Industrial Spillover Effects of Green Bond Issuance --Empirical Analysis Based on Multi-Period Double Difference Models

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Abstract. The purpose of this paper is to explore the industrial spillover effect, action mechanism and heterogeneity analysis of China's green bond issuance from 2014 to 2021 by the multi-period double difference model.The results of the study show that, firstly, the issuance of green bonds can significantly reduce the cost of debt financing of other enterprises in the same industry, which has an industrial spillover effect.Secondly, the spillover effect of the issuance of green bonds is mainly due to the learning and competition that increases the chance of issuance of other enterprises in the same industry, which in turn reduces the debt financing cost of enterprises.Third,there is industrial heterogeneity in green bonds, and the degree of spillover effect varies across different industries. Meanwhile, according to the characteristics of enterprises, the industrial spillover effect of green bonds issued by eco-friendly enterprises and non-polluting enterprises is stronger.

Keywords: green bonds, debt financing cost, spillover effect

1 Introduction

In recent years, with the environmental pollution and other ecological civilization issues have become increasingly important.Green low-carbon development has become a necessary path for China to actively respond to promote economic transformation and upgrading. The report of the 20th CPC National Congress puts forward that "accelerating the transformation of the development mode and promoting the greening and decarbonization of economic and social development are the key links to achieve high-quality development". As an important financing tool for green construction, green bonds play a huge role in the development of the carbon peaking and carbon neutrality goals. Coupled with the continuous improvement of green bond-related policies such as the "Green Bond Support Project Catalog" and the "China Green Bond Principles", it not only meets the demand for green transformation of enterprises, but also accelerates China's adjustment of its economic structure and promotes the development of green and low-carbon economy. According to the 2022 China Green Bond Annual Report released by the Green Finance International Research Institute of the Central University of Finance and Economics, the total scale of new green bonds in and out of China in 2022 was about 983.899 billion yuan, and the number of issuances was 568, with the innovative varieties of green bonds continuously enriched and the scale of issuance continuously expanded.

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Green bonds, as a kind of fixed-income securities that finance investments with environmental or climate-related benefits (Ehlers and Packer, 2017), are the main ingredient of the green financial system[6], which has seen a brand-new development opportunity and gained significant progress, and at the same time aroused the special concerns of investors and other economic agents about risks and returns (Liu Nana, 2022)[24]. For investors, some investors are willing to sacrifice part of the return to hold green bonds (Baker et al., 2018)[3].Heinkel et al. (2001), on the other hand, pointed out that green investors will avoid the stocks of polluting companies, while the financing cost of polluting companies will be relatively increased[11].Ehlers and Packer (2017) proved that investors attach importance to "green labeling", prefer to buy bonds with it[6], and at the same time value the financial performance of enterprises after issuance. As for the research on corporate characteristics, scholars have focused more on the impact of green bonds on enterprises and the risk spillover effect between markets.Flammer (2021) points out that green bond issuance can improve financial performance[7]. Gao Yang and Li Chunyu (2021) believe that risks are likely to accumulate and overflow during the integration of green bond market and traditional Chinese financial market[18].However, existing studies pay less attention to whether the issuance of green bonds has a spillover effect on peer firms and the specific mechanism of action.

At the same time, based on the model, this paper explains the correlation between the debt financing costs of green bond issuers and other enterprises, and verifies the spillover effect. The mechanism analysis and heterogeneity analysis were carried out, and the robustness test was used to ensure the reliability of the conclusions.

The possible marginal contributions lie in the following: Firstly, referring to the method of Wu Yuhui et al. (2022)[30],it further enriches the research theory of industrial spillover effect of green bond issuance, and chooses a different way of calculating debt financing cost, and verifies that the issuance of green bonds is able to significantly reduce debt financing cost of other enterprises in the same industry of listed companies after systematic analysis and empirical test, indicating the existence of industrial spillover effect.Second, this paper extends the research interval to 2021 and adds more data information to support more in-depth analysis. The paper also shifts focus to A-share listed companies to further explore the value of green bond based on its information disclosure.Third, this paper not only explores the heterogeneity of possible spillover effects between different industries, but also examines the intermediary mechanism of the spillover effect, examines whether the issuance of green bonds by an enterprise will promote the issuance of green bonds by other enterprises in the same industry, and probes into the specific action mechanism, expanding the related research on the effect of green bond issuance and providing reference for the development of green bonds.

2 Literature Review and Research Assumptions

2.1 Literature Review

1. Development of green bond market

Jointly responding to climate change has become an important political consensus of the contemporary international community .As an important part of the green financial system, the

green bond market has ushered in a brand new development opportunity and achieved remarkable results.

For the development of foreign green bond market, since 2007, the European Investment Bank (EIB) successfully launched the world's first green bond, the green bond market scale has been rapidly developing and expanding.Maltais and Nykvist (2020) emphasize that one of the most prominent financial innovations in the field of sustainable finance in the past decade is the development of green bonds[1].Shan Wenxiao (2018) believes that the rapid development of international green bond market is due to government support[27], the continuous improvement of the market mechanism and that the future development of the green bond market will be centered on the themes of energy, construction, and industry, etc. Banga (2019) points out that after the financial crisis in 2008, the international green bond market has shown exponential growth[2], while governments have encouraged investors to adjust their business models to create financial and social value under the impetus of the Paris Agreement in 2015.

The development of domestic green bonds started slightly later than the international green bond market. With the opening of the domestic green bond market in 2015, China's economy is undergoing a rapid transformation, and the fruits of this transformation had a positive impact on China's economy, leading to significant progress in the development of green bonds in China. Under the guidance of the carbon peaking and carbon neutrality goals, the low-carbon transition is accelerating, and the momentum for green bonds and investment is "double-growth" (Research Bureau of the People's Bank of China, 2022)[36]. With the continuous enrichment of the connotation of China's green development, industrial policies and related technical standards continue to be updated.The development of domestic green bonds will show a pattern of "supply and demand" (Zheng Kuifang, 2022)[34].

2. Research on the effect of green bond issuance.

Scholars at home and abroad mainly focus on the study of green bond issuance from the company level to study the specific impact of green bonds. In terms of corporate performance management and corporate value. Tang and Yupu (2020) show that the issuance of green bonds by enterprises will be beneficial to the shareholders of the enterprises[16], which can improve the return on investment of investors and increase their attention to the enterprises, and also help enterprises to improve the liquidity performance of the stock market.Flammer (2021) shows that the issuance of green bonds can play a role in improving the financial performance[7].

As for the impact on the level of corporate income and cost of capital, Zhang Lihong et al. (2021) use a matching method to analyze the yield spreads of green bonds over four years[33], indicating that green bonds can significantly reduce corporate financing cost compared to ordinary bonds;.Ma Yaming et al. (2020) verify that the issuance of green bonds can increase the value of the enterprise based on the double-difference model with industrial and regional heterogeneity[26]. Based on the basis of public data on green bond information of listed enterprises, Liang Zhihui (2018) empirically observed that green bonds make investors have a green preference for investing in the issuing enterprises[23], and as a result, increase the total market value of listed companies and reduce equity financing cost in the short term.Tripathy (2017) pointed out that the green bond market expands the scope of corporate financing through the commoditization of the environment[17].

In summary, although the models and methods used by various scholars are different, one thing that can be determined is that the issuance of green bonds can have a more positive impact on enterprises, and to a certain extent can improve corporate performance and reduce debt financing cost.

3. Spillover effect of green bonds

For the spillover effect of green bonds, it is because of its unique green attributes with different risk characteristics from general bonds, scholars focus more on the study of the risk spillover effect of green bonds. Li Yuhui (2022) found that the risk spillover effect of the green bond market on commercial banks is much larger than the risk spillover effect of commercial banks on the green bond market[22].And when exploring the extent and direction of information spillovers between green bonds and linked assets, Liu Nana(2022) finds that green bonds play the role of information spillover recipients at both yield and volatility levels[24], and their transmission mechanism is characterized by heterogeneity over multiple time scales.

Regarding the study on the spillover effect of green bonds in the international arena, Yang Chengyu (2022) points out that the EU's launch of a 250 billion euro sovereign green bond issuance program will help the EU to further release the dividends of green transformation[31], widen the green development gap with other countries and regions, and at the same time, help the EU consolidate the green rules and standards and consolidate its global leadership in green development, and generate spillover effects in the development of green bonds worldwide, inhibit the development of green bonds and reduce the impact of green bonds on the environment. At the same time, it will help the EU consolidate the green rules and standards, consolidate its global leadership in green development, and produce a spillover effect in the global green bond development, which will inhibit the green development of other countries, especially the development of emission reduction measures and low-carbon products.

2.2 Theoretical Analysis and Hypothesis Formulation

First, due to similar fundamentals and the influence of common economic factors, the financial characteristics and decisions of enterprises will have an externality effect on other enterprises in the industry (Wang Cai, Li Xiaohui, 2022)[28], so that there is a spillover effect of relevant decisions among enterprises in the whole industry. Cohort effect is usually defined as individuals with similar characteristics learning and imitating each other (Li Shu et al., 2021)[19]. Li Qiumei and Liang Quanxi(2020) found that "information learning" motivation[20], "agency costs", and "maintenance of competitive parity" are the factors driving the occurrence of the cohort effect. Informationally disadvantaged firms tend to follow informationally advantaged firms in their decision making.Lieberman and Asaba (2006) show that imitation between firms can stimulate productive innovation with positive or negative outcomes for the industry as a whole[13], and that imitation is more prevalent when the behaviors or methods of first movers are inherently less complex. This imitative behavior can increase the likelihood that when a firm in the industry issues green bonds other firms will follow suit.

Therefore, based on cohort imitation, a given decision can have spillover effects in the industry. For example, Li Shu et al. (2021) show that the tone of discussion and analysis by peer management can significantly enhance the effectiveness of firms' investment in innovation[19], and that this positive effect becomes more pronounced as the comparability of accounting information and disclosure between firms increases. Kim et al. (2008) confirm the fact that positive

information transfer within an industry due to industry commonality as well as negative information transfer due to competitive shifts[12].

Green bonds are characterized by high corresponding disclosure requirements as well as high market transparency, which promotes green signaling. At the same time, under the influence of industrial commonality and competitive pressure, the behavior will enhance the chances of other enterprises in the same industry to issue green bonds, which in turn spreads to the whole industry, so this paper proposes:

H1: The issuance of green bonds by a firm in the industry can enhance the probability of other firms in the same industry issuing green bonds

The issuance of green bonds reduces the information asymmetry with investors as well as the investment risk of investors, expands the financing surface while gaining more investors' favor for the company, and enhances the reputation and image of the industry.Plus the issuance of green bonds itself can reduce the transaction costs as well as alleviate the problems of maturity mismatches, which can reduce the cost of debt financing for the enterprises, and thus reduce the overall cost of debt financing for the whole industry. The overall debt financing cost of the whole industry will be reduced. Therefore, this paper proposes the following hypothesis:

H2: By issuing green bonds, the debt financing cost of other enterprises in the same industry can be significantly reduced.

3 Research Design

3.1 Sample selection and data sources

This paper selects the corporate bonds, enterprise bonds and medium-term notes issued by China's A-share listed companies from 2014 to 2021 as the data for analysis.The data and relevant characteristics of the debt-issuing enterprises come from the Wind database and the Csmar economic and financial research database, and at the same time, the debt-issuing enterprises are categorized according to the fourth level of industry classification in the Wind database. Referring to the existing literature, this paper processes the data as follows: (1) all bond samples of ST and *ST companies are excluded; (2) samples of bonds issued by financial listed companies are excluded; (3) samples of missing data are excluded; (4) samples related to green bonds are excluded; (5) extreme values of all continuous variables at the 1% and 99% levels are processed using the Winsorize method, and finally 1439 bond data samples were obtained.

3.2 Model construction and variable description

When studying the impact of green bond issuance on the debt financing cost of other enterprises in the same industry, due to the differences in the time point of green bond issuance by each enterprise, we draw on the method of policy time point inconsistency proposed by Beck et al. (2010)[4] as well as the model proposed by Wu Yuhui et al. (2022)[30], and set up the model as in model (1):

$$Cost_{it} = \alpha_0 + \alpha_1 Green_i \times Post_t + \sum \alpha_i Controls_{it-1} + \varepsilon_{it} \quad (1)$$

Where the explanatory variable $Cost_{it}$ is the firm's cost of debt financing. This paper draws on Li Guangzi et al. (2009)[21] and Wei Zhihua et al. (2012) [29]and examines it by calculating

the ratio between the firm's financial expenses and total liabilities at the end of the period (*Cost1*) and the ratio between the total amount of interest expenses, fee expenses, and other financial expenses and the total liabilities at the end of the period (*Cost2*).The higher the value $Cost_{it}$, the higher the firm's debt financing cost. Meanwhile, in order to reduce the endogeneity problem and the effect of reverse causality, this paper does lag one period for the control variables $Controls_{it-1}$.

The setting of Beck (2010)[4] is followed in equation (1), and only the cross-multiplier term is introduced as the main explanatory variable to avoid the effect of multi collinearity. $Green_i$ is a dummy variable, if there is an enterprise in the industry that issues green bonds, the other enterprises i in the industry of the enterprise is assigned a value of 1, otherwise it is 0. $Post_t$ is a time dummy variable, in the treatment group, if the other enterprises i in the same industry issue bonds after the time of the first issuance of green bonds in the industry, then it will take the value of 1, otherwise it will be 0, and all the enterprises in the control group take 0. If the coefficients of the $Green_i \times Post_t$ show a significant negative correlation, then it can be proved that the issuance of green bonds can reduce the debt financing cost of other enterprises in the same industry.

In addition based on the existing experimental information, the model has the following control variables, the first category indicates the control variables of bond characteristics, and the second category is the control variables of enterprise characteristics.The specific variable names and meanings are shown in Table 1. At the same time, industrial fixed effect is added in equation (1).In addition, i in equation (1) represents the enterprises issuing green bonds, while t represents the year of issuing green bonds, ε_{it} is a random perturbation term.

Table 1. List of variable definitions

Variable Type	Variable Name	Variable symbol	Variable Definition
Dependent Variable	Debt financing cost	*Cost1*	next year's finance cost / total liabilities at the end of the period
		Cost2	next year's (interest expense + fee expense + other finance costs) / total liabilities at the end of the period.
Independent Variable	Whether the industry issues Green bonds	$Green_i \times Post_t$	$Green_i$ represents a firm issues green bond in year t. Other firms in the same industry are 1 after year t and 0 otherwise; $Post_t$ takes the value of 1 in the treatment group if other firm iin the same industry issues bonds after the time t when the industry first issues green bonds and 0 otherwise
Firm characteristics Control Variables	Firm Size	*Size*	Natural logarithm of annual total book assets
	Financial Leverage	*Lev*	Year-end total liabilities / Year-end total assets
	Profitability	*ROA*	Net Profit to Total Assets
	Growth	*Growth*	(Operating Income -Previous Period Operating Income)/Previous Period Operating Income
	Asset Turnover	*Turnover*	Ratio of operating income to total assets
	Fixed Assets	*Property*	Fixed Assets to Total Assets
Bond Characteristics Control Variables	Credit Rating	*CreditRating*	Using debt rating from CCC-AAA, with "+" and "-" fine tuning, assigned 1-12 to indicate the rating from low to high.

	Maturity	*Maturity*	The natural logarithm of the maturity of the bond issue (in years).
	Issue Size	*Proceeds*	Natural logarithm of bond issue size (millions of dollars).
Fixed Effects	Industry Variables	*Industry*	Dummy Variables

4 Empirical Analysis

4.1 Descriptive statistics

Table 2 lists the descriptive statistics results of the main variables. The mean values of *Cost1* and *Cost2* are 0.0167 and 0.0231 respectively, indicating that the average debt financing cost of enterprises issuing bonds is 1.67% and 2.31%. The mean value of $Green_i \times Post_t$ is 0.2900,indicating that 29% of the firms will be affected by the issuance of green bonds by their peers. The mean value of the debt rating (*CreditRating*) of the sample firms is 11.43, which indicates that most of the firms have high credit ratings, mainly concentrated in the AA and AA+ levels. Among the control variables of enterprise characteristics, the average financial leverage (*Lev*) of enterprises is 63.50%, which indicates that on average 60% of the capital of enterprises is borrowed from the outside world, and some enterprises even reach a gearing ratio of 111.7%, which is insolvent and has a higher financial risk.The average profitability (*ROA*) of enterprises is 2.78%, which indicates that the efficiency of the use of assets and the profitability of the majority of enterprises are low.The growth capacity (*growth*)of enterprises is 2.78%, which indicates that the operating income of the enterprise is growing steadily and the development trend is better.The average values of *Turnover* and *Property* are 52.20% and 17.50% respectively, which indicates that the asset management efficiency of the enterprise is low.

Table 2. Descriptive statistics results of main variables

Variables	Observed value	Mean value	Standard Deviation	Minimum value	Maximum value
Cost1	1,439	0.0167	0.0133	-0.0338	0.0665
Cost2	1,439	0.0231	0.0117	0.0003	0.0644
$Green_i \times Post_t$	1,439	0.2900	0.4540	0.0000	1.0000
CreditRating	1,439	11.4300	0.8280	4.0000	12.0000
Maturity	1,439	5.3600	0.3240	0.0000	5.5490
Proceeds	1,439	10.2100	0.5790	8.2430	11.0300
Size	1,439	10.8300	0.7060	9.2120	12.3400
Lev	1,439	0.6350	0.1460	0.1850	0.8170
ROA	1,439	0.0278	0.0357	-0.3820	0.2480
Growth	1,439	0.2310	1.428	0.7680	1.9063
Turnover	1,439	0.5220	0.6000	0.0189	3.7190
Property	1,439	0.1750	0.1750	0.0003	0.8660

4.2 Basic regression results

Table 3 explores the industrial spillover effect of the impact of green bonds on the debt financing cost of other firms in the same industry. The results of the first two columns show that the coefficients of $Green_i \times Post_t$ without control variables are -0.0065 and -0.0054 respectively, and they are all significantly negative at 1%.Then after adding the effects of bond issuance

period, issuance size, financial leverage, total asset profit margin, operating income growth rate, total asset turnover, fixed capital ratio and company size, *Cost1* and *Cost2* are still at 1% significantly negative. This indicates that the conclusion is valid for both methods of calculating debt financing cost.That is, the issuance of green bonds can effectively reduce the debt financing cost of enterprises in the same industry, which in turn will enable enterprises to get more financing security and obtain more financial support.

Table 3. Regression results of industrial spillover effect of green bond issuance

Variables	*Cost1*	*Cost2*	*Cost1*	*Cost2*
$Green_i \times Post_t$	0.0065*** (-6.24)	-0.0054*** (-5.0288)	-0.0041*** (-3.97)	-0.0038*** (-3.49)
CreditRating			-0.0005 (-1.16)	-0.0009* (-1.95)
Maturity			0.0014* (1.70)	0.0023*** (2.74)
Proceeds			0.0004 (0.88)	-0.0001 (-0.11)
Lev			0.0172*** (5.72)	0.0036 (1.13)
ROA			-0.0214** (-2.29)	- 0.0438*** (-4.41)
Growth			-0.0002 (-0.86)	-0.0005** (-2.53)
Turnover			0.0014** (2.26)	0.0000 (0.04)
Property			0.0123*** (5.07)	-0.0013 (-0.51)
Size			-0.0057*** (-8.86)	-0.0022*** (-3.15)
_cons	0.0187*** (46.3588)	0.0246*** (59.7904)	0.0609*** (6.84)	0.0442*** (4.67)
Industry	Yes	Yes	Yes	Yes
N	1439	1439	1439	1439 1439
R.sq	0.470	0.301	0.535	0.335
Adj.Rsq	0.438	0.256	0.506	0.293

Note: Numbers in parentheses denote t-values, * denotes p<0.1, ** denotes p<0.05, *** denotes p<0.01, which are significant at 10%, 5%, and 1% levels respectively.

4.3 Robustness test.

1. Propensity score matching

In order to exclude the possible influence of certain corporate characteristics on the experiment, this paper adopts the propensity score matching method to match 1:1 nearest distance of the debt issuing enterprises, and selects enterprise size (*Size*), capital structure (*Lev*), and return on equity (*ROE*) as covariates to be matched, and ultimately obtains 746 bond observations, and estimates their correlation by using PSM-DID differencing method. The results show that the coefficients of $Green_i \times Post_t$ are significantly negatively correlated and tested at 1% significance level. The results are shown in Table 4, with the first two columns being the PSM-DID regression results.

2 Changes in debt financing cost measures

To ensure the robustness of the results, this paper changes the method of measuring the debt financing cost of enterprises, which is based on the model proposed by Zhou Kaitang et al. (2017)[35], i.e., to calculate by dividing the enterprise's interest expense by the average of long-term plus short-term liabilities as *Cost3*. In this case, short-term liabilities are short-term borrowings in the balance sheet, and long-term liabilities include long-term borrowings in the balance sheet, long-term borrowings due within one year, bonds payable and other forms of long-term liabilities. After re-regression analysis, we find that the coefficients for $Green_i \times Post_t$ are still significantly negative at the 5% level when controlling for the variables of firm and bond characteristics, as shown in the last two columns of Table 4. This suggests that the conclusion that issuing green bonds significantly reduces debt financing cost for other firms in the same industry is still valid under the *Cost3* measure.

Table 4. PSM-DID and Cost3 regression results

Variables	*Cost1*	*Cost2*	*Cost3*	*Cost3*
$Green_i \times Post_t$	-0.0038*** (-3.25)	-0.0044*** (-3.73)	-0.0053** (-2.0660)	-0.0053** (-2.01)
Controls$_{it-1}$	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
N	746	746	1439	1439
R.sq	0.6053	0.4228	0.135	0.167
Adj.Rsq	0.5669	0.5669	0.084	0.115

Note: Numbers in parentheses denote t-values, * denotes p<0.1, ** denotes p<0.05, *** denotes p<0.01, which are significant at 10%, 5% and 1% levels respectively, the same below.

3. Further Sample Screening

Since green bond issuers are mainly distributed in utilities, industry and other industries besides the financial industry. According to the Wind database, the issuance scale of green bonds of utilities in 2022 reaches RMB 79.190 billion, accounting for 36.96% of the total issuance, second only to the financial industry at 51.61%. Therefore, in order to mitigate the possible impact of industry aggregation, this paper deletes the data of 243 bonds that originally belonged to the bond-issuing enterprises of construction and engineering, electric power, and the relevant comprehensive categories classified according to the fourth level of industry classification in the Wind database, and the scale of green bonds issued by the remaining industries accounted for less than 10% of the overall scale of green bond issuance, which is then re-conducted for the regression analysis, and the results are shown in the first two columns of Table 5.

Meanwhile, in 2016, China's green bonds developed rapidly and became the world's largest green bond market, with its issuance volume accounting for 39.9% of the global total. Therefore, in order to improve the analytical quality of the regression results, the data of 2016-2021 are selected for re-regression by narrowing the sample interval, as shown in the last two columns of Table 5.

Table 5. Robustness test - further screening of the sample

	Excluding industries such as Electricity, Architecture and Engineering		Narrowing the sample interval	
Variables	*Cost1*	*Cost2*	*Cost1*	*Cost2*
$Green_i \times Post_t$	-0.0038*** (-2.96)	-0.0032** (-2.32)	-0.0029** (-2.50)	-0.0028** (-2.36)
$Controls_{it-1}$	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
N	1196	1196	1276	1276
R.sq	0.4985	0.3002	0.5341	0.3492
Adj.Rsq	0.4616	0.2487	0.5020	0.3044

4.4 Analysis of the mechanism of the spillover effect of green bond issuance

Driven by information transfer and competitive pressure, firms in the same industry usually imitate those firms with competitive advantages as well as stronger information channels. Lu Rong et al. (2017) [25]point out that due to reasons such as managerial reputation and information learning, the capital structure of listed companies in China is affected by the capital structure as well as the fundamental characteristics of their peers in the same industry.Duong and McGowan (2015) study the changes in debt maturity structure, finding that controlling for their own characteristics[5], firms exhibit imitation behavior that is significantly correlated with the externality characteristics of their peers.It means a change in decision-making by a firm in an industry affects the mutual decisions of firms.Graham (1999) supports through empirical analysis that herd behavior is closely related to economic activities[9], including investment, prices, and corporate conservatism.Grennan (2019) notes that dividend policy varies to some extent with the prevalence of the same behavior in the reference group containing firms[10], with a "cohort effect".Foucault and Fresard (2014) find that firms' sensitivity to peer stock prices increases with the informativeness of that price[8], and that peers always tend to imitate and learn from each other.Parsons et al. (2014) confirm that, due to the peer effect, firms' engage in misconduct tendency to engage in misbehavior increases as the rate of misbehavior in the same industry rises[14]. Therefore, when a firm in the same industry issues green bonds, other firms tend to engage in imitation decisions for reasons such as competition and information learning, thus increasing the likelihood of their issuing green bonds.

By studying Pevzner et al. (2015)[15], Yang Guochao and Pan Yuzhang (2019)[32], this paper tries to deeply explore the inner mechanism of the industrial spillover effect of green bond issuance, setting up model (2)(3) for testing:

$$Mediation_{it} = \alpha_0 + \alpha_1 Green_i \times Post_t + \sum \alpha_i Controls_{it-1} + \varepsilon_{it} \quad (2)$$

$$Cost_{it} = \alpha_0 + \alpha_1 Green_i \times Post_t + \alpha_2 Mediation_{it} + \sum \alpha_i Controls_{it-1} + \varepsilon_{it} \quad (3)$$

Where $Mediation_{it}$ measures whether other enterprises in the industry will adopt the same green bond issuance strategy (*Green Bond*), if follow the decision, marked as 1, and vice versa, marked as 0.

The test results of the mediating effect of green bond issuance by enterprises are shown in Table 6, and the regression analysis of model (2) is conducted through Logit model.The results in the first column show that the coefficient of $Green_i \times Post_t$ is 4.1447 at 1% significance level under the control of enterprise and industry characteristic variables, which is significantly positive, indicating that the issuance of green bonds by enterprises will significantly enhance the issuance

chances of other enterprises in the same industry. The last two columns are the regression results after *Green Bond* issuance as a mediating variable, we find that the coefficient of $Green_i \times Post_t$ is significantly negative at the 1% level, while the coefficient of *Green Bond* is also significantly negative, indicating that after the enterprise issues green bonds, out of competition and information learning, other enterprises in the same industry will also tend to issue green bonds.

Table 6. Analysis of the mechanism of the spillover effect of green bond issuance

	Whether to choose to issue	Mediating variable regression	
Variables	*Mediation*	*Cost1*	*Cost2*
$Green_i \times Post_t$	4.1447*** (20.51)	-0.0036*** (-3.11)	-0.0034*** (-2.77)
Green Bond	-	-0.0010* (-1.69)	-0.0008** (-2.29)
Controls$_{it-1}$	Yes	Yes	Yes
Industry	No	Yes	Yes
N	1435	1422	1422
R.sq	-	0.5357	0.3348
Adj.Rsq	-	0.5061	0.2924

4.5 Heterogeneity analysis of spillover effects of green bond issuance

1. Industry Heterogeneity.

Referring to the first level of industry classification of Wind database, this paper divides enterprises according to major industries, focuses on material industry and industrial industry, and conducts heterogeneity analysis to explore the differences of these industries, and the regression results are shown in Table 7. The regression results are shown in Table 7. It can be seen from the regression results that both the material industry and the industrial industry are significantly negative, and the spillover effect of the material industry is more significant. Taking into account the environmental problems of the materials industry, while the new materials industry for the development trend, should encourage the materials industry to increase the main body of green bond issuance, on the one hand, to solve the "financing difficulties, financing expensive" problem, enhance the spillover effect to reduce the debt financing cost.On the other hand, to grow the "green economy+new materials industry". and promote the sustainable development of the industry.

Table 7. Industry Heterogeneity Analysis

	Materials		Industrial	
Variables	*Cost1*	*Cost2*	*Cost1*	*Cost2*
$Green_i \times Post_t$	-0.0070*** (-3.67)	-0.0040* (-1.75)	-0.0024* (-1.85)	-0.0035** (-2.18)
Controls$_{it-1}$	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
N	160	160	423	423
R.sq	0.5576	0.2726	0.5106	0.4291
Adj.Rsq	0.4903	0.1619	0.4797	0.3932

2. Environmental performance of other enterprises in the same industry

This paper further explores the impact of enterprises' relevant environmental behavior on industrial spillover effects. In accordance with the "Green Industry Guidance Catalog (2019 Edition)", the bond-issuing enterprises are divided into eco-friendly enterprises and other enterprises.When the main business income of the bond-issuing enterprises is derived from the focus of green industry development, such as clean production, energy saving and environmental protection, the dummy variable of the eco-friendly enterprises (*Environment*) is assigned to 1, and the rest of the enterprises are assigned to 0. At the same time, this paper according to the "Listed Companies Environmental Verification Industry Classification and Management Directory", this paper divides other enterprises in the same industry into polluting enterprises and non-polluting enterprises, and polluting enterprises are assigned a value of 1 when the industry they belong to is one of the 16 industries with high pollution, such as thermal power, pulp, paper, and fermentation, and 0 otherwise.

Table 8 shows the regression results, under the calculation method of *Cost1* and *Cost2* ,$Green_i \times Post_t \times Environment$ is significantly negative at the 1% level, indicating that eco-friendly enterprises have a lower debt financing cost, investors have more trust in them and are willing to ask for a lower risk premium, and have a higher degree of trust in the enterprise. In exploring the difference between corporate issuance of green bonds in polluting and non-polluting enterprises, the coefficient of $Green_i \times Post_t \times Pollution$ is significantly positive, indicating that the debt financing cost is higher for polluting enterprises, and investors need to ask for more risk premium to compensate for it, and the spillover effect of issuing green bonds is also weaker. Comparative studies show that for eco-friendly enterprises, investors are more willing to favor such enterprises given their better corporate image. Therefore, when enterprises issue green bonds, these enterprises have more room for development and more significant spillover effects compared to other types of enterprises.

Table 8. Environmental performance of other enterprises in the same industry

	Eco-friendly enterprises		Polluting Enterprises	
Variables	*Cost1*	*Cost2*	*Cost1*	*Cost2*
$Green_i \times Post_t \times Environment$	-0.0039*** (-3.81)	-0.0040*** (-3.65)		
Environment	-0.0034* (-1.86)	-0.0043** (-2.18)		
$Green_i \times Post_t \times Pollution$			0.0039*** (2.84)	0.0021* (1.67)
Pollution			0.0055*** (2.78)	0.0061*** (2.90)
$Controls_{it-1}$	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
N	1422	1422	1422	1422
R.sq	0.5366	0.3369	0.5345	0.3330
Adj.Rsq	0.5071	0.2947	0.5049	0.2906

5 Conclusions

This paper takes the debt-issuing enterprises of listed companies in China from 2014 to 2021 as the research sample to explore the industrial spillover effect, the mechanism of action, and the heterogeneity analysis of green bond issuance. The research results is as follows.Firstly, there is an industrial spillover effect of green bond issuance in listed companies, and enterprises can significantly reduce the debt financing cost of other enterprises in the same industry by issuing green bonds.The conclusion is still significant after changing the debt financing cost measure, and a series of robustness tests such as the PSM, etc. Secondly, the green bond issuance spillover effect is mainly through learning and competition, which increases the chance of issuance by other enterprises within the same industry.Third, there is industry heterogeneity in green bonds, and the degree of spillover effect varies from industry to industry. Meanwhile, according to the characteristics of enterprises, the industrial spillover effect of green bonds issued by eco-friendly enterprises and non-polluting enterprises is stronger.

The research findings provide some insights into the further development of green bonds from the industrial spillover effect of green bond issuance: (1) Encourage more green bond issuers to optimize the industrial development effect. For companies, green bonds, which are used to finance environmental and climate-friendly projects, its issuance is not only conducive to enhancing the credibility of the enterprise itself, but also transmits a reliable signal of commitment to the environment, which reduces the investment risk of investors, and then feeds back to the enterprise itself, thus reducing the cost of debt financing. At the same time, it can improve market vitality and play a role in improving the environment; (2) Establish and improve the green bond certification mechanism and assessment system, improve the corresponding system of the green bond market, and give more protection to enterprises and investors; (3) improve the information disclosure mechanism related to green bonds, and further strengthen the market supervision to ensure that the green bonds are issued in a compliant and efficient manner, and to enhance their transparency and security, so as to promote the high quality development of the green bond market.

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