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The impact of environmental information disclosure on the cost of green bond: Evidence from China

Ying Tang, Biliang Wang, Ningning Pan *, Zhiyong Li

School of Finance, Southwestern University of Finance and Economics, 555 Liutai Avenue, Wenjiang District, Chengdu, China

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ABSTRACT

In light of the rapid development of the green bond market and the importance of environmental information disclosure (EID) for green bond issuance, this study investigates the association between EID and the financing cost of green bonds. Using a sample of 561 green bonds issued between 2016 and 2020 in China, we use the entropy method to calculate the EID quality index based on a comprehensive evaluating system for green bonds, and then examine the impact of EID quality on the cost of green bonds. The results show that higher EID quality helps to reduce the yield spread of green bonds. These findings hold after addressing potential concerns for endogeneity. Channel tests indicate that information transparency and investors' expected risk play a mediating role in the relationship between EID quality and green bond yield spread. Cross-sectional analysis shows that EID has a greater negative impact on the yield spread of green bonds among those issued by non-financial firms and by issuers with better historical reputation. Overall, our findings highlight the importance of EID in the green bond market and provide insightful implications for market participants and policymakers.

1. Introduction

To cope with climate changes and environmental pollution, many countries around the globe have started to promote a low-carbon lifestyle and sustainable development. As a financial instrument dedicated to this change, green bonds have shown a robust growth, due to the rapid development of green financing all over the world since 2013 (Flammer, 2021). According to the statistics of the Climate Bonds Initiative (CBI), global green bond issuance has achieved USD513bn in 2021, the highest value in the history of the green bond market.

China is the world's fastest growing green bond market. Driven by national policy initiatives and regulations, the annual issuance of China's domestic green bond market has experienced rapid growth since 2016, when the People's Bank of China (PBoC) and the National Development and Reform Commission (NDRC) first issued green bond guidelines to activate the market. Currently, China ranked the second largest green bond market in the world by both cumulative issuance (USD199.2bn) and annual issuance (USD68.2bn) accounts, thus cementing its leading position in the issuance of green bonds (CBI, 2021).[1]

Following the fast-growing trends across global markets, green bonds have attracted increasing attention of researchers, with extant literature investigating the motivation of issuing green bonds (Flammer, 2021; Sangiorgi and Schopohl, 2021), the determinants of green bond pricing (Bachelet et al., 2019; Chang et al., 2021; Wang et al., 2020), and the economic consequences for green bond issuers (Ehlers and Packer, 2017; Tang and Zhang, 2020; Wang et al., 2022). However, the role of the environmental information disclosure (EID) of green bonds issuance is still under-investigated.

One of the major features of green bonds is the disclosure of relevant environmental information is a compulsory prerequisite for green and environmental projects to successfully raise funds. EID is an efficient way to mitigate information asymmetry between issuers of green bonds and investors. Complete and detailed EID facilitates an investor's understanding of a new green project. A report by CBI reveals that at least USD12.4 billion were in fact allocated to eligible green projects out of the total USD24.5 billion of Chinese green bonds that failed to meet the international criteria in 2019, possibly due to lack of sufficient

* Corresponding author at: School of Finance, SWUFE, 555 Liutai Avenue, Wenjiang, Chengdu, Sichuan, China.
E-mail addresses: tangying@swufe.edu.cn (Y. Tang), ningnpan@swufe.edu.cn (N. Pan), liz@swufe.edu.cn (Z. Li).

[1] China Green Bond Market 2021 Research Report can be available on the website of Climate Bonds Initiative: https://www.climatebonds.net/files/reports/cbi_china_sotm_2021_0.pdf

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disclosure on the use of proceeds (CBI, 2020).[2] This also highlights the importance of EID in green bond issuance.

Greenwashing may be an important concern for green bond financing. Issuers may try to create an image of sustainable performance but poorly performing in environmental behaviors (Delmas and Burbano, 2011). In an attempt to minimize greenwashing concerns, green bond issuance has to be in accordance with regulatory requirements both in China and in the global green markets, and the majority of green bonds also have third-party certification. Prior literature documents that hard environmental disclosure based on clear and verifiable data can effectively mitigate greenwashing risk (Clarkson et al., 2008). With this in mind, we suggest that green bonds represent fewer greenwashing concerns and are therefore more suitable for studying EID than most other types of bonds. As such, clarifying the benefits of green bond EID and its impact may not only help market participants to understand the larger guiding principles of the climate bond market but also set out concrete implications for regulators and managers, thus encouraging better governance.

We use a set of unique, hand-collated data to measure the EID quality of green bonds, based on a sample of 561 green bonds issued within China between 2016 and 2020. In this paper, the list of green bonds is obtained from the Wind database, which labels bonds that meet the "green" criteria set out by the authorities with a green flag. First, we construct a comprehensive evaluation system for the EID quality of green bonds. Second, we empirically examine the relationship between EID quality and the yield spread of green bonds. Overall, the findings show that higher EID quality helps to reduce the cost of green bonds. Third, cross-sectional analysis shows that the negative association between EID quality and the financing cost of green bonds is more pronounced among those issued by non-financial firms, and by issuers with better historical reputation. However, we do not observe a significant difference among green bonds with third-party certification and those not, and no matter whether the green bond is issued by a first-time issuer or not. Our findings are robust to endogeneity checks and robustness tests.

This paper contributes to the literature in the following ways. First, this study is the first study to evaluate the EID quality for green bonds. Given that there is no commonly accepted definition of green bonds yet or the EID requirements, it is a great challenge to do this work. We choose the Chinese green bond market as the context, and propose an evaluation system with 6 primary indicators and 18 secondary indicators based on both international and Chinese regulatory documents on green bonds. Second, we are the first to investigate the impact of EID on the cost of green bond. Extant literature is mainly concentrated on the impact of corporate EID on the cost of debt financing (Fonseka et al., 2019; Luo et al., 2019). More recently, several studies investigate the impact of ESG on the cost of bonds (Yang et al., 2021; Baldi and Pandimiglio, 2022). At various with past literature, our work highlights the crucial role of EID for green bond issuance and the benefits of reducing the cost of green bonds for firms. Thirdly, we also investigate whether the association between EID quality and the cost of green bonds is moderated by bond and issuance level characteristics, which helps to enhance the understanding the impact of EID quality on the cost of green bonds.

The rest of the paper is structured as follows: Section 2 is a literature review, leading to the research hypotheses. Section 3 introduces the methodology, including data and sample used, as well as the variables and models. Section 4 presents empirical results. Section 5 is further analysis, including channel test and cross-sectional analysis. In last section, the results are discussed and future research directions are outlined.

[2] China Green Bond Market 2019 Research Report can be available on the website of Climate Bonds Initiative: https://www.climatebonds.net/resources/reports/china-green-bond-market-2019-research-report

2. Literature review and hypotheses

2.1. Green bonds

Green bonds have emerged as a new financial tool to respond to sustainability themes, by financing climate-related or environmentally friendly projects (Ehlers and Packer, 2017; Gianfrate and Peri, 2019; Russo et al., 2021). The issuance of green bonds may be driven by underlying motivations, signaling their commitment toward the environment and accessing a cheaper source of capital (e.g., Flammer, 2021).

Some literature studies the stock market reaction to the green bond issuance and provide supportive evidence for the signaling argument. Wang et al. (2020) examine both the debt and stock market reaction to corporate green bond issuance and suggest that firms benefit from issuing green bonds with a lower cost of debt and positive stock returns. In line with these findings, Tang and Zhang (2020) suggest that firms' issuance of green bond is beneficial to shareholders in terms of higher stock prices, positive stock returns, stock liquidity and institutional ownership. More recently, Flammer (2021) provides evidence suggesting that corporate green bonds serve as a credible signal of companies' commitment toward the environment.

For the cost of capital argument, prior literature investigates the pricing of green bonds. Some studies examine the potential factors affecting the yield spread of green bonds, including credit rating, corporate social responsibility performance, green certification, issuer ownership, liquidity risk, etc. (Hachenberg and Schiereck, 2018; Febi et al., 2018; Li et al., 2020). Further studies have investigated whether green bonds are priced at a premium compared to non-green bonds and their findings are mixed. Some provide supportive evidence for the green premium that green bonds are priced at a lower yield spread than non-green bonds (Baker et al., 2018; Karpf and Mandel, 2018; Zerbib, 2019; Wang et al., 2020). However, some recent studies find that green and non-green bonds follow identical pricing (Larcker and Watts, 2020; Flammer, 2021).

2.2. EID and green bond financing

The vital role of information disclosure in affecting the cost of capital has been documented in extant literature. In studies exploring the link between EID and corporate financing costs, scholars have firstly examined the impact of corporate EID on the cost of equity financing. For instance, Botosan (1997) find an increase in the quality of corporate information disclosure could significantly reduce the cost of equity for firms. Botosan and Plumlee (2002) reached a similar conclusion based on enterprises selected from 43 different industries between 1986 and 1996. Plumlee et al. (2015) found that an active disclosure of soft information lowered the corporate cost of capital, while a more passive disclosure of such information actually increased the cost. Dhaliwal et al. (2011) find that initiating CSR disclosure is associated with a reduced cost of equity capital.

Academic focus also stretches to the cost of debt depending on EID. Based on the data collected from 103 US-listed companies, Sengupta (1998) discovered that quality of information disclosure could in fact reduce the cost of debt. Easley and O'Hara (2004) put forward the idea that good disclosure could significantly reduce the financing cost. Bharath et al. (2008) found that the lower the quality of disclosure from a company, the higher the probability that it will fall prey to problems such as shorter credit periods and higher interest rates in loan contracts. Based on a study of Chinese energy companies between 2008 and 2014, Fonseka et al. (2019) find that EID exerted a negative impact on the cost of debt. The academic community therefore shares a consensus on the benefits that information disclosure can bring to a given company. Recent studies show that better CSR or ESG disclosure also reduces the cost of debt, due to that firms' assurance alleviates debtholders' concerns on their engagement in environmental issues (Chi et al., 2020; Raimo et al., 2021; Apergis et al., 2022).

Existing studies on EID and the cost of debt are primarily conducted at the corporate level. Few studies pay attention from a bond perspective. This paper attempts to supplement the existing literature on EID and green bond financing by examining the link between EID quality and the yield spread of green bonds. We suggest that the higher the EID quality during green bond issuance, the lower the yield spread of green bonds.

Firstly, information asymmetry exists between debtholders and bond issuers. Since green bonds are still relatively new to the capital market, information asymmetry may be much severer, given the long maturities and unfamiliar features of the bonds. In this case, investors may increase the risk premium, which in turn increases the cost of debt for green bond issuers. However, EID can act as a sound communication between green bond issuers and investors. This may improve investors' attitudes toward investment, and curb their demands for a risk premium. For example, in the work of Benlemlih et al. (2018), a negative and significant relation between environmental disclosure and potential risk to a firm has been found.

Secondly, following the signaling argument, positive EID could be a valuable signal to shape the investors' views of green bond environmental commitment (Lyon and Montgomery, 2015). By releasing sufficient and verifiable information to signal their commitment to undertake investments in green projects and improve their environmental performance, green bonds issuers are more likely to persuade investors (Flammer, 2021). In other words, when green bond issuers provide a timely and high-quality EID, including reliable information on subjects such as the use of proceeds, the development of green projects, environmental benefits, and regular updates, the investors should take this as a positive signal, which is conductive to reduce the cost of green bonds.

Thirdly, socially responsible investing literature documents that a subset of investors is willing to accept investments with lower financial performance that meet social objectives (e.g., Renneboog et al., 2008; Díaz and Escribano, 2021). Socially responsible investors are not only concerned about financial performance, but also non-financial performance, like the impact on the social relations and the environment. Therefore, green bonds with high-quality EID can attract more socially responsible investors. Given the greenness of green bonds and their associated projects, socially responsible investors may trade off the financial dimensions and the non-financial dimensions of performance. Taken together, we propose the following hypothesis:

Hypothesis 1. EID quality during green bond issuance is negatively associated with the yield spread of green bonds.

3. Methodology

3.1. Data and sample

International standards on green bonds mainly include the *Green Bond Principles* (GBP) published by the International Capital Market Association (ICMA)[3] and the *Climate Bonds Standard* (CBS) published by the Climate Bonds Initiative (CBI).[4] In defining green bonds, in the GBP, the proceeds of green bonds are required to either partly or fully fund green projects and satisfy major criteria (ICMA, 2018). In the CBS (2017), for instance, it is stated that green bonds must fulfil the requirements of climate bonds and also receive relevant approval from the board of Climate Bond Standards.

In 2015, the *China Green Bond Endorsed Project Catalogue* was issued by the People's Bank of China (PBoC) as the first official regulatory document of green bonds in China,[5] wherein green bond investment projects are classified into 6 main categories and 31 sub-categories. In 2021, Chinese regulatory bodies produced a new version of the list which contains 6 main categories and 25 sub-categories. Moreover, the *Green Bond Issuing Guidelines* issued by the National Development and Reform Commission of China states that a green bond is a corporate bond that requires the investment of its raised funds in 12 highly-endorsed green-cycle, low-carbon development projects.[6]

Generally speaking, a bond is referred to as “green” if the proceeds from the bond's issuance are used for green industries, green projects, or green economic activities.[7] In this paper, data on green bond at issuance is obtained from the Wind database. In this database, a green flag is attached for (labelled) bonds that meet the green criteria set out by the authorities, who include the PBoC, the National Development and Reform Commission of China, the National Association of Financial Market Institutional Investors, the Shanghai Stock Exchange, and the Shenzhen Stock Exchange. Meanwhile, the database also includes those non-labelled green bonds which are not approved by regulators but nevertheless meet the identifying criteria for green bonds and for investing in green projects (Li et al., 2022). In the Chinese market, these non-labelled green bonds play an important role in funding green projects and reducing carbon emissions.

The selection of Chinese green bonds in this paper also follows these guidelines. As the first green bond was issued in China in 2016, we select green bonds issued in China between 2016 and 2020 as our sample. Specifically, we download the green bond data at the moment of their issuance from the Wind database, and the sample is cross-sectional. The initial green bond sample comprises 1905 bonds including corporate bonds, enterprise bonds, financial bonds, asset-backed securities, and government related bonds. To ensure the availability of environmental information data, as well as financial data related to bond issuers, we exclude the bonds that are floating-rate, non-CNY (Chinese Yuan) denominated, issued by international institutions, green assets-backed securities and any private bonds that do not disclose their information publicly. The final green bond sample consists of 561 bonds issued by 237 issuers, which includes 150 green financial bonds, 229 green enterprise bonds, 98 green corporate bonds and 84 green mid-term notes. From among these, 214 green bonds were issued in the Shenzhen and Shanghai Stock Exchanges and 347 green bonds were issued in the inter-bank market. Issuers of sample green bonds come from a wide array of industries, although financial institutions account for a dominant proportion (28.88%). A detailed sector breakdown of green bond issuers is shown in Fig. 1.

Our data on bond characteristics, issuer financial information and the China Green Bond Index are obtained from the Wind database. Treasury yield rates are collected from ChinaBond.com.cn. The required data for measuring the EID quality of green bonds have been hand-collected from issuers' annual reports, bond prospectuses and third-party certification reports. Macro-economic data including CPI index and GDP is obtained from the National Bureau of Statistics.

3.2. EID quality of green bonds

In the international normative documents of green bonds, EID is regarded as being a key element. Specifically, the GBP requires green

[3] The Green Bond Principles 2018 can be available on the website of International Capital Market Association: https://www.icmagroup.org/green-social-and-sustainability-bonds/green-bond-principles-gbp/

[4] Climate Bonds Standard V3.0 can be available on the website of Climate Bonds Initiative: https://www.climatebonds.net/climate-bonds-standard-v3

[5] The China Green Bond Endorsed Project Catalogue (2015) can be available on the government website: http://www.gov.cn/xinwen/2015-12/22/content_5026636.htm

[6] The Green Bond Issuing Guidelines can be available on the government website of the National Development and Reform Commission of China: http://zfxxgk.ndrc.gov.cn/web/iteminfo.jsp?id=2363

[7] In China, the proportion of funds invested in green industrial projects must not be <50%.

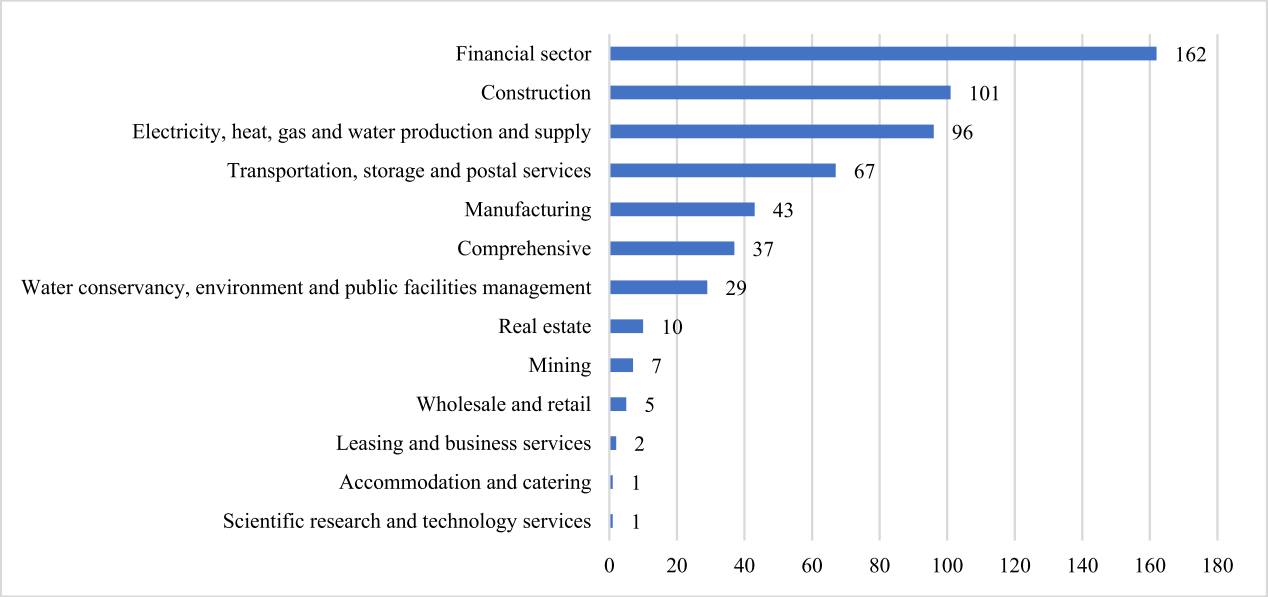

Fig. 1. Sector breakdown of Chinese Green Bond Issuers.

bond issuers to disclose environmental information to the public on a yearly basis until the raised fund is used up. The CBS has an even higher standard in terms of the disclosing frequency. It requires issuers to carry out disclosure at least once a year and to disclose the quantitative objectives of environmental benefits prior to the green bond's issuance. Additionally, regulatory authorities in some countries, such as Japan, and some international stock exchanges, such as the New York, London or Luxembourg Stock Exchanges, have also laid out requirements for the EID of green bonds.

In China, green bonds are mainly regulated by three ministry-level authorities, and thus the requirements for the EID are not uniform during our sample period.[8] More specifically, the EID of green financial bonds needs to comply with the *Notice of Issues Concerning the Issuance of Green Financial Bonds*, issued by the People's Bank of China in 2015.[9] The EID of green debt financing instruments registered and issued by non-financial enterprises in the inter-bank bond market needs to comply with the *Guidelines on the Business of Green Debt Financing Instrument of Non-financial enterprises* issued in 2017.[10] To comply with the *Green Bond Issuing Guidelines*, both the Shanghai and Shenzhen Stock Exchanges published detailed programs in March 2016 and in April 2016 respectively, asking green corporate bond issuers to disclose environmental information for investors.

There are three main approaches to measure EID quality in extant studies. The first is to adopt the evaluation results issued by professional and authoritative agencies. The second is to obtain the relevant information either from the issuer's annual financial reports or social responsibility reports, and to generate proxies to reflect the EID quality. For example, some scholars (e.g. Bhattacharya et al., 2003) use the quality of surplus disclosure in listed companies' financial reports to measure their quality of information disclosure. The third approach is content analysis, that is, setting multiple dimensions of evaluation indicators, assigning weights to these different indicators based on their information disclosure, and finally obtaining a score for the overall disclosure quality. The above three approaches each have their own advantages and disadvantages when applied in the context of green bonds. We adopt the content analysis to comprehensively measure the quality of EID of green bonds in this paper.

In the content analysis, we need to assign weights to our indicators, and there are several approaches, including (but not limited to): 0–1 scoring, quantitative scoring and qualitative scoring. Among these, the 0–1 scoring method is simply a dummy to denote whether a certain piece of information is disclosed or not, but it cannot reflect the precise quality of details disclosed with the different indicators, nor the differences between them (Halme and Huse, 1997). Quantitative scoring is a measure of the number of words, sentences, pages and so forth which come together to construct an information set, but the quality of information is still in doubt (Hooks and van Staden, 2011). As a result, the qualitative scoring method, focusing on the actual content of information was proposed, allowing us to consider the type and level of details for the information disclosed, by assigning different weights to each indicator. Relevant studies employing qualitative scoring include Iatridis (2013) and Fonseka et al. (2019). As such, we will use the qualitative scoring method to evaluate the EID quality of green bonds.

As introduced above, both international and Chinese regulatory documents on green bonds have common requirements on the basic conditions, the management and use of proceeds, and the overall environmental benefits of green projects. We studied them carefully and followed all necessary requirements in order to quantify information disclosure quality, and now propose an evaluation system for green bonds, which includes 6 primary indicators and 18 secondary indicators. The descriptions of indicators and criteria are shown in Table 1. We collected data to evaluate the EID quality of green bonds manually from the annual reports of issuers, bond prospectuses and third-party certification reports.

A two-person independent scoring approach is adopted in this study. Two raters were asked to read the full reports for each green bond issuance in order to familiarize themselves, and then contrast each item in the "Indicator system for evaluating EID quality of green bonds" to capture and mark out the required information, and also strengthen semantic validity. Following Wong et al. (2018), we adopt a two-stage scoring process. In the trial scoring stage, the two scorers finished the scores of 113 green bonds (representing 20% of the total number of

[8] In 2021, The people's Bank of China, the Development and Reform Commission and the China Securities Regulatory Commission issued *the Catalogue of Green Bond Support Projects (2021 version)*. And in 2022, the Green Bond Standards Committee issued *China Green Bond Principles*. These documents mark the unified supervision of China's green bond market.

[9] The Notice can be available in Note 5.

[10] The Guidelines can be available on the website of the National Association of Financial Market Institutional Investors: http://www.nafmii.org.cn/ggtz/gg/201703/t20170322_60431.html

Table 1
Indicator system for evaluating EID quality of green bonds.

Primary indicator	Total Score	Secondary indicator	Criteria	Point range
Environmental Awareness and Responsibility	9	Corporate Social Responsibility Report	Yes-1, No-0	0–1
		Environmental Policies	No disclosure-0, Simple Qualitative Information-1, Detailed Qualitative Information-2	0–2
		Green Strategies	No disclosure - 0, Simple Qualitative Information-1, Detailed Qualitative Information-2, Qualitative and Quantitative Information-3	0–3
		Negative Information such as Punishment	No disclosure-0, Simple Qualitative Information-1, Detailed Qualitative Information-2, Qualitative and Quantitative Information-3	0–3
Basic Description of Green Projects	7	Green Bond Prospectus	Yes-1, No-0	0–1
		Basic Description of Green Projects	No disclosure-0, Qualitative Information-1, Quantitative Information-2, Qualitative and Quantitative Information-3	0–3
		Analysis of Typical Cases	No disclosure-0, Qualitative Information-1, Quantitative Information-2, Qualitative and Quantitative Information-3	0–3
Use and Management of Raised Funds	11	Use of Proceeds	Qualitative Information-1, Quantitative Information-2,	1–2
		Breakdown of Investment of Proceeds	No disclosure - 0, Overall disclosure-1, Disclosure by Class-2, Disclosure by Category-3	0–3
		Reporting Frequency of the Use of Proceeds	No disclosure-0, Yearly disclosure-1, Half-yearly disclosure-2, Quarterly disclosure-3	0–3
		Management of the Use of Proceeds	No disclosure-0, Simple Qualitative Information-1, Detailed Qualitative Information-2, Detailed Qualitative and Disclosure of Bank Account Number-3	0–3
Functional Organization	9	Green Bond Management	Disclosure of Information about Corporate Governance Structure-1, Simple, Qualitative Disclosure of Green Bond Management Structure-2, Detailed, Qualitative Disclosure of Green Bond Management Structure-3	1–3
		Criteria for Project Selection	No disclosure - 0, Simple Qualitative Information-1, Detailed Quantitative Information-2, Detailed Qualitative and Quantitative Information - 3	0–3
		Decision-making process of Projects	Brief description of investment decision-making system as robust-1, Brief description of the Decision-making Process-2, Detailed Description of the Decision-making Process-3	1–3
Environmental Benefits	7	Environmental Benefits of Green Projects	No disclosure-0, Overall Qualitative Information-1, Partial Qualitative Information by Category-2, All Qualitative Information by Category-3, Overall Quantitative Information-4, Partial Quantitative Information by Category-5, All Quantitative Information by Category-6, All Quantitative Information by Category Plus Calculation Method-7	0–7
Continuous Reporting and Disclosure	9	Information Disclosure System	No disclosure-0, Simple Qualitative Information-1, Detailed Quantitative Information-2	0–2
		Third-party Certification Report	Non-existent-0, Certified but not disclosed-1, Simple Qualitative Information-2, Simple Quantitative Information-3, Detailed Qualitative and Quantitative Information-4	0–4
		Tracking Assessment	Non-existent-0, Simple Qualitative Information-1, Detailed Qualitative Information-2, Qualitative and Quantitative Information-3	0–3

green bonds), and we conducted an inter-rater reliability test to verify the percentage of agreement between them. Cronbash's α value is above 0.9, and Cohen's kappa is above 0.8, thus ensuring the inter-coder reliability of the scores. Only then are the two scorers able to start the formal scoring. Finally, we use the average value of both scores as the measure of EID quality for each green bond.

By applying this scoring system, we can create a standardized and consistent score for each green bond, and thus represents a powerful tool for ranking the bonds. The higher the positive score, the better EID quality at the green bond level. To overcome the limitation of subjectivity of the weights on the indicators, we use the entropy method to calculate the weight of each indicator (Liu and Zhang, 2011; Shi et al., 2022). Specifically, the calculation steps are as follows:

First, the value of all the indicators is normalized as the following transforming formula, when we take it that all of these indicators are positively related to EID quality:

$$x_{ij}^{'} = \frac{x_{ij} - min\{x_{ij}, \ldots x_{nj}\}}{max\{x_{1j}, \ldots x_{nj}\} - min\{x_{1j}, \ldots x_{nj}\}} \quad (1)$$

where $i = 1, 2, \ldots, n$; $j = 1, 2, \ldots, 18$.

Second, we calculate the ratio of the value of each bond to the sum of all the values for each indicator.

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (2)$$

where $i = 1, 2, \ldots, n$; $j = 1, 2, \ldots, 18$.

Third, we calculate the entropy of each indicator. A smaller entropy of an indicator indicates a greater variation of its value, which provides more information and thus accounts for a greater weight in the comprehensive evaluating system.

$$e_j = -k\sum_{i=1}^{n} p_{ij} ln(p_{ij}) \quad (3)$$

where $k = 1/ln(n)$, i=1, 2, …, n ; $j = 1, 2, \ldots, 18$.

Lastly, we calculate the weight of each indicator using the following formula:

$$w_j = \frac{1 - e_j}{\sum(1 - e_j)} \quad (4)$$

where $j = 1, 2, \ldots, 18$.

The calculation results of weights are shown in Table 2, and the distribution of the final scores measuring the EID quality of all sample green bonds are shown in Fig. 2.

3.3. Variables

Financing cost of green bonds. This paper follows the practice of most related studies (Boubakri and Ghouma, 2010; Meng and Yin, 2019) and uses yield spread in the primary market to measure the financing cost of green bonds. We calculate the yield spread of green bonds (*spread*) by the difference between the yield to maturity on a treasury bond issued at the same time with a comparable maturity (r) and the coupon rate of green bonds (R). Given the tax exemption of treasury bonds, we use the bond rate of China Development Bank as the benchmark in the robustness tests, to ensure the reliability of our results.

Control variables. Following prior literature (Husted and de Sousa-Filho, 2019; Li et al., 2020; Fatica et al., 2021), we control for bond-level characteristics, including maturity, issuance amount, debt credit rating and whether a put/call option is involved in the bond contract. We also control for issuer-level characteristics, including firm size, leverage, ROE and cash holding. We also control for macro-economic variables that may affect the cost of green bond, including CPI and GDP growth. In addition, we control for the impact of green bond market environment on the cost of green bonds, and use the China Green Bond Index for each issuing date as the indicator.[11] All variables are shown in Table 3.

Table 2
Weighting results based on the entropy method.

Primary indicator	Weight	Secondary indicator	Weight
Environmental Awareness and Responsibility	0.3821	Corporate Social Responsibility Report	0.2094
		Environmental Policies	0.0303
		Green Strategies	0.0426
		Information such as Punishment	0.0998
Basic Description of Green Projects	0.0872	Green Bond Prospectus	0.0024
		Basic Description of Green Projects	0.0328
		Analysis of Typical Cases	0.0520
Use and Management of Proceeds	0.1114	Use of Proceeds	0.0053
		Breakdown of Investment of Proceeds	0.0171
		Reporting Frequency of the Use of Proceeds	0.0119
		Management of the Use of Proceeds	0.0770
		Green Bond Management	0.0201
Functional Organization	0.1757	Criteria for Project Selection	0.1316
		Decision-making process of Projects	0.0241
Environmental Benefits	0.0699	Environmental Benefits of Green Projects	0.0699
Continuous Reporting and Disclosure	0.1738	Information Disclosure System	0.0233
		Third-party Certification Report	0.1122
		Tracking Assessment	0.0382

3.4. Model setting

We estimate the following regression model to examine the association between EID quality and the financing cost of green bonds:

$$spread_{i,t} = \beta_0 + \beta_1 EIDS_{it} + \sum bond\_controls_{i,t} + \sum issuer\_controls_{i,t-1} + \sum macro\_controls_{i,t} + \theta_i + \gamma_{i,t} + \phi_{i,t} + \varepsilon_{i,t} \quad (5)$$

where, $spread_{i,t}$ is the yield spread for green bond i; $EIDS_i$ is the EID quality at the moment of the green bond's issuance; $bond\_control_{i,t}$ and $macro\_control_{i,t}$ represent bond-level characteristics and macro-economic variables respectively; $issuer\_control_{i,t-1}$ represents the on-year lagged variables for issuer-level characteristics, including firm size, leverage, ROE and cash holding. Following Flammer (2021) and Fatica et al. (2021), we include Issuer fixed effects to control for time-invariant, unobservable, firm-specific factors that might affect the primary green bond market (θ_i), and also include the interaction fixed effects, Year*Industry ($\gamma_{i,t}$) and Year*Province ($\phi_{i,t}$). $\varepsilon_{i,t}$ is the error term. All continuous variables are winsorized at 1% and 99% to avoid the effect of outliers.

4. Empirical results

4.1. Descriptive statistics

The descriptive statistics of all variables are shown in Table 4. The range of the yield spread is >400 bp, indicating that the financing cost of

[11] This index consists of over 800 green bonds and has been published daily by the China Securities Depository and Clearing Corporation since 2016.

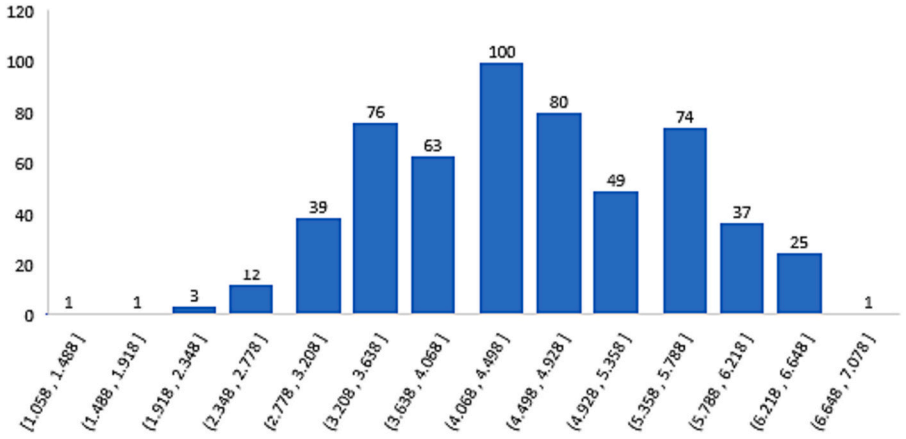

Fig. 2. Distribution of EID quality scores.
This figure is based on the original EID quality scores calculated using the entropy method.

Table 3
Variable description.

Variable	Description
Spread	Yield spread, the difference between the coupon rate at issuance of the green bond and the yield spread of treasury bond with a comparable maturity
EIDS	Quality indicators of EID of green bonds based on entropy method
Rating	Bond rating, AAA is 5, AA+ is 4, AA is 3, AA- is 2, A+ is 1
Maturity	Green bond maturity in years
Amount	Natural logarithm of green bond issuance amount
Call	Dummy variable, which equals 1 if a call option is involved in the green bond contract, and 0 otherwise.
Put	Dummy variable, which equals to 1 if a put option is involved in the green bond contract, and 0 otherwise.
CPI	Monthly CPI on the issue date
GDP	Quarterly GDP index on the issue date
Index	China Green Bond Index on the issue date
Size	Natural logarithm of total assets
Leverage	Liabilities/assets
ROE	Return on equity
Cash	Cash/asset

Table 4
Descriptive statistics.

	Obs	Mean	Std.Dev.	Min	Max
Spread	561	1.608	0.938	0.306	4.446
EIDS	561	4.495	1.002	2.394	6.466
Rating	561	3.098	1.652	0.000	5.000
Maturity	561	5.193	2.537	3.000	15.000
Amount	561	2.412	0.916	0.000	5.298
Put	561	0.253	0.435	0.000	1.000
Call	561	0.125	0.331	0.000	1.000
CPI	561	102.493	0.971	101.400	105.280
GDP	561	105.381	3.206	93.200	107.000
Index	561	157.072	10.160	141.832	171.928
Size	561	6.920	1.704	4.074	12.014
Leverage	561	0.671	0.192	0.256	0.947
ROE	561	0.067	0.057	−0.015	0.198
Cash	561	0.135	0.187	0.000	1.123

This table reports summary statistics for all the variables. All the variables follow definitions in Table 3. All continuous variables are winsorized at the 1% and 99% levels.

green bonds in the sample varies. The EID quality index (*EIDS*) has an average value of 4.495, with a maximum value of 6.466, and a minimum of 2.394. The credit rating (*Rating*) shows that the overall creditworthiness of green bonds when they are issued is relatively high (they are mostly concentrated in AAA). The mean maturity is 5.193 years, indicating that most green bonds are mid-to-long term. We can also observe that few green bonds introduce the call option or the put option.

Table 5 provides the Pearson correlations of variables. The correlation between the main variables is in line with our expectations. Though some of the pairs have high correlations, we further analyze the variance inflation factors (VIF) of all variables and show the results below 5, which reveals a low degree of multicollinearity.

4.2. EID quality and the financing cost of green bond

We ran an OLS regression on our basic model, and the results are reported in Table 6. In Column (1), we include Issuer and Year*Province fixed effect in the regression model and present the results. The coefficient of EIDS is −0.075 and significant at 5% level. These results indicate that the improvement of EID quality for green bonds at issuance lead to a reduction in yield spread. Therefore, Hypothesis 1 holds. From the results of the control variables, green bonds with put option in the bond contract are issued at a lower yield spread. In addition, we can also see that if the green bonds are issued during periods when the China Green Bond Index is higher, the yield spread is lower. We suggest that investor attention increases during these periods, and investors are more likely to ask for lower risk premium (Pham and Huynh, 2020).

Section 3.1 show that our sample covers 561 green bonds, including 150 issued by financial institutions and 411 issued by non-financial enterprises. In China, green bonds issued by financial institutions are currently subject to stricter disclosure guidelines in terms of information disclosure. Therefore, we are concerned about whether investors prize the EID quality for green bonds across types of issuers. We construct a dummy variable, *Type*, which equals 1 if the green bond is issued by a financial institution, and equals 0 if not. Then, we include the interaction term (*EIDS*Type*) between *EIDS* and *Type* in our empirical specification, and the interaction term is the variable of our interest. The results are presented in Column (2) of Table 6. We find that the interaction term has a positive coefficient (significant at 1% level), suggesting that the improvement in EID quality helps to reduce the financing cost among green bonds issued by non-financial enterprises. This is in line with the work of Fatica et al. (2021) that also finds a significant greenium only for non-financial companies. One possible reason for these finding is that it may be more difficult for financial institutions to signal the greenness of issued bonds by improving the EID quality than non-financial companies.

4.3. Endogeneity

In this study, one empirical challenge is that the EID quality is endogenous with respect to the yield spread of green bond, that is,

Table 5
Correlation tests.

	Spread	EIDS	Rating	Maturity	Amount	Put	Call	CPI	GDP	Index	Size	Leverage	ROE	Cash
Spread	1													
EIDS	−0.330***	1												
Rating	−0.008	−0.001	1											
Maturity	0.179***	−0.322***	0.039	1										
Amount	−0.499***	0.137***	−0.168***	−0.045	1									
Put	−0.036	−0.171***	−0.037	0.431***	−0.090**	1								
Call	0.172***	−0.213***	−0.022	−0.037	−0.094**	−0.071*	1							
CPI	0.055	−0.054	0.515***	0.078*	−0.067	−0.097**	−0.055	1						
GDP	0.010	0.016	−0.366***	−0.048	0.039	0.115***	0.071*	−0.767***	1					
Index	0.078*	−0.053	0.720***	0.083*	−0.108**	−0.044	−0.037	0.797***	−0.498***	1				
Size	−0.596***	0.336***	−0.200***	−0.185***	0.713***	−0.150***	−0.199***	−0.121***	0.080*	−0.130***	1			
Leverage	−0.325***	0.327***	−0.210***	−0.391***	0.207***	−0.199***	−0.147***	−0.249***	0.229***	−0.274***	0.454***	1		
ROE	−0.254***	0.361***	−0.251***	−0.417***	0.113***	−0.112***	−0.145***	−0.304***	0.209***	−0.388***	0.219***	0.547***	1	
Cash	0.417***	−0.337***	0.004	0.343***	−0.240***	0.080*	0.228***	0.032	0.024	0.031	−0.438***	−0.529***	−0.371***	1

This table presents the Pearson correlation tests for the variables. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6
OLS results for the impact of EID on the financing cost of green bonds.

	(1)	(2)
VARIABLES	Spread	Spread
EIDS	−0.075**	−0.119***
	(0.037)	(0.030)
EIDS*Type		0.169***
		(0.049)
Rating	−0.084	−0.086
	(0.094)	(0.093)
Maturity	0.025	0.026*
	(0.016)	(0.015)
Amount	−0.034	−0.038
	(0.057)	(0.057)
Put	−0.443***	−0.461***
	(0.094)	(0.092)
Call	0.051	0.023
	(0.205)	(0.213)
CPI	0.070	0.070
	(0.077)	(0.077)
GDP	0.013	0.012
	(0.013)	(0.013)
Index	−0.037*	−0.036*
	(0.020)	(0.020)
Size	0.327	0.764
	(0.776)	(0.823)
Leverage	0.853	0.065
	(1.550)	(1.482)
ROE	0.131	0.070
	(1.632)	(1.637)
Cash	4.013	3.475
	(2.507)	(2.451)
Constant	−3.862	−6.388
	(9.537)	(9.407)
Observations	561	561
R-squared	0.981	0.982
Issuer FE	Yes	Yes
Year*Industry FE	Yes	Yes
Year*Province FE	Yes	Yes

This table reports the estimates of OLS regressions of EID quality on the financing cost of green bonds. Issuer FE is the fixed effect for the company issuing the bond. Year*Industry FE and Year*Province FE are the interaction fixed effects. Variable definitions are shown in Table 3. Robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

simultaneity and reverse causality. Even though we control issuer fixed effect in the baseline analysis, there still can be other uncontrolled bond-level and macro-economic variables affecting the yield spread of green bond. Therefore, we try the following ways to alleviate the endogeneity concerns.

First, we perform an instrumental variable 2SLS regression analysis. In the spirit of the existing literature, notably Larcker and Rusticus (2010), an industry-based average is adopted as the instrument variable. El Ghoul et al. (2011) use the industry average CSR score to investigate the relationship between corporate social responsibility and the cost of capital. Since our sample size is not large and the issuers are concentrated in several sectors such as finance and construction, we use the type-based average of EID score as the instrumental variable. Green bonds in the Chinese market can be subdivided into financial bonds, enterprise bonds, corporate bonds, and medium-term notes. We calculate the average EID score at the green bond type level. One the one hand, green bonds issuers of the same type will be subject to the same regulatory policies, including the requirements of environmental information disclosure. Thus, the type-based average EID score is related to the EID quality of each individual green bond, which satisfies the relevant conditions of an instrumental variable. On the other hand, the type-based average EID score does not directly affect the yield spread of individual green bonds, which also satisfies the exclusion requirements of valid instruments. Our IV is consistent with the approach of Fonseka et al. (2019) who employ the average value for the energy product-year

from EID Composite index to examine the impact of environmental information disclosure on the cost of debt.

The results of the 2SLS regression are reported in Columns (1)–(2) of Table 7. In the first stage regression, the endogenous variable (*EIDS*) is regressed using instrumental variable (*EIDL*) and control variables to obtain the predicted value of EID quality ($\widehat{EIDS}$). We find that our IV (*EIDL*) is positively and significantly associated with the endogenous variable. Kleibergen-Paap rk Wald F-statistics (weak identification test) is 17.180, indicating that the IV is relevant and not weak. In the second stage regression, the yield spread (*Spread*) is regressed using the predicted value ($\widehat{EIDS}$) and control variables. The results show that the negative association between predicted EID quality and the yield spread of green bonds still holds, providing support for our baseline results.

Secondly, we carry out a quasi-natural experiment using a regulatory policy issued by the People's Bank of China. In March 2018, the People's Bank of China issued the *Notice of the People's Bank of China on Strengthening the Supervision and Management of the Duration of Green Finance Bonds*, and at the same time, issued the *Information Disclosure Standards for the Duration of Green Financial Bonds* and the information disclosure report template. The new regulations mean that the information disclosure content of green financial bonds have become more detailed and standardized, which helps to improve the quality of environmental information disclosure. We therefore take this policy as the exogenous shock and investigate the impact of the policy on the cost of green financial bonds. We generate a dummy variable, *Post*, which equals 1 if the green bond is issued after 2018, and 0 otherwise, and construct an interaction term (*Post*Type*) between *Post* and *Type*. We include the interaction term in the baseline model and report the results in Column (3) of Table 7. We can see that the coefficient of *Post*Type* is negative and significant (−0.184), suggesting that the negative impact of EID quality on the cost of green bond is further supported.

4.4. Robustness checks

We ran a series of robustness tests to ensure the reliability of our results.

Table 7
Endogeneity.

	(1)	(2)	(3)
	2SLS-1st stage regression	2SLS-2nd stage regression	Quasi natural experiment
VARIABLES	EIDS	Spread	Spread
EIDL	0.958***		
	(0.231)		
$\widehat{EIDS}$		−0.217***	
		(0.070)	
Post*Type			−0.184**
			(0.093)
Controls	Yes	Yes	Yes
Observations	561	561	561
R-squared	0.954	0.980	0.969
Issuer FE	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	No
Year*Province FE	Yes	Yes	No

This table reports the estimates of 2SLS regressions and the impact of exogenous events. In Column (1), *EIDS* is treated as the endogenous variable, and the type-based average of *EIDS (EIDL)* is used as instrumental variable to predict *EIDS*. Column (2) reports the results of the second stage regressions using *spread* as the dependent variable. Column (3) reports the results of the impact of the exogenous policy on the cost of green financial bonds. Issuer FE is the fixed effect for the company issuing the bond, Year*Industry FE and Year*Province FE are the interaction fixed effects. Variable definitions are shown in Table 3. Robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Firstly, we employ an alternative benchmark to calculate the yield spread of green bonds, namely the China Development Bank bond (*Spread1*) with comparable maturity.[12] In comparison to treasury bonds, China Development Bank bonds are also low risk, but not tax-exempt. We rerun the baseline model and the results are presented in Column (1) of Table 8. We can find that the negative association between EID quality.

In addition, our dependent variable is the yield spread of green bonds. In doing this, an alternative explanation may be that the yield spread of green bond may be driven by green premium. Therefore, we perform additional tests to address the alternative green premium explanation. To obtain a plausible answer to this question, we use a matching methodology to control for the bond issuer and calculates the difference in yield spread between green bonds and matched non-green bonds, and then investigate whether the negative association between EID quality and the yield spread still holds.

In the first step, we match each green bond to a non-green bond issued by the same issuer. Specifically, we follow Larcker and Watts's (2020) and Flammer (2021) and select the nearest neighbor based on a set of covariates, including bond rating, bond issuer (financial or non-financial), issuance amount, issuing date and maturity. This matching procedure provides for each green bond a matched non-green bond by the same issuer that is as similar as possible except for the "greenness". Finally, we obtain 155 green bonds and 88 non-green bonds issued by 74 issuers.

In the second step, we compute the difference in the coupon rates of each matched group (*Spread2*). The results show that the there is no noticeable difference between the yields of green bonds and matched non-green bonds. The mean difference is statistically insignificant (*p*-value = 0.475). Prior literature on green bond pricing provides mixed evidence for the existence of green premium (Karpf and Mandel, 2018; Baker et al., 2018; Zerbib, 2019; Larcker and Watts, 2020; Tang and Zhang, 2020; Flammer, 2021). Our findings are in line with the work of Tang and Zhang (2020), Larcker and Watts (2020) and Flammer (2021), suggesting that the green premium does not exist in the Chinese green bond market. This supports the arguments that investors would not invest in green bonds if the returns are not competitive and green bond issuers would not benefit from a cheaper source of financing by issuing green bonds (e.g., Chiang, 2017). In addition, Sangiorgi and Schopohl (2021) suggest that green bond issuance costs is even higher than those of comparable plain vanilla bonds using survey evidence of global issuers.

In the third step, we use *Spread2* as the dependent variable and rerun the basic model. The results are reported in the Column (2) in Table 8. This indicates that the negative association between EID quality and the yield spread of green bonds still holds.

Secondly, we also employ alternative weighting methods to calculate the EID quality, in order to alleviate any possible impact on our baseline results. Specifically, we use the average weighting method and Principal Component Analysis (PCA) to calculate the EID quality, and then rerun the regression models. The results are shown in Column (3) and Column (4) of Table 8. We observe that the negative association between EID quality and the cost of green bond still holds, thereby supporting our baseline results.

Thirdly, we include Issuer fixed effect and the interaction fixed effect Year*Industry and Year*Province in our baseline regression to control for unobservable factors that might affect the cost of green bonds. We now control for low-order fixed effects of Year and Industry in our robustness checks. The regression results are reported in Columns (5)–(6) of Table 8. From the results, we observe that the coefficient of *EIDS* is both negative and significant, thus supporting H1.

Finally, there are some green bonds which can be traded at both the

[12] Data on the China Development Bank bond is obtained from https://yield.chinabond.com.cn/gkh/yield.

Table 8
OLS results for robustness tests.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Spread1	Spread2	Spread	Spread	Spread	Spread	Spread
EIDS	−0.070***	−0.413*			−0.105**	−0.092*	−0.070*
	(0.026)	(0.229)			(0.047)	(0.047)	(0.041)
EIDA			−2.671***				
			(0.975)				
EIDP				−0.091***			
				(0.035)			
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	561	155	561	561	561	561	444
R-squared	0.982	0.956	0.982	0.982	0.506	0.553	0.977
Year FE	No	No	No	No	Yes	Yes	No
Industry FE	No	No	No	No	No	Yes	No
Issuer FE	Yes	Yes	Yes	Yes	No	No	Yes
Year*Industry FE	Yes	Yes	Yes	Yes	No	No	Yes
Year*Province FE	Yes	Yes	Yes	Yes	No	No	Yes

This table reports the regression results of our robustness tests. Column (1) reports the regression results with alternative measures of yield spread, using the China Development Bank bond rate as the benchmark. Column (2) reports the regression results using the matching and the green premium as the dependent variable (*Spread2*). Column (3) reports the regression results using average weights to calculate the EID quality (*EIDA*). Column (4) reports the regression results using PCA weights to calculate the EID quality (*EIDP*). Column (5) reports the regression results controlling for Year fixed effect. Column (6) reports the regression results controlling for Year and Industry fixed effects. Column (7) reports the regression results with a reduced sample removing green bonds which can be traded at both the inter-bank market and two national exchange markets have been removed. Issuer is the fixed effect for the company issuing the bond, year*industry FE and year*province FE are the interaction terms. Variable definitions are shown in Table 3. Robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

inter-bank market and two national exchange markets (the Shanghai and Shenzhen Stock Exchanges) in our sample, but they are subject to slightly different regulations for each of the exchanges. For further robustness estimation, green bonds in the above case were removed and the remaining 444 samples went through regression analysis. The results are shown in Column (7) of Table 8. The results suggest that the negative relationship between EID quality and the yield spread of green bonds still holds.

5. Further analysis

5.1. Channel test

After documenting the negative relationship between EID quality and the yield spread of green bond, we extend our study by investigating the potential channels via which this negative association happens. Specifically, we propose the following two channels:

The first is the channel of information transparency. Investor uncertainty regarding a firm's value is a key factor driving both managers' disclosure choices and investors' information collection. Nagar et al. (2019) found that managers respond to investor uncertainty by increasing their voluntary disclosures, in an attempt to improve the company's various "information environments". For green bonds with low EID quality, investors may feel that there is less transparency of information disclosure, and are thus motivated to search for more information regarding the green bonds. As documented by Chen and Wu (2022), this kind of increase in retail investor attention may help to lower information asymmetry. We therefore expect that investor attention will increase for green bonds with lower EID quality, and vice versa.

We regress investor attention on the EID quality of green bond to properly investigate whether this channel does indeed exist. For each green bond, we search for news reports containing an abbreviation of the bond in the title, using the best-known news search engine in China, "Baidu News" (http://news.baidu.com), and then screen the news reports by month of bond issue. The Baidu News Search Engine automatically outputs the corresponding number of news stories. We use its natural logarithm (*Attention*) to measure the investor's attention level per green bond. The regression results are reported in Column (1) of Table 9. Consistent with our expectation, we find that the coefficient of

Table 9
Meditation analysis.

	(1)	(2)
VARIABLES	Attention	RiskTdum
EIDS	−0.316**	−0.014*
	(0.150)	(0.008)
Rating	0.109	0.003
	(0.091)	(0.018)
Maturity	0.014	0.003
	(0.018)	(0.004)
Amount	0.147	−0.010
	(0.094)	(0.010)
Put	0.058	−0.006
	(0.165)	(0.041)
Call	−0.913***	−0.017
	(0.269)	(0.069)
CPI	−0.142	−0.002
	(0.121)	(0.011)
GDP	−0.034	−0.001
	(0.021)	(0.002)
Index	0.044*	0.007
	(0.026)	(0.005)
Size	1.987	−0.819*
	(1.390)	(0.482)
Leverage	−3.979	1.800
	(3.755)	(1.679)
ROE	−2.805	4.003
	(4.292)	(3.605)
Cash	4.569	−2.938
	(3.668)	(2.142)
Constant	3.268	4.298
	(14.649)	(3.311)
Observations	561	561
R-squared	0.710	0.988
Issuer FE	Yes	Yes
Year*Industry FE	Yes	Yes
Year*Province FE	Yes	Yes

This table reports the channel tests for the negative association between EID quality and the financing cost of green bonds. Column (1) shows the influence of EID quality on investor attention (*Attention*), and Column (2) shows the influence of EID quality on investors' expected risk (*RiskTdum*). Issuer FE is the fixed effect for the company issuing the bond, while year*industry FE and year*province FE are the interaction fixed effects. Variable definitions are shown in Table 3. Robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

EID quality is negative and significant at the 5% level, indicating that higher EID quality is associated with less investor attention. This supports the notion that information transparency plays a mediating role in the relationship between EID quality and green bond yield spread.

The second channel we explore is that of investors' expected risk. Investor expectations of risk are a key factor which determines the cost of bond financing, and CSR performance has a significant impact on corporate risk taking. Harjoto and Laksmana (2018) document how CSR performance reduces excessive corporate risk taking and thus helps to increase firm value. Prior literature has provided evidence that a better quality of information disclosure can help investors shape their predictions of expected future cash flows, thereby leading to a decline in the cost of capital (Lambert et al., 2007). Therefore, we suggest that EID quality has a significant impact on the cost of green bond, by influencing investors' expectations of risk.

Following prior literature (Boubakri et al., 2013), we use the volatility of firm-level profitability over a four-year period as the measure of issuer risk-taking (*RiskT*). Firm-level profitability is measured as a firm's return on assets (*ROA*). We then generate a dummy (*RiskTdum*), which equals 1 if *RiskT* is above the median, and equals 0 otherwise. We regress issuer risk-taking on EID quality, and the regression results are reported in Column (2) of Table 9. From the results, we observe that the coefficient of EID quality is significantly negative, indicating that higher EID quality is associated with less risk-taking by green bond issuers, through which investors' expected risks are reduced. This supports the idea that issuer risk-taking plays a mediating role in the association between EID quality and green bond yield spread.

5.2. Cross-sectional analysis

5.2.1. Third-party certification

Green bond issuers are voluntary to get a third-party certification. The certification may signal the greenness of the projects for which the bond proceeds are used in a more transparent way. It also alleviates information asymmetry for investors and lowers the greenwashing risk which may affects the yield spread in the green bond market (Xu et al., 2022). Therefore, market participants may react to certified and non-certified green bonds differently. We attempt to investigate whether the third-party certificate moderates the association between EID quality and the yield spread of green bonds.

Although the People's Bank of China and Chinese Banking and Insurance Regulatory Commission encourage green bonds issuers to get third-party certification approved by professional associations, the issuer may still be hindered by the extra costs (Li et al., 2020). In our sample, there are 283 green bonds with a third-party certification,[13] and 278 without a third-party certification. We construct a dummy variable, *Certified*, which equals 1 if the green bond is certified and 0 if else. Then, we include the interaction term between *EIDS* and *Certified* in our empirical specification, and the interaction term is the variable of our interest. The results are presented in Column (1) of Table 10. The interaction term (*EIDS*Certified*) has an insignificant coefficient, suggesting that the impact of EID quality on the yield spread of green bonds is not moderated by the third-party certificate.

[13] For example, Foran Energy issued a green mid-term note (132,000,036.IB) in 2020 and invited China Lianhe Equator Environmental Impact Assessment to give a third-party certification, which is a verification agency recognized by the Climate Bond Initiative and an observer for the Green Bond Principles of the International Capital Markets Association. After comprehensive analysis and evaluation on the use and management of raised funds, project evaluation and screening, information disclosure and reporting, China Lianhe Equator Environmental Impact Assessment documented that the funds raised from the green mid-term note were mainly used for green projects, in line with relevant regulations.

Table 10
OLS results for cross-sectional analyses.

	(1)	(2)	(3)
VARIABLES	Spread	Spread	Spread
EIDS	−0.102**	−0.252**	−0.088**
	(0.045)	(0.107)	(0.039)
Certified	−0.496		
	(0.487)		
EIDS*Certified	0.096		
	(0.089)		
EIDS*CSRdum		−1.150***	
		(0.399)	
First			−0.287
			(0.262)
EIDS*First			0.064
			(0.058)
Controls	Yes	Yes	Yes
Observations	561	98	561
R-squared	0.982	0.993	0.982
Issuer FE	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes
Year*Province FE	Yes	Yes	Yes

This table reports the cross-sectional analyses on the negative association between EID quality and the financing cost of green bonds. Columns (1)–(3) reports the influence of third-party certification, issuer reputation and first-time issuance on the association between EIDS and the financing cost of green bonds. Issuer FE is the fixed effect for the company issuing the bond, Year*Industry FE and Year*Province FE are the interaction fixed effects. Variable definitions are shown in Table 3. Robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

5.2.2. Issuer reputation

A firm's investment in corporate social responsibility (CSR) builds a positive image and provide potential economic benefits to the firm due to a positive reputation effect (Verschoor, 2005). Recent literature provide evidence for the impact of CSR performance on the cost of debt. For example, Ge and Liu (2015) find that better CSR performance is associated with lower yield spreads of new bond issues using a US sample. Gong et al. (2018) also finds that firms with high CSR disclosure quality are associated with lower costs of corporate bonds using a Chinese sample. Therefore, we attempt to investigate whether the reputation effect of CSR performance of issuers moderates the impact of EID quality on the yield spread of green bonds.

We use the CSR rating from Hexun, an independent company that rates CSR performance for listed companies in China, to proxy issuer reputation in the green bond market. A higher rating from Hexun represents a higher CSR performance. Based on the CSR rating, a dummy variable, *CSRdum*, is generated, which equals 1 if the CSR rating is higher than B, and 0 otherwise. Then, we include the interaction term between *EIDS* and *CSRdum* in our empirical specification, and the interaction term is the variable of our interest. The results are presented in Column (2) of Table 10. We find that the interaction term (*EIDS*CSRdum*) has a significant and negative coefficient, suggesting that the impact of EID quality on the yield spread of green bonds is more pronounced for green bonds issued by firms with better reputation.

5.2.3. First-time issuance

The signaling argument suggests that green bond issuance provides a credible signal of an issuer's commitment to the environment, and is expected to elicit a stronger response when the green bond signal is provided to the market for the first time, as seen in Flammer (2021), who documents a stronger market response for first-time issuers. Hu et al. (2022) find that certified green bonds are associated with higher prices when they are issued for the first time. As such, we expect that the first-time issuance of a green bond may affect the association between EID quality and the cost of the bond. Specifically, the negative impact of EID quality on the cost of green bonds is expected to be more pronounced for first-time issuers.

Therefore, we generate a dummy variable (*First*), which equals 1 if the green bond is issued by first-time issuers, and 0 otherwise. We also include the interaction term of this dummy and EID quality (*EIDS*First*) in our baseline model. The regression results are reported in Column (3) of Table 10. We observe that the coefficient of the interaction term is insignificant. This indicates that EID quality is of equal importance, no matter whether the green bond is issued by a first-time issuer or not.

6. Conclusion

In this paper, we first construct an evaluation system for EID quality of green bonds at issuance and then empirically explore the association between EID quality and the yield spread of green bonds, based on the green bonds issued in China between 2016 and 2020. We find that there is a significant negative relationship between the EID quality and the yield spread of green bonds, indicating that the value and importance of the EID quality in the green bond market. To add more insights into the finding, we further examine how the impact of the EID quality on the yield spread of green bonds varies according to bond-level, issuer-level, and external macro environment characteristics. We find that, the negative relationship between EID quality and the yield spread of green bonds is more significant among those issued by non-financial firms, and by issuers with better historical reputation. However, we do not observe a significant difference among green bonds with third-party certification and those not, and no matter whether the green bond is issued by a first-time issuer or not.

These findings may provide implications for market participants and policy makers.

For green bond issuers, they should pay enough attention to EID in issuing green bonds. Our findings show that high-quality EID is helpful to lower the yield spread of green bonds at issuance, even if the issuer has the green bond issuance experience before. Accordingly, green bond issuers should strive to ensure the EID quality by strengthening the disclose of hard and verifiable information, such as the measurement methods and evaluation standards of environmental benefit objectives of green projects. In addition, bond issuers should also attach importance to CSR performance, which is linked to market reputation. Sound reputation capital can promote the mitigating effect of EID quality on the yield spread of green bonds.

For investors, they should embrace socially responsible investment in the wave of sustainable development. In addition to financial performance, investors may also trade off the non-financial dimension of the investments, especially the impact on the environment. More investor attention is helpful to boost the growth of green bond market. In addition, our findings show that third-part certification does not moderate the association between EID quality and the cost of green bonds. We suggest that EID is a credible tool for investors to screen green bonds and associated green projects, which is more important than third-part certification.

For policy makers, our study highlights the importance of EID for green bond issuance. Currently, several problems, such as insufficient mandatory disclosure requirement of green information and inconsistent disclosure standards, prevail in China's green bond market. This leads to the lack of awareness of the issuers of green bonds to actively disclose green information and greater challenge for implementing the regulatory policies. Therefore, we call for the establishment of a unified standard of EID in the green bond market and the improvement of EID system. It would be helpful to incentive bond issuers to improve the EID quality and improve stakeholders' awareness of EID for green bonds.

This study has some limitations which may open up paths for future research. Firstly, our findings may be subject to Chinese institutional environment and may not have a universal effect. Our study for the Chinese green bond market could stimulate future research on this topic in different institutional markets. Secondly, the comparison between green bonds and conventional bonds in terms of EID and the difference in its impacts on yield spread, as described in Flammer (2021), may be worth investigating further. Though the dimensions of the evaluating system are not applicable or available for conventional bonds, Chinese regulators are implementing stricter rules on environmental information disclosure for listed firms. As an extension to the current research, we will be able to more clearly focus on Chinese publicly-listed issuers and compare green and conventional bonds in terms of their disclosure quality.

CRediT authorship contribution statement

Ying Tang: Conceptualization, Writing – original draft, Visualization, Funding acquisition, Supervision, Project administration. **Biliang Wang:** Methodology, Data curation, Software. **Ningning Pan:** Data curation, Investigation, Resources. **Zhiyong Li:** Formal analysis, Writing – review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2023.107008.

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