0499
Green × *Post*	11,428	0.1160	0.3203	0.0000	0.0000	1.0000
Analyst	8908	1.9356	1.0799	0.0000	2.0794	3.8501
Media	11,428	3.5101	1.3786	0.0000	3.4012	7.4128
Investor	10,552	12.6265	1.8141	0.0000	12.7808	17.1909
Rd	11,428	0.0214	0.0216	0.0001	0.0168	0.1412
Size	11,428	22.8538	1.3968	20.2300	22.6925	26.8319
Lev	11,428	0.5048	0.1948	0.0779	0.5118	0.9208
Roa	11,428	0.0418	0.0550	−0.1768	0.0378	0.2027
Fixed	11,428	0.2385	0.1725	0.0017	0.2066	0.7082
Growth	11,428	0.1965	0.4103	−0.5098	0.1285	2.6647
Board	11,428	2.1527	0.2025	1.6094	2.1972	2.7081
Indep	11,428	0.3762	0.0551	0.3333	0.3636	0.5714
Dual	11,428	0.2409	0.4276	0.0000	0.0000	1.0000
Top	11,428	0.5435	0.1607	0.1928	0.5415	0.9075
TobinQ	11,428	1.6859	0.9013	0.8347	1.3882	6.0218
Big4	11,428	0.0897	0.2858	0.0000	0.0000	1.0000
Opinion	11,428	0.9721	0.1647	0.0000	1.0000	1.0000

4.2. Analysis of the Empirical Results

Table 3 shows that the *Green* × *Post* variables are significantly positive regardless of whether control variables are added or not. From an economic standpoint, green bond issuance improved peer enterprises' *GTI*, the level of green technology innovation of peer enterprises increased by 15.34%. Hypothesis 1 was verified.

Table 3. Baseline regression results.

Variable	(1)	(2)
	GTI	
Green × *Post*	0.1589 *** (3.23)	0.1534 *** (3.96)
Rd		7.3691 *** (18.14)
Size		0.5444 *** (49.56)
Lev		−0.4479 *** (−7.07)
Roa		−0.3970 ** (−1.99)
Fixed		−0.7330 *** (−10.80)
Growth		−0.0347 (−1.61)
Board		0.1229 ** (2.24)
Indep		0.6073 *** (3.29)
Dual		0.0177 (0.86)
Top		−0.0598 (−1.05)
TobinQ		0.0464 *** (4.17)
Big4		0.2384 *** (6.28)
Opinion		0.2916 *** (5.62)
Constant	0.3498 *** (4.67)	−12.8767 *** (−46.88)
Year/Industry	Yes	Yes
N	11,428	11,428
adj. R^2	0.206	0.462

Note: *** and ** denote significance at the 1% and 5% levels, respectively. We use robust standard errors. T values are reported in parentheses. The criteria in the table below are the same.

4.3. Robustness Tests

4.3.1. Relieving the Deviation of Sample Selection

We divided the bond-issuing enterprises in the 17 industries in which there are green bond issues into a treatment group, while the control group consists of enterprises in the 27 industries belonging to the same primary industry as the 17 industries. Nonetheless, substantial disparities might exist between enterprises in sectors that release green bonds and those that do not, particularly regarding attributes like company size and financial ratios. Therefore, the grouping method may not guarantee the randomness of the sample. We employed the PSM method to reallocate the control group for testing purposes to circumvent estimation bias resulting from discrepancies between treatment and control groups. First, the variables were screened by maximum likelihood estimation, and the relevant variables relating to enterprise characteristics, such as enterprise size, asset–liability ratio, proportion of independent directors, two-position status, ownership concentration,

Tobin's Q value, and enterprise establishment period were selected as covariates. Second, the kernel matching method[1] was utilized to re-match treatment and control groups. Finally, re-matched samples were subjected to regression test.

The Heckman selection model [65] is utilized to examine if there are sample selection errors. Drawing on existing research, considering a green bond issuance's number in an enterprise's region, enterprises' financial structure and profitability and other factors may affect green bond issuance. Initially, we utilized the Probit model with *Green* × *Post* as the explanatory variable and the number of green bond issuances in the same year of the same province (*GB*) as the explanatory variable. Estimate the inverse Mills ratio (*IMR*). Then, *IMR* is incorporated into Equation (1) for analysis.

In Table 4, after accounting for self-selection bias, the conclusions remain consistent.

Table 4. Relieving the deviation of sample selection.

Variable	PSM Model	Heckman Selection Model
	(1)	(2)
	GTI	
Green × *Post*	0.1490 *** (3.86)	0.1616 *** (4.17)
IMR		−0.1232 *** (−3.87)
Constant	−12.7738 *** (−46.33)	−12.1629 *** (−36.73)
Controls/Year/Industry	Yes	Yes
N	11,378	11,428
adj. R^2	0.460	0.463

Note: *** denotes significance at the 1% level.

4.3.2. Adding Individual and Provincial Fixed Effects

To exclude the influence of the economic development of the enterprise's location and other missing enterprise characteristics on the conclusions of this paper, individual fixed effects and provincial fixed effects were incorporated into the analysis. In Table 5, *Green* × *Post* remained notably positive, suggesting that including other potential missing control variables did not fundamentally alter the findings of this study.

Table 5. Partial robustness test 1.

Variable	Adding Individual and Provincial Fixed Effects		Excluding the Influence of Industry Aggregation	Adding Related Omitted Variables
	(1)	(2)	(3)	(4)
			GTI	
Green × *Post*	0.1530 *** (4.01)	0.1692 *** (5.91)	0.1106 *** (2.62)	0.1559 *** (4.05)
Per-GDP				0.0065 (1.05)
GDP-growth				0.0189 *** (3.30)
Marketization				0.0000 *** (7.65)
Constant	−12.0775 *** (−42.82)	−8.4202 *** (−14.69)	−12.4774 *** (−44.74)	−13.1489 *** (−45.12)

Table 5. *Cont.*

Variable	Adding Individual and Provincial Fixed Effects		Excluding the Influence of Industry Aggregation	Adding Related Omitted Variables
	(1)	(2)	(3)	(4)
			GTI	
Controls/Year	Yes	Yes	Yes	Yes
Industry	Yes	No	Yes	Yes
Id	No	Yes	No	No
Province	Yes	No	No	No
N	11,428	11,428	10,878	11,428
adj. R^2	0.474	0.741	0.461	0.467

Note: *** denotes significance at the 1% level.

4.3.3. Excluding the Influence of Industry Aggregation

While this study reduces the influence of industry regulations by accounting for corporate fixed effects, green bond issuers are predominantly found in sectors like construction and electricity. To mitigate the potential impact of industry clustering, this study omits bond-issuing enterprises in the construction and power sectors, keeps industries with fewer green bonds, and re-performs the regression analysis. In Table 5, *Green* × *Post* is significantly positive. After excluding the influence of industry policy and industry agglomeration, green bond issuance's spillover effect still exists.

4.3.4. Adding Related Omitted Variables

As regional economic development level and marketization level may also affect green bond issuance and green technology innovation, consequently, we incorporate factors like regional per capita GDP (*Per-GDP*), GDP growth rate (*GDP-growth*), and the degree of regional marketization (*Marketization*) into the model. As shown in Table 5, after controlling for various observable omitted variables, the spillover effect of green bond issuance still exists.

4.3.5. Excluding the Interference of Other Policies

Taking into account other policies may affect enterprises' *GTI* during the sample period.

The policy of "green financial reform and innovation pilot area" might affect the empirical regression outcomes of this study. To avoid policy interference, we eliminate the samples in the provinces where the policy is located and re-run the regression. "Green credit policy" may also have an impact on enterprise green governance performance. According to the "key evaluation indicators for the implementation of green credit", we determine if enterprises in Class A, which have environmental and social risks, belong to a green credit-restricted industry to mitigate potential policy impacts. In Table 6, the benchmark regression is robust.

Table 6. Partial robustness test 2.

Variable	Excluding the Policy 1	Excluding the Policy 2	Considering the Lag Effect	Tobit Model	Logit Model
	(1)	(2)	(3)	(4)	(5)
	GTI	*GTI*	*F.GTI*	*GTI*	*GTI*
Green × *Post*	0.2303 ***	0.1553 ***	0.1974 ***	0.1534 ***	0.2169 **
	(4.97)	(4.01)	(4.15)	(3.98)	(2.11)
GcresPolicy		−0.1150			
		(−1.03)			

Table 6. *Cont.*

Variable	Excluding the Policy 1	Excluding the Policy 2	Considering the Lag Effect	Tobit Model	Logit Model
	(1)	(2)	(3)	(4)	(5)
	GTI	*GTI*	*F.GTI*	*GTI*	*GTI*
Constant	−13.3176 *** (−40.62)	−12.7816 *** (−44.28)	−13.4483 *** (−44.78)	−12.8767 *** (−47.02)	−23.6164 *** (−30.25)
Controls/Year/Industry	Yes	Yes	Yes	Yes	Yes
N	7720	11,428	9741	11,428	11,428
adj. R^2	0.493	0.462	0.465		

Note: *** and ** denote significance at the 1% and 5% levels, respectively.

4.3.6. Considering the Lag Effect of Green Technology Innovation

Given that enterprises require specific timeframes to implement technological advancements, we use the number of enterprises' green inventions independently in T + 1 period plus one logarithm as the explanatory variable to re-test. Results are shown in Table 6.

4.3.7. Replacing the Regression Model

Results in Table 6. First, since *Green* × *Post* is a dummy variable taking values of 0 or 1, we use a Tobit model to replace the benchmark regression ordinary OLS model for empirical testing. Second, referring to the method utilized by Li et al. (2020) [66], the division standard is represented by whether or not the number of green inventions applied independently is zero. Dummy variables were constructed to measure the innovation willingness of enterprises to implement green technology, and a Logit model was used for empirical testing.

5. Further Analysis

5.1. Test of Moderating Effects

We developed and validated models to delve deeper into how market attention influences the spillover effect of green technology innovation from green bond issuance.

Equation (2) incorporated the interaction between green bond issuance and analyst attention, building upon Equation (1). Equation (2) is specifically expressed as:

$$GTI_{i,t} = \beta_0 + \beta_1 Green \times Post_{i,t} + \beta_2 Analyst_{i,t} + \beta_3 Green \times Post_{i,t} \times Analyst_{i,t} + \beta_i Controls_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (2)$$

where β_0 is denoted by the intercept term, respectively, while β_1, β_2, β_3, and β_i represent the coefficients.

We created an interaction term for regression analysis to examine how analyst attention influences the spillover effect of green bond issuance. In Table 7, *Green* × *Post* × *Analyst* is significant. Hypothesis 2 was verified. In other words, when analysts paid greater attention to an enterprise, the enterprise was more willing to respond to the green signal transmitted by the industry's green bond issuance, thereby improving their *GTI*.

Equation (3) was constructed to test the role of media attention.

$$GTI_{i,t} = \gamma_0 + \gamma_1 Green \times Post_{i,t} + \gamma_2 Media_{i,t} + \gamma_3 Green \times Post_{i,t} \times Media_{i,t} + \gamma_i Controls_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (3)$$

Among them, γ_0 is denoted by the respective intercept terms; and γ_1, γ_2, γ_3, and γ_i represent the coefficients.

In Table 7, *Green* × *Post* × *Media* is significant. Hypothesis 3 was verified.

Equation (4) was constructed to test the role of media attention.

$$GTI_{i,t} = \delta_0 + \delta_1 Green \times Post_{i,t} + \delta_2 Investor_{i,t} + \delta_3 Green \times Post_{i,t} \times Investor_{i,t} + \delta_i Controls_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (4)$$

where δ_0 is denoted by the respective intercept terms; δ_1, δ_2, δ_3, and δ_i represent the coefficients.

In Table 7, *Green* × *Post* × *Investor* is significant. Hypothesis 4 was verified.

Table 7. The role of market attention.

Variable	Analyst Attention		Media Attention		Investor Attention	
	(1)	(2)	(3)	(4)	(5)	(6)
			GTI			
Green × *Post*	0.2091 *** (4.50)	0.2065 *** (4.47)	0.1586 *** (4.11)	0.1818 *** (4.62)	0.1464 *** (3.70)	0.1613 *** (4.05)
Analyst	0.0313 *** (2.79)	0.0188 (1.63)				
Green × *Post* × *Analyst*		0.1134 *** (3.43)				
Media			0.0687 *** (8.71)	0.0557 *** (6.88)		
Green × *Post* × *Media*				0.1059 *** (4.57)		
Investor					0.0204 ** (2.35)	0.0025 (0.27)
Green × *Post* × *Investor*						0.1004 *** (4.45)
Constant	−13.0832 *** (−39.21)	−13.0232 *** (−38.95)	−12.0384 *** (−41.76)	−11.9657 *** (−41.41)	−12.9791 *** (−44.71)	−12.8862 *** (−44.31)
Controls/Year/Industry	Yes	Yes	Yes	Yes	Yes	Yes
N	8908	8908	11,428	11,428	10,552	10,552
adj. R^2	0.490	0.491	0.466	0.467	0.464	0.465

Note: *** and ** denote significance at the 1% and 5% levels, respectively.

5.2. Heterogeneity Analysis

5.2.1. Enterprises' Property Right Nature

Organizations with varying ownership structures have distinct social duties, leading to diverse responses to the spillover effect of *GTI* when the industry issued green bonds. We categorized the sample into state-owned and non-state-owned enterprises based on property rights, followed by conducting regression analysis. Table 8 indicates that state-owned enterprises' *Green* × *Post* is notably positive.

The plausible explanations for the test outcomes are as follows: Firstly, state-owned enterprises have a higher likelihood of securing innovative resources like funding and talent compared to their non-state-owned counterparts, thereby equipping them with the necessary resources for green technology innovation [67]. State-owned enterprises are crucial in promoting energy efficiency and reducing emissions, and their leadership faces strict penalties if they do not successfully carry out these initiatives [68]. Consequently, when enterprises within the sector release green bonds to fund green technological advancements, state-owned enterprises will proactively embrace this environmental cue and enhance their green tech innovation capabilities.

Table 8. Heterogeneity analysis: the nature of property rights.

Variable	State-Owned Enterprise	Non-State-Owned Enterprises
	(1)	(2)
	GTI	
Green × *Post*	0.2147 ***	0.0351
	(3.91)	(0.65)
Constant	−14.7498 ***	−10.7618 ***
	(−34.81)	(−25.00)
Controls/Year/Industry	Yes	Yes
N	4757	6671
adj. R^2	0.573	0.366

Note: *** denotes significance at the 1% level.

5.2.2. Scale of the Enterprises

The scale of enterprises varies, given the fact that there are differences in the operation mode, financing capacity, and other aspects. Therefore, each enterprise will react differently to the industry's green signal. Since 2016 is the time node for enterprises to start issuing green bonds, this paper took the median total assets of bond-issuing enterprises in 2016 as the standard for dividing the scale of enterprises and divided the samples into two categories: large- and small-scale enterprise. In Table 9, *Green* × *Post* for large enterprises is 0.1613 and positive.

Table 9. Heterogeneity analysis: the scale of the enterprises.

Variable	Large-Scale Enterprises	Small-Scale Enterprises
	(1)	(2)
	GTI	
Green × *Post*	0.1574 ***	−0.0466
	(3.06)	(−0.87)
Constant	−16.6836 ***	−6.3497 ***
	(−37.60)	(−13.53)
Controls/Year/Industry	Yes	Yes
N	5714	5714
adj. R^2	0.522	0.205

Note: *** denotes significance at the 1% level.

The above test results can be realistically explained as follows: Firstly, large-scale enterprises possess more comprehensive organizational framework and a greater level of specialization, enabling them to implement green technology innovation and secure competitive edges. Nonetheless, in their quest for financial gains, large-scale enterprises will also meet their social obligations and aim for sustainable growth and eco-friendly transformation [69]. Consequently, when the industry receives the green signal, large-scale enterprises respond more robustly and allocate greater resources, including manpower, materials, and capital, to R&D efforts aimed at green technology innovation, compared to smaller enterprises.

5.2.3. The Development Level of Regional Green Finance

Regional green finance advancement exerts disparate influences on the capital allocation of enterprises [70]. We refer to the provincial green finance index constructed by Zhang et al. (2020) [71] to assess the extent of green finance progress across various areas. Moreover, the median value of the green finance index acts as the standard for classifying the phases of green financial advancement. A value of 1 was given to the sample exceeding the median, indicating the group with an elevated level of green financial development.

Samples below the median were given a value of 0, indicating a lower tier of green financial development. The grouped regression was then performed. As depicted in Table 10, *Green* × *Post* for enterprises in regions with advanced green financial growth is 0.1105, indicating a substantial positive.

Table 10. Heterogeneity analysis: the development level of regional green finance.

Variable	High Level	Low Level
	(1)	(2)
	GTI	
Green × *Post*	0.1030 **	0.0249
	(2.02)	(0.12)
Constant	−14.2323 ***	−11.3994 ***
	(−36.69)	(−29.20)
Controls/Year/Industry	Yes	Yes
N	5758	5670
adj. R^2	0.454	0.434

Note: *** and ** denote significance at the 1% and 5% levels, respectively.

A plausible interpretation of the test outcomes is that, based on the economic growth theory, technological advancement is central to economic expansion. Enterprises can secure financial backing for their R&D efforts through venture capital, thereby achieving technological innovation. The expansion of green finance contributes to increased local development in this field, aiding enterprises in obtaining collaborations or investments for the advancement of green technology innovation.

6. Conclusions and Implication

Achieving carbon peak and neutrality goals, along with advancing green finance, are interdependent and enhance each other. Driven by the ongoing pursuit of the "dual carbon" objective, the green bond market is steadily growing. Issuing green bonds provides financial advantages for enterprises and simultaneously benefits ecological and environmental conservation. The extant literature on green bond issuance and green technology innovation have focused on the perspective of bond-issuing enterprises. Since the financing cost of green bonds is lower than that of ordinary bonds [12], the financing constraints of enterprises are eased [5], financing channels are improved [72], and internal capital allocation is more fully utilized [7]. At the same time, the issuance of green bonds by enterprises improves the transparency of information [16] and eases the agency costs of enterprises [8], which promotes enterprises to carry out green technology innovation. And when the region where the enterprises issuing green bonds are located has stricter environmental regulations, it is more favorable for the enterprises to carry out green technology innovation [7]. In contrast to the existing literature on this topic, we put forward two original research perspectives. The question thus arises as to whether green bonds' issuance generates the spillover effect in the industry. This is to say, whether the signals conveyed by the issuance of green bonds by enterprises will be noticed and learned from by enterprises in the same industry, which in turn will promote the green technology innovation of peer enterprises. And, we investigate whether market attention, including those expressed by analysts, the media, and investors, influence the extent to which the issuance of green bonds affects green technology innovation within the industry.

From the perspective of market attention, we examined the influence that exists between green bond issuance and the spillover effect. We took bond-issuing enterprises listed in A-shares from 2010 to 2021 to empirically test the relationship. We further examined the moderating effect of three variables, namely analyst attention, media attention, and investor attention, from the perspective of market attention. The following conclusions can be drawn: First, green bond issuance can promote the spillover effect of green technology

innovation in the industry. Second, analyst, media, and investor attention were found to play positive moderating roles with respect to green bond issuance and the spillover effect of green technology innovation in the industry. Third, the results revealed that green bond issuance's spillover effect is more significant in state-owned enterprises, large-scale enterprises, and enterprises located in areas with advanced green financial development.

This paper provides several practical implications. First, green bond issuance can generate a spillover effect in the industry, boosting peer enterprises' green technology innovation. Therefore, relevant departments should enhance incentive structures and risk management systems, promote green technology innovation via green bond financing, and urge more enterprises to strive for sustainable economic growth. The government ought to financially support enterprises for eco-friendly innovation, bolster their resource reserves, alleviate financial strain, and offer policy assistance to facilitate the adoption of green technologies.

Second, analysts use their professional expertise and information processing skills to analyze and summarize the information obtained. Investors can "supervise" enterprise managers who are subject to analyst attention to avoid hindering enterprises' green technology innovation due to their interests, while media attention and investor attention also play an external supervisory role. Enhancing external oversight can encourage peer enterprises to invest and development in green technology research due to its beneficial effects on economic growth and environmental sustainability. This promotes the progression of green industrial transformation and nurtures superior economic development.

Third, government ought to encourage and guide the beneficial influence of green bonds in the industry and offer policy assistance to enterprises eager to advance in green technology but lacking necessary resources to advance their initiatives. In areas where green finance is underdeveloped, reforms should be implemented in accordance with current conditions and in response to evolving trends. This approach aims to foster the integration of green finance with other sectors, establish a supportive external environment for enterprises to innovate in green technology, and ultimately ensure sustainable economic growth.

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Notes

[1] Kernel matching: A matching method in which the weights between individuals in the control group and the treatment group are calculated by the kernel function. This method is one of the common PSM matching methods.

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