



# The price of frequent issuance: the value of information in the green bond market

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## Abstract

Information asymmetry related to environmental impacts and greenwashing-related reputational risks poses a key challenge for green bond market development. Information enhancers-such as green labels, certifications, and external reviewers-help reduce information asymmetry, thereby lowering bond yields. This study examines whether frequent green bond issuance, as a new information channel, is priced in as frequent issuers offer greater information transparency and signal stronger environmental commitment. Using global green bond issuance from 2014 to 2019, we found that on average, infrequent green bond issuers pay 114–177 basis points more than frequent green bond issuers. Results from the Blinder-Oaxaca decomposition further show that 8 basis points of this yield difference cannot be explained by common pricing factors, partly reflecting the value of information. These findings show that green bond issuers can cost-efficiently convey information via frequent issuance. Policy makers should encourage frequent green bond issuance to lower information asymmetry, thereby boosting green investment and fostering green recovery.

**Keywords** Green bonds · Information asymmetry · Green recovery · Frequent issuance

**JEL Classification** G10 · G12 · G14 · G18

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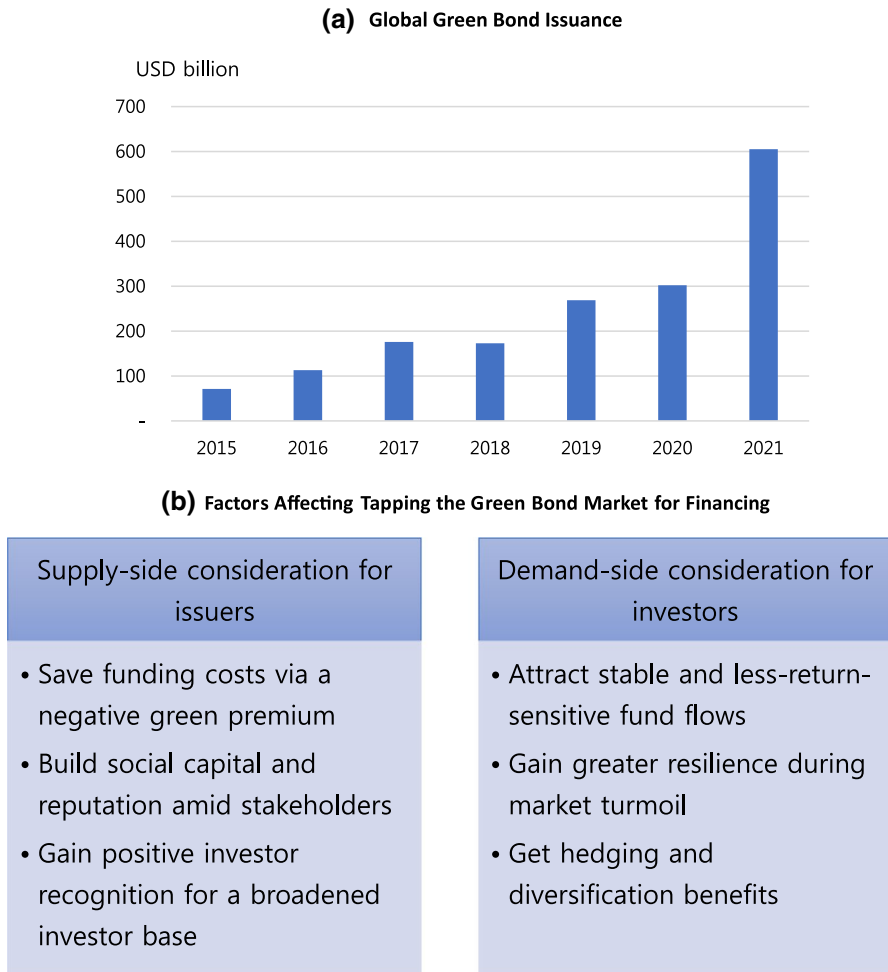
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# 1 Introduction

In recent years, green bonds have become an increasingly important financing instrument to fund projects with positive environmental impacts. According to Bloomberg, the global green bond market reached USD1,501 billion at the end of 2021, more than five times its size of USD274 billion at the end of 2015. A healthy green bond market helps to channel capital from both the public and private sectors to investments with positive environmental benefits, fostering risk sharing in green development and reducing costs to green industries, while driving economic growth. Mohsin et al. (2021a) show that green investments, such as renewable energy infrastructure, not only help improve economic growth but also reduce greenhouse gas emissions. Anh Tu and Rasoulnezhad (2021) find that green bond financing is positively related to energy efficiency. Zhang et al. (2021) find that green public finance, in the form of public spending on human capital and research and development in clean energy technologies, promotes green economic growth. Agyekum et al. (2021) find that the high cost of capital is a critical challenge for long-term investments such as renewable energy. Thus, a well-functioning green bond market can foster the transition to a green growth trajectory. Reflecting the development of the global green bond market, green bond issuance worldwide increased from USD71 billion in 2015 to USD605 billion in 2021 (Fig. 1a).

With increasing awareness of the risks associated with climate change, financial markets have priced in such risks, boosting the supply of and demand for green bonds worldwide. On the supply side, the literature shows that green bond issuers can benefit in several different aspects from issuing green bonds. For example, issuing green bonds may save funding costs through a negative premium, also known as “greenium,” a phenomenon that has been documented multiple times for green bonds relative to similar conventional bonds (see, for example, Ehlers and Packer 2017; Baker et al. 2018; Zerbib 2019; Gianfrate and Peri 2019, and Climate Bonds Initiative (CBI 2021). Green bond issuers can also build social capital by developing a good reputation with stakeholders, which can pay off during the periods of crisis at the market level and firm level (Lins et al. 2017). Issuing green bonds can also gain positive investor recognition and attract a more diversified investor base (Flammer 2021). On the demand side, from an institutional investors’ perspective, investing in green bonds offers several benefits. For instance, investing in socially responsible projects helps to bring stable capital inflows (Ghoul and Karoui 2017; Riedl and Smeets 2017). Companies that issue green bonds have also demonstrated greater resilience during market turmoil, which is related to their accumulation of social capital (Tang 2021). Green bond investments thus offer hedging and diversification benefits (Naeem et al. 2021). Figure 1b visualizes existing knowledge about various factors that affect financing decisions in the green bond market.

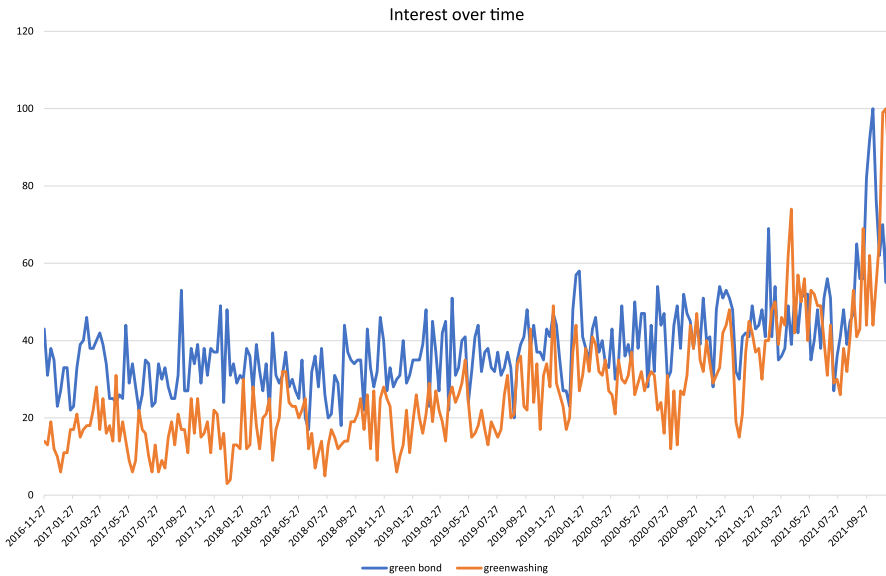
Nevertheless, the global green bond market’s development still faces several key challenges. One of the most pronounced is severe information asymmetry, which has always been a key issue in financial markets. Greater information



**Fig. 1** **a** Global Green Bond Issuance. Source: Bloomberg, **b** Factors Affecting Tapping the Green Bond Market for Financing. Source: Authors' compilation

transparency signals high institutional quality, which not only helps mitigate the possible negative impact of borrowing on growth (Mohsin et al. 2021a, b), but also boosts investor confidence and market sentiment. Investor sentiment has a causal impact on pricing in stock and bond markets (Mezghani et al. 2021).

In the green bond market, information asymmetry is more challenging, as it is directly related to the possible reputational risks associated with greenwashing—when companies make false or exaggerated environmental allegations to help them raise money—that can undermine investor confidence. The rapid growth of a green bond market can cause devastating problems for both regulators and investors who are concerned about greenwashing. Greenwashing can mean both overstating environmental impacts and channeling green bond proceeds to other projects with



**Fig. 2** Increasing Interest in Green Bonds and Greenwashing. The lines represent daily searches on Google. Source: Google Trends

negligible or even negative environmental impacts. Greenwashing posts reputational risks to ethical investors who seek to diversify their investment portfolios by investing in environmental, social, and governance financial instruments. Based on a review of all green bonds in the Climate Bonds Database that were issued between November 2017 and March 2019, only 77% of green bond issuers published information on the allocation of proceeds, and only 59% quantified the environmental impact of the projects being financed (Shapiro 2021).

Compared to the conventional bond market, green bond investors face additional information asymmetry and reputational risk regarding a green bond's environmental performance. In addition to evaluating the conventional bond characteristics of green bonds, green bond investors need to assess the peculiar environmental impacts of the projects that the green bonds finance. Demand for greater transparency and integrity on the use of green bond proceeds has substantially grown in parallel with the rapid expansion of green bond markets worldwide, as investors need to know exactly how their money is being invested. Information disclosure and integrity in the environmental performance of green bonds will boost investor confidence and thus is a key requirement for the further growth of green bond markets.

Figure 2 shows how often people are searching for the terms “green bonds” and “greenwashing” on Google. The interest in greenwashing has increased over time in parallel with the exponential growth in issuance of sustainability and green bonds in recent years. As there are increasing concerns that potentially misleading practices of greenwashing are taking place, regulations and information disclosure help mitigate information asymmetry and lower the risk of greenwashing or sustainability-washing. For example, Flammer (2021) shows that stock

markets demonstrate more positive reactions to green bonds with certifications. Hyun et al. (2020) report that green bonds that deliver greater information in the form of green certification enjoy lower bond yields compared to similar green bonds.

To avoid greenwashing, regulators and the investment community have developed taxonomies to define green projects and outline a negative list to explicitly exclude environmentally unfriendly investments. Such eligibility criteria (or taxonomy) help streamline green projects and address the greenwashing risk. The two most widely recognized international market standards are the Green Bond Principles and the Climate Bonds Standard. The Green Bond Principles were first introduced by the International Capital Market Association in 2014 to provide voluntary guidelines for market participants, including principles regarding the use of proceeds, a process for project evaluation, the selection and management of proceeds, and reporting for green bond issuances. The Climate Bonds Standard was launched by the CBI, together with a green bond certification scheme, to provide a climate bond taxonomy and certify green bonds that finance projects aligned with specified eligibility criteria.

In addition to a clear taxonomy, external verification, certification, and green bond labels have been introduced as part of the green bond market ecosystem. Such information-enhancing mechanisms have been documented to help mitigate information asymmetry and reputational risks in environmental, social, and governance portfolios. With international market standards and third-party assessments to help lower information asymmetry regarding the use of green bond proceeds, the green bond market can price in unobservable asymmetric information. When a bond is certified as green, the risk of greenwashing becomes lower, and investors might require a lower risk premium. There is evidence to show that green bonds that offer reliable environmental information-in the form of labelling, external verification, or third-party certification-tend to face a larger negative yield premium compared to similar green bonds (Hyun et al. 2020, 2021). The information asymmetry related to integrity issues and the risk of greenwashing has been documented to be relatively higher in emerging markets. For example, Tu et al. (2020) explore Viet Nam's green bond market and find that market integrity and improving the risk-return profile are two key policy issues for green bond market development. Taghizadeh-Hesary et al. (2021) show that compared to the European and North American markets, Asia's green bond market offers higher returns to compensate associated higher risks.

While information disclosure in the form of green bond labels and third-party verification helps to reduce information asymmetry, it also poses extra costs to issuers, which may affect their decision to tap the green bond market for financing. Compared with conventional bond issuance, green bond issuers face extra costs to build capacity in identifying green projects, managing a separate account, regularly reporting and tracking green bond's proceeds usage, and engaging a third-party intermediary to review or certify their green bonds. Despite the various benefits of green bond issuance documented in the literature, profit-maximizing and ethical issuers may be discouraged from issuing green bonds due to the extra costs. Such costs are particularly high for first-time issuers and infrequent green bond issuers, as the capacity of issuing and managing green bonds can be recycled for additional

green bond issuances. This cost concern has limited the expansion of the green bond supply, which, in turn, constrains the development of the green bond market.

The extra costs associated with external verification and certification notwithstanding, there are other attributes that mitigate information asymmetry on the greenness of bonds. One possible action that can lower costs for green bond issuers is to issue green bonds frequently. Green bond issuers tend to obtain knowledge and build relevant capacity after their first green bond issuance, which makes the marginal costs of an additional green bond issuance less costly. The experience of a collaborative relationship with green bond underwriters and verifiers can be utilized to further reduce issuance costs. Therefore, frequent green bond issuers can relatively costlessly provide more information to investors on their issuances compared to new or infrequent green bond issuers.

Meanwhile, frequent issuance also lowers information costs for green bond investors, as they may have already conducted research on a frequent green bond issuer, while previous green bond issuance records and performances also provide additional information to help investors assess the risk associated with subsequent green bond issuances by the same issuer. Hence, a well-established reputation for frequent issuers not only reduces asymmetric information but also provides assurance to existing investors against greenwashing.

Other than information asymmetry, frequent issuance also reinforces the signaling effect. Companies can utilize green bond issuances to signal to the market their commitment to positive environment impacts. Flammer (2021) finds the evidence that green bond issuance signals green commitment to the market and that the market reacts positively to first-time issuers and green bonds with certifications. Intuitively, when a green bond issuer repeatedly taps the green bond market for financing, the frequency of their green bond issuance serves as a strong signal that the issuer is committed to delivering environmental impacts. With a previous green bond issuance record available, frequent green bond issuers further strengthen their social capital and thus benefit from information disclosure more than less frequent issuers. Thus, frequent bond issuances mitigate asymmetric information between issuers and investors, while serving as a signal of green commitment.

The objective of this paper is to provide new evidence on an information-enhancing mechanism in the green bond market, thus contributing to green finance development and supporting green recovery and sustainable development. Specifically, this paper explores a new information channel-frequent green bond issuances-that contribute to green bond market development by reducing information costs, boosting supply and demand, enhancing investor confidence, and improving market integrity. By studying the role of frequent issuers, this study extends existing knowledge on the cost benefits of information enhancers such as green bond certificates, green labels, and third-party verifications, with a new type of information enhancer. Moreover, this study also offers practical implications to issuers, investors, and policy makers with a cost-efficient information channel in the green bond market. In doing so, the findings in this paper can encourage more financing and investments in green projects via a new and cost-efficient information channel.

This study thus contributes to the literature with new knowledge on whether the green bond market compensates frequent issuers and, if so, how to maximize the

benefits of frequent issuance in the green bond market. This paper is the first study to consider the effect of frequent issuance on green bond pricing and fills the void in the current literature by answering the following research questions: First, is there a price difference between frequent and less frequent green bond issuers? And second, if such a price difference exists, is it driven by conventional fundamental bond features or by the reduced asymmetric information of frequent issuers relative to infrequent issuers? Intuitively, if the green bond market prices frequent issuances as a proxy for information transparency and creditworthiness, it might explain the difference in yields between frequent and infrequent green bond issuers.

Using global green bond issuance data from 2014 to 2019, this study utilizes the Blinder–Oaxaca decomposition approach to explore price differences between frequent and infrequent green bond issuers. It shows that on average, infrequent green bond issuers pay 114–177 basis points more on their bond issuances relative to frequent green bond issuers. The decomposition of the price difference between frequent and infrequent green bond issuers helps show what factors are contributing to this difference. Specifically, this paper reveals to what extent the unexplained part, which is partly related to the information asymmetry profiles of frequent and infrequent issuers, contributes to the price difference. The paper finds that around 8 basis points of the bond yield difference between frequent and infrequent issuers cannot be explained by common pricing factors such as credit rating, maturity, coupon rates, and existing green bond labels. This part of the unexplained pricing difference thus captures some additional pricing mechanism between frequent and infrequent issuers. Given that frequent issuers tend to have more information disclosure on their green bond practices, the frequent issuance is also priced in as serving as a new information channel.

By examining how frequent green bond issuances may reduce asymmetric information and reputational risk via pricing mechanisms in green bond markets, this study contributes to the existing green bond literature with new evidence on the price difference between frequent and infrequent issuers in green bond markets. Moreover, this study discusses the economic interpretations and policy implications of frequent green bond issuance to support further development of green bond markets. This is particularly important as the cost of information asymmetry remains relatively high during the early development stage of a green bond market.

This paper also offers useful insights for policy makers to further develop green bond markets. While they make efforts to complete the market ecosystem by strengthening information disclosure practices, they can also encourage existing green bond issuers to continue tapping the green bond market to reduce information asymmetry. Frequent issuance not only benefits issuers with reduced funding costs, it also improves investor confidence. Further, it contributes to green bond market development by boosting supply and demand for green bonds, supporting green recovery and sustainable development in the post-COVID-19 era.

The reminder of this paper is organized as follows. Section 2 reviews the related literature on green bond markets and information asymmetry in financial markets. Section 3 explains the research method. Section 4 discusses empirical results, while Sect. 5 elaborates on policy implications and concludes the paper.

## 2 Literature review

### 2.1 Green bond pricing

The literature exploring the pricing mechanism for green bonds largely focuses on factors that drive price differences between green bonds and similar conventional bonds. This literature thus helps identify whether the market values positive environmental externalities delivered by green bonds, compared to conventional bonds. If investors value the positive environmental externalities created by green bonds, there should be a yield discount, or a negative yield premium, for green bonds relative to conventional bonds that bear similar common pricing factors. However, with asymmetric information related to greenwashing or reputational risk, the pricing of the benefit or value of being environmentally friendly for green bonds has been relatively mixed, particularly in the early years of a green bond market's development.

Some studies document that green bonds enjoy a negative yield premium relative to conventional bonds. For example, Ehlers and Packer (2017) find that green bonds are priced with an average negative yield premium at issuance, but are traded similarly with conventional bonds in the secondary market over time. Baker et al. (2018) reveal that in the United States, green municipal bonds are issued at a negative premium compared to similar conventional bonds. And the pricing benefit is more pronounced for green bonds with external certification. Zerbib (2019) documented a moderate average negative green bond premium of 2 basis points driven by investors' preference for positive environmental impacts. Gianfrate and Peri (2019) show that compared to similar conventional bonds, green bonds offer a lower return of 0.2% to investors, providing issuers with cost savings. The cost benefit to green bond issuers still holds after considering certification costs. Hachenberg and Schiereck (2018) report that green bonds, on average, are traded at a lower yield compared to nongreen bonds from the same issuer, and the negative premiums are more widespread amid corporate issuers than public sector issuers. The CBI (2021) found that 81% of the green bonds it monitored demonstrated a negative premium. Green bonds perform well in the secondary market relative to a comparable basket of conventional bonds.

A few studies show that the negative green bond premium may not apply to all green bond issuers. For example, Fatica et al. (2021) find that nonfinancial corporate issuers tend to benefit from the negative green bond premium, but no yield differences are documented for financial institution green bond issuers. Preclaw and Bakshi (2015) also show that the market witnesses a range of green premiums from zero to 17 basis points. Hyun et al. (2020) also documented that on average, there is no significant negative green premium across the market, but green bonds with certification are priced 7–9 basis point lower than similar green bonds without a third-party certification or independent reviewer. Similarly, the role of a green bond label, certification, and external review in lowering green bond yields has also been documented in Fatica et al. (2021) and Baker et al. (2018).

Overall, the current literature indicates that on average, a green bond benefits from a lower interest rate than a conventional bond that bears similar pricing



characteristics such as maturity and credit rating. Thus, the green bond market is able to price in environmental impacts through lower bond yields to support green investments, despite the negative green premium not necessarily holding for all green bonds. The price benefits may arise from investor preference for green investments. Moreover, there is consistent evidence that the negative premium for green bonds is more pronounced for issuers with greater information transparency in the form of an external reviewer and independent certification or verification.

The literature emphasizes the role of information-enhancing mechanisms in the green bond market, such as an external verifier, to reduce greenwashing risk and therefore lead to further reductions in bond yields. This study adds to the extant green bond pricing literature with a new information-enhancing channel: frequent green bond issuance. Thus, this paper is the first study to examine green bond pricing behavior using frequent bond issuance as a proxy for the reduced level of asymmetric information.

## **2.2 Information asymmetry in the green bond market**

Another strand of literature on the green bond market discusses the role of information asymmetry and its implications for green bond market development. Healy and Palepu (2001) suggest that the demand for disclosure is driven by information asymmetry. Their findings are reaffirmed by Brown and Hillegeist (2007), who proxy for information asymmetry by looking at the probability of trading on private information. They find that more disclosure reduces information asymmetry. In line with this, Dhaliwal et al. (2011) indicate that issuing corporate social responsibility reports reduce information asymmetry, regardless of a positive or negative impact document therein. Hahn and Kühnen (2013) further argue that sustainability is a typical example of information asymmetry given the existence of information gaps between company management and external investors and stakeholders regarding sustainability practices. It is difficult and costly to obtain credible information on an issuer's sustainability performance. Flammer (2021) indicates that green bond issuers signal their environmental commitment to investors and thus benefit from the reputation of being an environmentally conscious company. This, however, does not exclude the possibility that green bonds involve some form of greenwashing by using the proceeds for nongreen projects. With no legal or compulsory requirements on reporting, a green bond issuance itself might not constitute a credible signal.

To examine this issue of greenwashing, Deng et al. (2020) explore the People's Republic of China's green bond market in which part of the proceeds from a green bond can be used for nongreen projects. They find that green bonds with relatively more proceeds used for green projects are sold at a premium (i.e., lower yield). Green bonds also have lower yields if verified by a third party, and the negative premium is more pronounced if the third party is more reputable. These results suggest that investors are able to identify greenwashing and reward greenness. An information enhancer such as verification creates value to investors and issuers.

In the green bond market, asymmetric information on actual greenness characteristics varies across issuers with different reputational profiles and across green bond issuances with and without green verification. Katori (2018) compares green bonds issued under different schemes and focuses on the effects of third-party certification as a mechanism to ensure that green bonds finance environmentally friendly projects. He finds that green bonds that either complied with CBI standards or received a green bond rating from a rating agency have a longer maturity but carry a lower yield compared to nongreen counterparts.

Overall, the current literature has repeatedly revealed that alignment with existing international standards, external reviewers, third-party verifiers, and certification all help differentiate credible green bonds from those with a higher risk of greenwashing by reducing information asymmetry. Thus, green bond issuers need a valid mechanism to reduce information asymmetry between issuers and their investors, which helps lower capital costs. Here, this paper complements the existing literature by exploring whether frequent green bond issuance is another mechanism to reduce information asymmetry.

### 3 Research method

This paper aims to empirically investigate the yield discrepancy between frequent and infrequent green bond issuers, and how this yield discrepancy can be explained by common-pricing-related bond characteristics. In an empirical design, this paper defines frequent issuers in two ways. First, frequent issuers are those who issued green bonds more than once between 2014 and 2019, and infrequent issuers are those who issued a green bond just once during the same period. Second, frequent issuers are further defined as issuers that rely mostly on a medium-term note (MTN) program that allows for the issuance of notes in a series in an efficient and less expensive way. An MTN program offers flexible bond issuances subject to a maximum limit, allowing bonds to be issued in multiple series, different currencies, various maturities, and with different interest provisions, among other characteristics. In general, MTNs are small frequent borrowings as opposed to large intermittent debt issues.

The key theme of this study is to understand whether there is a yield difference between green bonds issued by frequent and infrequent green bond issuers. The conceptual framework of the empirical design in this study is to first gauge to what extent existing common pricing risk factors—such as credit rating, maturity, coupon rates, and existing green bond labels—can explain the yield difference between frequent and infrequent issuers. The unexplained yield difference thus reflects some pricing mechanism that is not known or accounted for in the existing literature. As frequent issuers tend to deliver more information reporting compared to infrequent issuers, this unexplained component in yield differences thus captures information-profile differences between frequent and infrequent green bond issuers.

In our empirical analysis, the paper first obtains the yield difference ( $\Delta\bar{y}$ ) between green bonds issued by frequent and infrequent issuers as the difference of average yields on green bonds issued by infrequent issuers and frequent issuers. The

vectors of information and bond characteristics as common pricing factors are then regressed on the yield difference between the two groups as shown in Eq. (1):

$$\Delta \bar{y} = \bar{y}_{infre} - \bar{y}_{fre} = \bar{x}_{infre} \hat{\beta}_{infre} - \bar{x}_{fre} \hat{\beta}_{fre} \quad (1)$$

where  $\bar{x}$  and  $\bar{y}$  are the mean values of explanatory variables and average bond yields, respectively, and  $\hat{\beta}$  are the estimated regression coefficients. Average yields can therefore be expressed as the products of a vector of pricing factors ( $\bar{x}_{infre}$ ) and a vector of their risk loadings ( $\hat{\beta}_{infre}$ ) for infrequent issuers, and a vector of pricing factors ( $\bar{x}_{fre}$ ) and a vector of their risk loadings ( $\hat{\beta}_{fre}$ ) for frequent issuers.

The vector of explanatory variables consists of two key variables: one is whether a bond issuer is a publicly listed company. Relative to nonlisted companies, listed companies tend to have greater information disclosure. The other variable is whether the green bond issuer tends to use a green label or not. Normally, a green label means a green bond tends to be more reliable in terms of environmental performance. In addition, the vector of bond characteristics includes the following:

- (i) Liquidity. Liquidity is an important pricing factor related to market efficiency. Favero et al. (2010) state that liquid securities tend to have lower transaction costs and risks, which leads to lower risk premiums and bond yields.
- (ii) Maturity. This is the bond's length of time to maturity. In the bond market, a longer maturity date is associated with greater uncertainty in future cash flows that the investor will receive, either in the form of coupon payments or capital gains. The greater risk related to longer maturities will require a higher bond yield as a risk premium.
- (iii) Coupon rate. The coupon rate is the interest rate paid by the issuer to the investor periodically until the bond matures. The coupon rate is one of the determinants of the bond yield. Chen et al. (2010) show that high coupon payments have an impact on high bond yields.
- (iv) Credit rating. A credit rating reflects the default risk of a bond and the quality of bond issuers. Bond ratings thus directly tie to the yield of a bond. Bonds with a high rating are basically bonds that are relatively secure and have lower bonds yields.
- (v) Issuance size. Issuance size is measured as the amount of proceeds financed by a bond issuance. A larger bond issuance size not only reflects greater market acceptance but also implies there is greater potential for bond trading and more depth in the bond market.

The paper also controls issuers' sector and some other bond attributes-such as fixed or flow coupon type, collateral conditions, and denominating currencies-to further understand to what extent common pricing factors-such as issuance size, liquidity, coupon rate, maturity, and credit rating-explain the price difference. Therefore, the unexplained part in the price difference would be at least partly driven by a premium related to information asymmetry.

This paper follows Karpf and Mandel (2018) and utilizes the Blinder–Oaxaca decomposition approach to examine the yield difference between infrequent and frequent

issuers in green bond markets. The Blinder–Oaxaca decomposition method is especially useful for identifying and quantifying the separate contributions of group differences in measurable characteristics. The Blinder–Oaxaca decomposition approach was originally introduced to quantify gender-based wage discrimination in the labor market.

The value of the Blinder–Oaxaca decomposition is in explaining how much of the difference in mean outcomes across two groups is due to group differences in the levels of explanatory variables and how much is due to differences in the magnitude of regression coefficients (Oaxaca 1973; Blinder 1973). In the context of this study, the benefit of the Blinder–Oaxaca decomposition method is that it allows us to separate this yield difference into an “explained” part, which is due to common pricing factors (fundamental bond characteristics) between the frequent and infrequent green bond issuers, and an “unexplained” component, which is not explained by common pricing fundamentals and can be interpreted as the existence of price discrimination resulting from asymmetric information:

$$\begin{aligned}\Delta\bar{y} &= \textit{explained} + \textit{unexplained}(\textit{infrequent}) + \textit{unexplained}(\textit{frequent}) \\ &= (\bar{x}_{\textit{infre}} - \bar{x}_{\textit{fre}})\hat{\beta}_{\textit{ref}} + \bar{x}_{\textit{infre}}(\hat{\beta}_{\textit{inref}} - \hat{\beta}_{\textit{ref}}) + \bar{x}_{\textit{fre}}(\hat{\beta}_{\textit{ref}} - \hat{\beta}_{\textit{fre}})\end{aligned}\quad (2)$$

Alternatively, Eq. (1) can be further expressed as the sum of the following three terms in Eq. (2) in the form of a twofold Blinder–Oaxaca decomposition. The twofold approach decomposes the mean outcome difference with respect to a vector of reference coefficients ( $\hat{\beta}_{\textit{ref}}$ ). The reference coefficient vector has typically been interpreted to be nondiscriminatory, or as the set of regression coefficients that would emerge in a world of no price discrimination.

The first component is the price that can be explained by common pricing factors, which is the product of the difference in common pricing factors between the frequent and infrequent issuers ( $\Delta\bar{x}$ ) and the risk loading for the reference group ( $\hat{\beta}_{\textit{ref}}$ ). The second component is the product of the pricing factors of the infrequent issuers ( $x_{\textit{infre}}$ ) and the difference between the risk loadings of the two groups ( $\hat{\beta}_{\textit{inref}} - \hat{\beta}_{\textit{ref}}$ ). It denotes unexplained bond yields for infrequent issuers, capturing price discrimination for infrequent issuers. The third component is the product of the pricing factors of the frequent issuers ( $x_{\textit{fre}}$ ) and the difference between risk loadings between the two groups ( $\hat{\beta}_{\textit{ref}} - \hat{\beta}_{\textit{fre}}$ ). It is the unexplained yield for frequent issuers that captures possible price discrimination for frequent issuers.

In a common Blinder–Oaxaca decomposition setting, the difference between the infrequent issuer group and the frequent issuer group is decomposed into the explained component, which is an explanatory variable (or endowment-related effect), and an unexplained component, which is a coefficient-related effect. In this paper’s setting, the explanatory variable-related effect corresponds to the difference in average yields calculated for the two groups. Thus, it measures how much of the difference is explained by the explanatory variables or common risk factors. The coefficient-related effect corresponds to the yield difference obtained by applying the same set of common risk factors for the target and reference groups to the difference in risk loadings between the two groups. Hence, it measures how infrequent issuers have a different risk profile in the market from frequent issuers, as the price

difference is largely driven by risk loadings between the two groups given their common pricing factors. This effect cannot be explained by the common factors (fundamentals) and may be attributed to bond price discrimination in the form of a risk premium on information asymmetry.

Overall, the Blinder-Oaxaca decomposition method separates the yield difference into an explained part, resulting from differences in the pricing bond characteristics (fundamentals) between the two groups, and an unexplained component, which is not due to fundamentals but may be related to a risk premium due to asymmetric information as shown in Eq. (2). In other words, the unexplained components measure how the average yield on green bonds issued by infrequent issuers would change if they were assessed by the market in the same way as those issued by frequent issuers.

To implement the empirical analysis, This study collected green bond issuance information and bond yield data for 2014–2019 from the Bloomberg terminal and implemented the empirical analysis by using Oaxaca package in R (Hlavac 2018).

## 4 Empirical analysis

This section presents the empirical results. Table 1 reports the regression analysis results of bond yield determinants in the literature such as Favero et al. (2010) and Chen et al. (2010). The results are consistent with theoretical relationships established in bond markets. In particular, frequent issuers that are publicly listed and issue labeled green bonds normally enjoy a significant yield discount relative to other frequent issuers. However, the roles of public listing and a green label are not significant amid infrequent green bond issuers and the overall sample. This means that the market can price in information transparency for frequent issuers, who tend to put more available information in the market. Turning to other bond characteristics, the bond yields are higher for a higher coupon rate, illiquidity (i.e., wider bid–ask spread), and a longer maturity, while the yields decrease as the credit rating improves and when a bond offers callable options (i.e., option value).

To further investigate whether this price difference is related to fundamental bond features, or asymmetric information between frequent and infrequent issues of green bonds, the Blinder-Oaxaca decomposition was applied to 118 (210) infrequent issuers and 383 (291) frequent issuers in the analyzed sample.<sup>1</sup> Applied to a sample of 501 observations, the Blinder-Oaxaca decomposition allows us to separate the impact on yield difference of observable common pricing bond characteristics from the effect of asymmetric information. Following a Neumark (1988) decomposition, the paper also uses pooled regression as the reference coefficient set.<sup>2</sup> The results of

<sup>1</sup> The numbers in parentheses represent the number of observations for MTN issuers among both infrequent and frequent issuers.

<sup>2</sup> When estimating the twofold decomposition with two groups coefficients, the paper uses their equally weighted average (Reimers 1983), a weighted average that reflects the number of observations in two groups (Cotton 1988), as well as pooled coefficients both including and excluding the group indicator variable (Neumark 1988, Jann 2008). In this study, the reference coefficients come from pooled regressions without the group indicator variable included as a covariate.

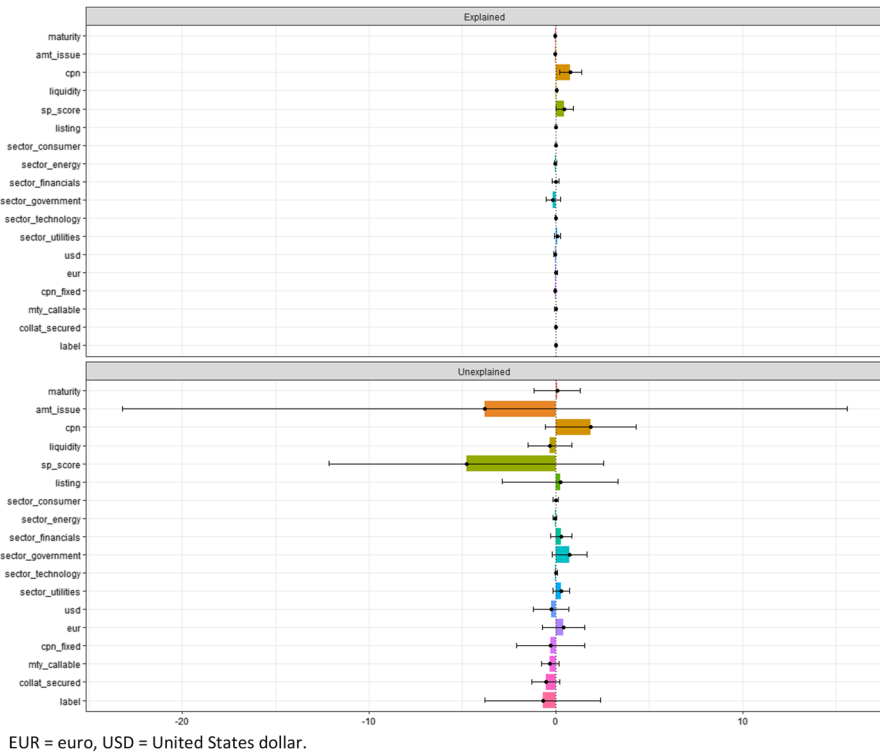
**Table 1** Green bond yields for infrequent and frequent issuers

	Dependent variable: bond yield				
	Number of issuances			MTN issuers	
	Infrequent issuers	Frequent issuers	Infrequent issuers	Frequent issuers	Full sample
maturity	0.02 (−0.07)	0.01*** (−0.01)	0.04 (−0.02)	0.03*** (−0.01)	0.01 (−0.01)
amt_issue	−0.15 (−0.37)	0.04 (−0.03)	0.16 (−0.18)	0.03 (−0.03)	0.1 (−0.08)
cpn	1.36*** (−0.28)	0.55*** (−0.03)	1.21*** (−0.17)	0.55*** (−0.04)	0.99*** (−0.08)
liquidity	−0.06 (−0.72)	0.41*** (−0.07)	0.48 (−0.33)	0.01 (−0.11)	0.43** (−0.18)
sp_score	−0.42*** (−0.13)	−0.13*** (−0.02)	−0.37*** (−0.08)	−0.07*** (−0.02)	−0.26*** (−0.04)
listing	0.18 (−1.39)	−0.09 (−0.1)	−0.06 (−0.65)	−0.20* (−0.11)	0.2 (−0.27)
label	−1.21 (−1.05)	−0.46*** (−0.12)	−0.08 (−0.58)	−0.28** (−0.14)	−0.38 (−0.3)
eur	0.87 (−1.27)	−0.15* (−0.09)	1.16* (−0.65)	−0.22** (−0.09)	0.32 (−0.23)
usd	−0.75 (−1.14)	−0.04 (−0.09)	0.26 (−0.57)	−0.1 (−0.1)	−0.37 (−0.23)
cpn_fixed	−0.53 (−1.26)	−0.21** (−0.1)	−1 (−0.72)	−0.07 (−0.1)	−0.55** (−0.27)
mt_y_callable	−0.84 (−0.68)	0.04 (−0.08)	−0.97** (−0.43)	−0.11 (−0.08)	−0.47** (−0.2)
collat_secured	−1.16* (−0.68)	0.25*** (−0.06)	−0.26 (−0.34)	0.03 (−0.06)	0.09 (−0.15)
Constant	10.16 (−8.47)	2.97*** (−0.75)	1.46 (−4.41)	1.06 (−0.75)	2.17 (−1.91)
Observations	118	383	210	291	501
Time dummy	yes	yes	yes	Yes	yes
Sector dummy	yes	yes	yes	Yes	yes
R <sup>2</sup>	0.67	0.88	0.66	0.81	0.64
Adjusted R <sup>2</sup>	0.58	0.87	0.61	0.8	0.63

EUR = euro, USD = United States dollar

This table reports regression results of key bond pricing characteristics. Bootstrapped standard errors are calculated based on 1,000 replications. amt\_issue is the logarithm of bond issuance amount (USD million), and maturity is measured in number of years remaining on a bond issuance. cpn is the coupon rate of the bond in basis points. Liquidity is measured as the bid–ask spread. SP\_score indicates bond credit rating ranging from 1(D) to 22(AAA). Listing is a dummy variable indicating the exchange listing

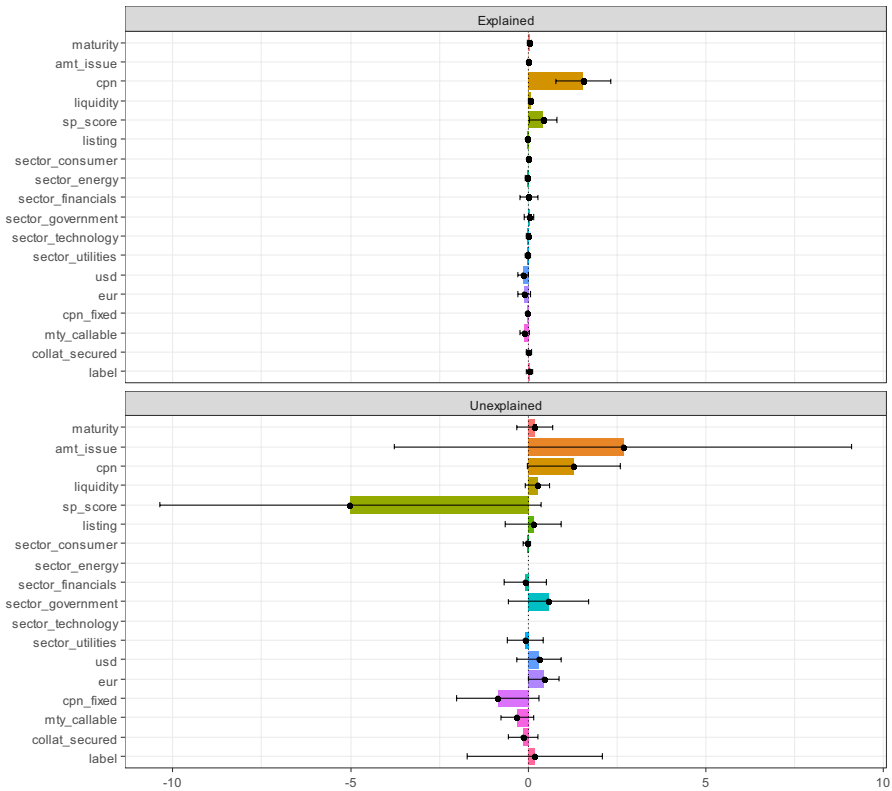
Source: Authors' calculations



**Fig. 3** The Explained and Unexplained Components of a Twofold Blinder-Oaxaca Decomposition of the Yield Difference of Frequent versus Infrequent Issuers-Number of Issuances. EUR = euro, USD = United States dollar. This figure shows a twofold decomposition by variables, along with error bars that indicate 95% confidence intervals. Bootstrapped standard errors are calculated based on 1,000 replications. amt\_issue is the logarithm of bond issuance amount (USD million), and maturity is measured in number of years remaining on a bond issuance. cpn is the coupon rate of the bond in basis points. Liquidity is measured as the bid-ask spread. SP\_score indicates bond credit rating. Listing is a dummy variable indicating the exchange listing and sector the issuer belongs to. \*\*\*, \*\*, and \* denote statistical significance at the 1, 5, and 10% levels, respectively. () stands for standard error. Source: Authors' calculations

the Blinder–Oaxaca decomposition are displayed in Fig. 3 and Fig. 4 for frequent and infrequent issuers.

Figures 3 and 4 show the twofold decomposition by variables, along with error bars that indicate 95% confidence intervals. Bootstrapped standard errors are calculated based on 1,000 replications. In the explained component, most variables appear to have a statistically insignificant (or only marginally significant) impact. However, it appears that a significant portion of the yield difference is driven by coupon rate and credit score in the explained component, while all parameters are not statistically significant in the unexplained component. Contrary to the expectation, information provision, such as listing and green labeling, does not affect bond pricing based on the results of the Blinder–Oaxaca decomposition. It might be interpreted that current green bond disclosure is not enough for overcoming asymmetric

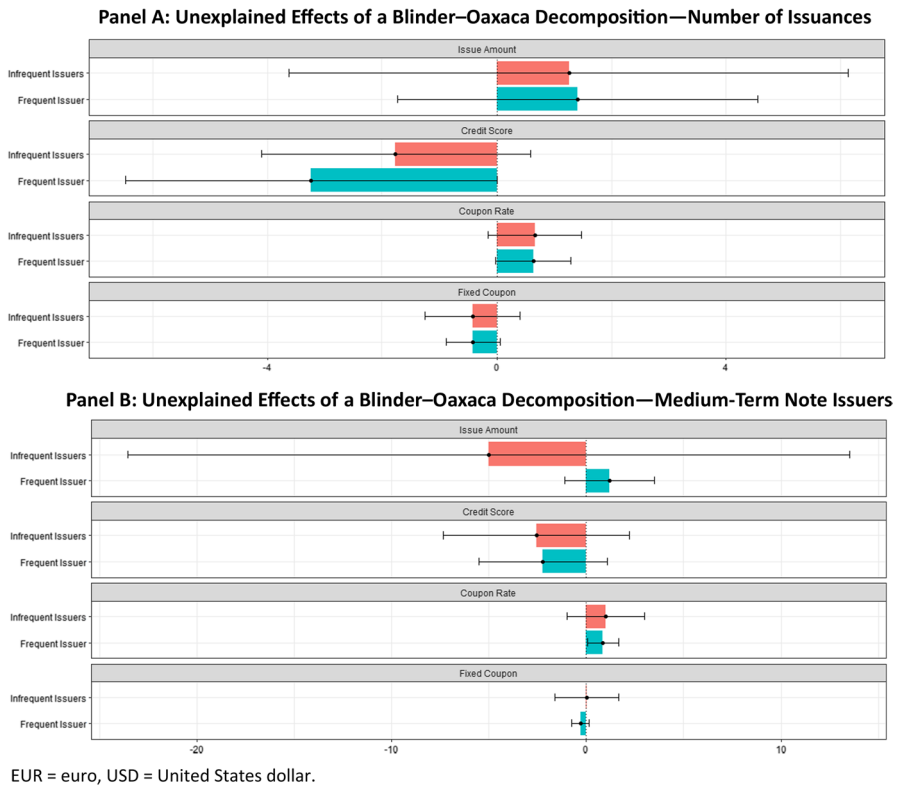


**Fig. 4** The Explained and Unexplained Components of a Twofold Blinder-Oaxaca Decomposition of the Yield Difference of Frequent versus Infrequent Issuers-Medium-Term Note Issuers. EUR=euro, USD=United States dollar. This figure shows a twofold decomposition by variables, along with error bars that indicate 95% confidence intervals. Bootstrapped standard errors are calculated based on 1,000 replications. *amt\_issue* is the logarithm of bond issuance amount (USD million), and *maturity* is measured in number of years remaining on a bond issuance. *cpn* is the coupon rate of the bond in basis points. *Liquidity* is measured as the bid-ask spread. *SP\_score* indicates bond credit rating. *Listing* is a dummy variable indicating the exchange listing and sector the issuer belongs to. \*\*\*, \*\*, and \* denote statistical significance at the 1, 5, and 10% levels, respectively. () stands for standard error. Source: Authors' calculations

information when issuing green bonds. It would also be necessary to disclose non-financial information such as green bond project impact information.

The unexplained part can be decomposed further into the unexplained component for infrequent issuers (i.e., price discrimination against infrequent issuers) and the unexplained component for frequent issuers (i.e., price discrimination against frequent issuers). For the unexplained components, Fig. 5 visualizes how much issuance amount, credit rating, and coupon rate contribute to price discrimination for infrequent issuers versus frequent issuers. However, all parameters are not statistically significant. The frequent issuers in panel A are defined as number of issuances, while those in panel B are defined as MTN issuers.





**Fig. 5** The Unexplained Effects of a Twofold Blinder–Oaxaca Decomposition of the Yield Difference of Frequent versus Infrequent, IssuersPanel A: Unexplained Effects of a Blinder–Oaxaca Decomposition–Number of Issuances. Panel B: Unexplained Effects of a Blinder–Oaxaca Decomposition–Medium-Term Note Issuers. EUR=euro, USD=United States dollar. This figure shows a twofold decomposition by variables, along with error bars that indicate 95% confidence intervals. Bootstrapped standard errors are calculated based on 1,000 replications. *amt\_issue* is the logarithm of bond issuance amount (USD million), and maturity is measured in number of years remaining on a bond issuance. *cpn* is the coupon rate of the bond in basis points. Liquidity is measured as the bid–ask spread. *SP\_score* indicates bond credit rating ranging from 1(D) to 22(AAA). Listing is a dummy variable indicating the exchange listing. Source: Authors' calculations

The results of the overall decomposition are displayed in Table 2. The overall explained mean difference in bond yield between infrequent issuers and frequent issuers is 114 basis points (177 basis points for MTN issuers) when the frequent green bond issuer is defined in terms of the number of bond issuances. This difference is statistically significant over the drawn bootstrap sample. The evidence shows that frequent issuer's yields are comparatively lower than those of infrequent issuers. Thus, investors require a higher interest rate on green bonds for infrequent issuers due to greater information asymmetry.

Turning to the parameters estimated for the unexplained parts, an unexplained yield difference of 8 basis points is documented by the Blinder–Oaxaca

**Table 2** Blinder-oaxaca decomposition of the yield differences between infrequent and frequent issuers

Panel A	Explained		Unexplained		Unexplained (Infrequent issuers)		Unexplained (Frequent issuers)	
	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E
Number of Issuances								
overall	1.1441	0.3661	0.1016	0.1188	0.0777	0.0000	0.1220	0.1512
amt_issue	-0.0184	0.0171	-3.7973	9.9080	-5.0081	9.4673	1.2108	1.1749
cpn	0.7937	0.2953	1.8583	1.2438	1.0081	1.0166	0.8502	0.4059
sp_score	0.4730	0.2284	-4.7849	3.7509	-2.5602	2.4381	-2.2247	1.6781
usd	-0.0528	0.0351	-0.2488	0.4900	-0.1595	0.4779	-0.0893	0.0444
Panel B	Explained		Unexplained		Unexplained (Infrequent issuers)		Unexplained (Frequent issuers)	
MTN Issuers	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	coefficient	S.E
overall	1.7656	0.3157			-0.0646	0.0620		
amt_issue	0.0035	0.0113	2.6649	3.2886	1.2550	2.5321	1.4099	1.5886
cpn	1.5629	0.3949	1.2907	0.6653	0.6561	0.4138	0.6346	0.3351
sp_score	0.4267	0.1926	-5.0038	2.7386	-1.7636	1.2021	-3.2402	1.7515
cpn_fixed	-0.0289	0.0204	-0.8522	0.5921	-0.4300	0.4352	-0.4222	0.2389

EUR = euro, S.E. = standard error, USD = United States dollar

This table reports major results from a Blinder-Oaxaca decomposition of the yield differences between infrequent and frequent bond issuers. Bootstrapped standard errors are calculated based on 1,000 replications. amt\_issue is the logarithm of bond issuance amount (USD million), and maturity is measured in number of years remaining on a bond issuance. cpn is the coupon rate of the bond in basis points. Liquidity is measured as the bid-ask spread. SP\_score indicates bond credit rating ranging from 1(D) to 22(AAA). The cpn\_fixed is a dummies variable for fixed interest bonds

Source: Authors' calculations

decomposition, while the unexplained yield difference for MTN issuers is not statistically significant. The unexplained bond yield difference may originate from asymmetric information among infrequent issuers.

Overall, the evidence shows that common pricing factors contribute to the price difference between frequent and infrequent issuers' bond yields, particularly information-related factors. According to the Blinder-Oaxaca decomposition, the common factors help explain between 114 and 177 basis points of bond yield difference, while a difference of 8 basis points from unexplained components is related to possible differences in the information profiles of frequent versus infrequent issuers. This 8-basis-point yield difference for frequent issuers as a new information mechanism is comparable to existing information-enhancing mechanisms such as green certification. For example, in Hyun et al. (2020), green bonds certification, as a widely documented information channel in the green bond

market, is found to save 7–9 basis point for certified bond issuance compared to similar noncertified green bonds.

## 5 Conclusion and policy recommendations

Information asymmetry is an important theoretical and practical topic in financial markets. It poses extra risk in green bond markets related to environmental performance and greenwashing practices, which can expose investors to additional reputational risks beyond cash flow risks in conventional bond markets. In terms of asymmetric information between issuers and investors, green bond authenticity is based on invisible characteristics subject to asymmetric information. Demand for available information on the use of proceeds has substantially grown as green bonds have become one of main instruments to finance environmentally friendly investments. The disclosure of project environmental information and external certification can lower the degree of asymmetric information for green bonds and thus lower financing costs. While existing evidence has repeatedly shown that information-enhancing mechanisms—such as green bond labels, certification, external review, and verification—will add value to investors by reducing information asymmetry and related costs, these mechanisms also incur additional costs to green bond issuers, mitigating the benefit of greater information transparency.

This study adds to the existing literature by identifying a cost-efficient, information-enhancing mechanism in the green bond market: frequent green bond issuance. In terms of asymmetric information in green bonds markets, frequent green bond issuers already have a track record of reporting environmental performance and established reputations before they seek additional financing in the green bond market. Thus, a returning green bond issuer enjoys greater information transparency compared to first-time issuers and infrequent green bond issuers. Meanwhile, by frequently issuing green bonds, issuers also send a strong signal of environmental commitment by demonstrating repeated investment in environmentally friendly projects. Thus, the green bond market rationally prices in the difference in information quality between frequent and infrequent green bond issuers.

This is the first paper to analyze the price difference between frequent and infrequent issuers in the green bond market, providing a relatively cheaper way to enhance information transparency. Frequent issuance does not necessarily add extra cost as an information enhancer but provides the potential to lower financing costs relative to infrequent issuers, even after controlling for existing external information enhancers such as green labeling.

Using global green bond data from 2014 to 2019, empirical results show that on average, the market requires a higher yield from infrequent green bonds issuers of around 114–177 basis points relative to frequent green bond issuers. This is related to common pricing factors, as implied by the explained component in the decomposition for common risk factors such as coupon rate, liquidity (bid-ask spread), and maturity. The unexplained components in price difference are partly related to the information asymmetry profiles of frequent versus infrequent issuers. With all other conditions equal, the market discriminates against infrequent green bonds issuers by requiring an 8-basis-point higher yield, on average, relative to frequent issuers. This yield

difference cannot be explained by common bond pricing factors-such as credit rating, maturity, coupon rates, and existing green bond labels-and thus captures information-profile differences between frequent and infrequent green bond issuers. As frequent issuers tend to have more information disclosure for their green bond practices, frequent issuance is found to be priced into the market as a new information channel.

This study offers practical policy implications. While it is important to further develop the market ecosystem to reduce information asymmetry via disclosure requirements, information-enhancing financial services, and intermediaries, policy makers should encourage existing green bond issuers to continue issuing green bonds. Frequent green bond issuance not only reduces investors' information asymmetry but also cost-efficiently lowers financing costs for issuers. From a market development perspective, encouraging frequent green bond issuance and mandatory disclosure would also boost the supply of and demand for green bonds, thereby benefiting market depth and liquidity. Such policy implications can also contribute to a green recovery in the aftermath of the COVID-19 pandemic by guiding investments toward more environmentally friendly projects.

Green bonds currently can be issued under different green definitions and various voluntary standards and principles developed by the International Capital Markets Association and the CBI at the international level, and by the Association of Southeast Asian Nations and the European Union at the regional level. Also, many economies publish green bond guidelines, which are not mandatory, at the domestic level. These situations can generate investor skepticism about greenwashing without further improvements in information disclosure that require issuers to demonstrate that the proceeds of green bond sales are being properly used to fund green projects. The central question of whether green bond standards should remain voluntary or become mandatory will be a key point in further developing green bonds markets from the perspective of information asymmetry. In other words, it is a question about striking the right balance between market transparency and financial innovation.

Further research may explore factors that affect the decision of whether to frequently issue green bonds, including nonfinancial variables for environmental impacts, to provide policy implications on how to reduce information asymmetry in green bond issuance. The limitation of the research is that the relatively limited scope of the green bond universe limits further applications to issuers in advanced green bond markets rather than issuers in less developed green bond markets. Recommendations for future research include uncovering other possible information channels in the green bond market that can reduce information asymmetry and boost investment in green projects for a green recovery.

## Appendix

See Appendix Tables 3 and 4.

**Table 3** Variable List

Variables	Definition	Unit
maturity	Number of years before maturity at bond issuance	Year
n_issue	Number of bond issuance	
cpn	Coupon rate	Basis points
liquidity	Bid-ask spread	Basis points
yield	Bond yield	Basis points
listing	Dummy variable for exchange listing	
mtn_dum	Dummy variable for medium-term note program	
sp_score	Bond credit rating assign it into numerical value from 1(D) to 22(AAA)	
sector_consumer	Dummy variable for consumer sector	
sector_energy	Dummy variable for energy sector	
sector_financials	Dummy variable for financial sector	
sector_government	Dummy variable for government sector	
sector_others	Dummy variable for other sectors	
sector_technology	Dummy variable for technology sector	
sector_utilities	Dummy variable for utilities sector	
eur	Dummy variable for euro	
usd	Dummy variable for us dollar	
others	Dummy variable for other currency	
cpn_fixed	Dummy variable for fixed coupon	
cpn_typ_others	Dummy variable for other coupon	
mtty_callable	Dummy variable for callable bonds	
collat_secured	Dummy variable for secured bonds	
amt_Issue	Logarithm of bond issuance amount	USD million
label	Dummy variable for green label	

USD=United States dollar

Source: Authors' compilation

**Table 4** Descriptive statistics

Statistic	Infrequent issuers( <i>n</i> = 118)	Frequent issuers( <i>n</i> = 383)	t-statistics	Infrequent issuers( <i>n</i> = 210)	Frequent issuers( <i>n</i> = 291)	t-statistics
	Mean	Mean		Mean	Mean	
bond yield	2.30	1.10	3.06	2.30	0.70	6.74
maturity	8.10	9.60	−2.47	11.10	8.00	5.00
cpn	2.70	1.90	3.86	3.00	1.50	10.70
liquidity	0.70	0.60	2.00	0.70	0.50	2.94
listing	0.90	0.90	1.24	0.90	0.90	−1.69
sp_score	15.40	17.30	−4.76	15.90	17.50	−.22
eur	0.40	0.40	1.39	0.20	0.50	−8.39
usd	0.40	0.30	2.82	0.50	0.10	10.26
cpn_fixed	0.90	0.90	1.40	0.90	0.90	2.17
mtty_callable	0.40	0.30	0.43	0.50	0.20	5.12
collat_secured	0.40	0.40	−0.21	0.50	0.30	3.53
amt_issue	20.10	20.30	−2.04	20.30	20.20	0.39
label	0.90	0.90	−0.77	0.90	1.00	−2.95

Source: Authors' calculations

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