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The effect of issuance documentation disclosure and readability on liquidity: Evidence from green bonds

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ABSTRACT

This paper investigates the potential effects of the disclosure and the readability of a green bond's issuance documentation on its liquidity. Using a sample of 274 green bonds issued by both corporate and financial issuers (102 unique firms) worldwide (23 countries) from 2011 to 2018, we show that both the disclosure of green bond frameworks and annual reports and their readability increase the bond's liquidity. Our results are robust to checks for endogeneity and to alternative estimation techniques. Both disclosure and readability have a more important impact on liquidity for bonds issued by nonfinancial (vs. financial) issuers, bonds with longer maturities, and those with lower credit ratings.

JEL classifications:

G10

G11

G12

Keywords:

Green bonds

Disclosure of green issuance documentation

Green bond framework

Green bond reports

Readability

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Green and sustainable finance

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1. Introduction

Today, companies and other economic entities may see environmental considerations as constraints that keep them from maximizing profits and reduce their ability to compete globally. Consumers may see environmental impacts as secondary to the ratio between price and utility. However, from both points of view, things are changing, as we realize that our impact on natural resources, biodiversity, pollution, and climate might, in the long term, harm the whole economy, including us directly. Many social actors are developing interesting ways to be environment-friendly while remaining economically stable. Companies and products are chosen for their low impact on the environment, notably in sectors like energy, consumer goods, transportation, and real estate.

Despite this goodwill, such adaptation is far from being costless. The International Energy Agency (IEA) estimates the cost of a global energy transition at around three and a half billion dollars a year in energy-sector investments until 2050.[1] To realize this transition, every company must find massive amounts of capital that are hard to get through simple bank loans, so financial markets are an attractive source of financing.

As intermediaries between supply and demand of capital, financial markets have a huge role to play in the sustainable development of companies and government-related entities. From the supply side, the orientation of investors' capital can have massive effects on the evolution of companies' businesses and public policies and practices. Institutional investors, asset owners, and asset managers are adapting their investment strategies to match the environmental requirements of a large proportion of small savers. Notably, strategies select investments according to environmental, social, and governance (ESG) criteria, excluding the

[1] https://www.iea.org/news/deep-energy-transformation-needed-by-2050-to-limit-rise-in-global-temperature

worst practices and preferring the best ones within a given sector; this is what we call the "best in class" approach.

Beyond this simple approach, investors can use debt instruments specifically aimed at financing environment-friendly assets and projects: green bonds. A green bond can be defined as a bond whose proceeds are used to finance or refinance projects and assets with positive environmental externalities. The European Investment Bank in 2007 and the World Bank in 2008 issued the first known green bonds, under the name "climate bond". In 2014, the International Capital Market Association (ICMA) published its Green Bond Principles, which go beyond precisely defining project categories that can be considered "green" to require that an issuer clearly communicate (1) the use of proceeds, (2) the process for project selection and evaluation, and (3) the management of proceeds (that is, the issuer's internal tracking of the funds). They also require (4) that the issuer subsequently describe the use of funds and impact of projects in its annual report. These Green Bond Principles are still considered the "green market standard" followed by both issuers and investors worldwide.

Although green bonds have become increasingly popular in practice owing to the widespread need for sustainable development, they are still subject to debate, especially in the investor community. Asset owners and managers often point out that some companies might use them only to improve their image and not to effectively finance the reduction of their environmental impact. Seeking to mitigate greenwashing behavior, the ICMA Green Bond Principles brought clarity and transparency by imposing more stringent disclosure requirements on the issuers of green bonds, notably the disclosure of Green Bond Frameworks and Green Bond Annual Reports. The resulting improved transparency may have encouraged investors to trade more in green bonds, thus enhancing the development of the green bond market.

So far, the academic literature on green financing has mainly focused on the green bond premium or "greenium"; it remains silent regarding the challenges of information disclosure on green issuances to the public at large. In this paper, we dig deeper into understanding how the quality of green bond-related information influences investors' willingness to trade in green bonds, i.e., green bond liquidity. We particularly focus on the disclosure and the readability of green bond-related documents, i.e., Green Bond Frameworks and Green Bond Annual Reports. We aim to answer the following question: Do the disclosure and the readability of this issuance documentation reduce information asymmetry between the issuer and investors and therefore affect the green bond's liquidity?

To answer this question empirically, we use an international sample of green bonds, compiled from different sources, across 23 countries over 2011–2018. The present paper offers, to the best of our knowledge, the first comprehensive analysis of the relationship between two aspects of information asymmetry—disclosure and readability—and liquidity in the green bond market. Our study contributes to the literature at least in two important ways. First, we extend the literature on corporate narrative reporting, by going beyond the well-documented readability of common financial annual reports (Berger, 2011; Beyer, Cohen, Lys, & Walther, 2010) and exploring green bond-related documents. Second, our study furthers the understanding of the determinants of bond liquidity by looking beyond well-established firm-specific factors or external economic shocks and exploring the environmental dimensions of information disclosure.

The remainder of the paper is organized as follows. Section 2 reviews the main literatures on the green bond market, readability, and corporate bond liquidity and develops the hypotheses. Section 3 presents the green bond data, readability data, liquidity data, and financial data, as well as the sample selection process and descriptive statistics. Section 4

presents the model and results. Section 5 provides sensitivity checks and additional analyses. Finally, section 6 concludes the paper.

2. Literature review

2.1. The green bond market

The green bond is a very new instrument and has been studied by both academic researchers and professionals, with most of the research focusing on optimizing asset management and comparing green with traditional bonds. Since the early stage of the green bond market, investors and issuers have discussed the effectiveness of this instrument. For instance, Dupont, Levitt, and Bilmes (2015) use interviews with professionals and case studies to investigate the effectiveness of green bonds to finance water and storm water management projects, and suggest that issuers consider this financing tool to realize projects related to land conservation.

Many of the academic articles on green bonds have compared the interest rate on green bonds to that on conventional bonds, at the time of issuance in the primary market. From a fixed-income portfolio manager's point of view, Baker, Bergstresser, Serafeim, and Wurgler (2018) study whether green bonds carry a specific premium, or yield level. Analyzing a U.S. sample of around 2,000 green bonds issued by municipalities in the United States from 2010 to 2016 and 19 green bonds issued by corporations from 2014 to 2016, the authors find no significant difference in premium between the sample green bonds and equivalent (in financial characteristics) nongreen bonds. Zerbib (2019) also studies this issue with a different sample, benefiting from longer historical data and considering geographically more diverse issuances, and concludes that green bonds might show lower yield levels than equivalent traditional bonds, especially issuances that are USD and EUR-denominated, investment grade rated, and above USD 100 million. Agliardi and Agliardi (2019) look at this question from the issuer's point of view and find that a potential "green premium" or "greenium" might be

especially significant when the underlying assets financed are highly volatile, or when the company benefits from lower tax rates. According to Hachenberg and Schierech (2018), the "green premium" might also be affected by other characteristics. Comparing the spreads on daily observations of green bonds and their nongreen equivalents, the authors conclude that green bonds rated between AA and BBB might present higher premiums, especially if issued by either financial or nonfinancial corporations rather than government-related entities. Interestingly, they find that issue size, maturity, and currency do not affect the premium at the time of issuance of green bonds. Finally, taking a quite similar approach but suggesting different conclusions, Larcker and Watts (2020) argue that portfolio managers, and investors more broadly, are not willing to curtail yields for the sake of a positive environmental impact and that, so far, there is no significant, concrete green bond premium.[2]

A few empirical studies analyze the liquidity risk of green bonds. For instance, Wulandari, Schaefer, Stephan, and Sun (2018), using a correlation test on a broad sample of green bonds, demonstrate the impact of liquidity risk on yield spread and conclude that lower liquidity risk might increase the chances of success in financing environment-friendly projects. The liquidity risk can be lowered by reducing adverse selection costs and increasing transparency about the potential financial performance of green projects.

Partridge and Medda (2018) propose the first market indices of U.S. municipal bonds aligned with green and climate standards and labels, issued from 2014 to 2017. These indices show a compound annual growth of 1.5 basis points above the S&P IG Municipal Index. Tang and Zhang (2020) assess the effects of green bond issuance on underlying stock price for a panel of 28 companies from 2007 to 2017. The authors find that stock prices significantly increased after issuance, especially for first-time issuances and for corporate issuers,

[2] For a review of the literature about the green premium, see MacAskill, Roca, Liu, Stewart, and Sahin (2021).

compared to financial ones. However, the authors conclude that the yield levels are substantially the same as those of conventional bonds, confirming the absence of a green premium.

Beyond simple financial considerations, some articles have treated the ethical and environmental impacts of green bonds. Flammer (2021) demonstrates both financial and environmental benefits: positive stock market reaction following green bond issuances by a panel of corporate issuers, long-term value creation through the diversification of the issuer's investor base, and positive environmental externalities through the use of the proceeds. The author shows that a corporate green bond issuer usually reduces its environmental footprint, notably its carbon emission levels.

In the green bond market, few market-recognized entities provide certifications. There are currently three main recognized programs: The Green Bond Principles from the International Capital Market Association (ICMA), the Climate Bond certification from the Climate Bond Initiative (CBI), and the Green Bond Assessment from Moody's. These global standards remain essential to unlock the potential of the green bond market (Deschryver & de Mariz, 2020; Rose, 2018).

Revelli and Paranque (2019) emphasize that the clarity, measurability, and traceability of the use of proceeds are critically important to investors willing to be convinced of the concrete impact of green bonds. According to Park (2018), government and public institutions, although increasingly present as issuers, need not play a predominant role as regulators in the decentralized green bond market, where a constellation of private entities can efficiently set standards and react rapidly to evolving market needs. Noting, however, that a lack of legitimacy, consistency, and accountability might lead to greenwashing, the author concludes that a mix of public and private contributions could lead to optimal regulation of the green bond market.

One group plays a crucial role in the transparency of information between investors and issuers: *second party opinion* providers. These entities, mainly environmental expertise entities and ESG data providers, have imposed themselves as certifiers of the "greenness" of green bonds. Their role consists mainly in assuring that the issuer's green bond framework complies with green market standards, notably the ICMA's Green Bond Principles. They do this through publicly available documents called "second party opinions". For additional in-depth analysis, rating agencies and auditors publish quantitative green bond ratings. Even if such ratings can help investors make decisions, the diversity of assessment methods and the lack of transparency about them can be confusing. Reed, Cort, and Yonavjak (2019) propose a new method to make robust and relevant assessments of green bonds, replacing external rating services and lowering their cost.

In sum, the growth of the green bond market necessitates further understanding how the disclosure and the clarity of issuance documentation affect green bond tradability. We are the first to examine this topic, and our sample is the most exhaustive database about green bonds issued by both corporate and financial issuers.

2.2. Readability

Given the number of new green bond issuances every day and the purchases and resales involved in managing a green bond portfolio, it is nearly impossible for an investor to check the veracity of the issuers' concrete investments. The only way to get information about projected and realized investments is by analyzing, respectively, the issuers' green bond frameworks and their green bond periodic allocation and impact reports. Therefore, to optimize the financing of environment-friendly capital and operational expenditures, such documents must be transparent and readable.

Because of the growing complexity of annual reports, regulators in several countries have taken initiatives to increase their readability—for instance, the American "Plain English

Handbook" (SEC 1998) and the British "Clear & Concise" initiative (U.K. Financial Reporting Council, 2015). However, to our knowledge, the narrative quality of green bond documentation has not yet been studied.

Loughran and McDonald (2014) have questioned the relevance of the traditional measures of text readability. In a study using a sample of all 10-K documents available on EDGAR from 1994 to 2011, the authors conclude that 10-K document file size provides a satisfactory readability proxy because it does not require document syntax analysis, it facilitates replication, and it is correlated with alternative readability constructs. However, other researchers have used different proxies, such as the fog, Flesch, or Flesch-Kincaid indices.

Lehavy, Li, and Merkley (2011) study how the readability of firms' written communication affects the behavior of sell-side financial analysts. Analyzing 33,704 observations of 10-K filings from 1995 to 2006, the authors show that less readable 10-Ks increase analysts' following and the effort they put in to generate their reports, and are often associated with higher forecast dispersion, weaker accuracy, and greater overall uncertainty—a conclusion that agrees with that of Boubaker, Gounopoulos, and Rjiba (2019).

Franco et al. (2015) study several measures for two dimensions of analyst report readability: straightforward language and concision. The first dimension is measured by three commonly used indices of readability (fog, Flesch, and Flesch-Kincaid), and the second by the number of words and the number of characters in the report. For a sample of 356,463 sell-side equity analysts' reports from 2002 to 2009, the authors conclude that trading volumes increase when readability is high, in accord with commonly accepted models predicting that precise information correlates positively with investors' initiating trades.

Li (2008), using the Gunning Fog Index as a measure of the readability of annual reports on a sample of 55,719 public company firm-years from 1994 to 2004, finds that the

reports of firms with lower earnings are more difficult to read, and vice versa—suggesting that managers might choose to hide adverse information in the annual reports to avoid negative reaction from investors. Li also finds that the positive earnings of firms with readable reports are more persistent over time. Lo, Ramos, and Rogo (2017) consider a panel of 26,967 firm-years and 4,855 unique firms' data from 2000 to 2012. They use the fog index to measure readability, and focus on the management discussion and analysis section (MD&A) of the annual report. They conclude that firms that managed their earnings with the main purpose of beating the previous year's earnings present more complex MD&As than other firms.

Hasan (2020) asks whether managerial ability might also be connected to readability. The author measures managerial ability as the ability to understand the functioning of the company and to take careful and timely economic decisions that allow managers to convert corporate resources efficiently into financial profits, and finds that it is significantly and positively associated with the readability of narrative disclosures in 10-K reports.

Several studies have focused on how financial disclosure readability affects a company's stock. Boubaker et al. (2019) analyze whether, and how, the textual complexity of the annual report affects stock liquidity, by testing the correlation between the Gunning Fog Index and stock liquidity on a sample of 3,899 firm-year observations representing 507 unique French firms between 2002 and 2013. The authors conclude that hard-to-read annual reports lower investors' capacity to analyze information in the reports, eventually reducing their willingness to trade and decreasing stock liquidity even if the stock appreciates, and finally increasing the risk of price manipulation.

Mine, Jin, Jiaping, and Chi (2017) study whether, and how, the readability and tonal ambiguity of financial disclosure documents are related to bank loan contracting. The authors find that firms with larger 10-K file sizes and higher frequency of uncertain and weak modal

words obtain loans on stricter contract terms, which in turn are associated with a greater risk of future stock price crash. This evidence suggests that information hiding by top managers might have a knock-on effect on shareholders' exposure to higher cost of external financing.

The bond market is also affected by the clarity and transparency of the issuer's financial information disclosure. Bonsall and Miller (2017) find that less readable disclosures are associated with worse credit ratings, symbolizing a higher risk of default, and with more disagreement between credit rating agencies and, consequently, a higher cost of debt capital. In a more detailed study with similar findings, Fang-Klingler (2019) examines the correlation between annual report readability (measured again with the fog index) and a panel of debt-related indicators for a sample of USD and EUR bonds from around 850 companies. In the U.S. market, companies with less readable reports have significantly higher and more volatile credit spreads, transaction costs, and numbers of trades, and lower issue size capacity. In the EUR market, such companies have a significantly lower credit spread.

2.3. Corporate bond liquidity

Among the different elements that affect an investment strategy, liquidity is essential, whatever the nature of the underlying asset. In the context of portfolio management, we define liquidity as an investor's capacity to easily buy or sell an asset at a price that reflects its real, or intrinsic, value, and without incurring important transaction costs.

A portfolio manager who wishes to buy or sell a significant quantity of securities that have a low outstanding amount or that are not being traded a lot must ask whether the market can absorb the trade; in the (even temporary) absence of sufficient market counterparts, such transactions can sometimes cause excessive price rises or falls. Liquidity is even more decisive in bond portfolio management since the bond market is over the counter. An illiquid bond can limit an investor's ability to react quickly.

Hameed, Helwege, Li, and Packer (2019) distinguish two main ways to assess bond liquidity: price-based and quantity-based. After analyzing five different liquidity indicators from both approaches, the authors conclude that quantity-based indicators seem to be more reliable than price-based ones—a finding that may help regulators and market participants solicit the right liquidity metrics.

However, many authors consider the bid-ask spread as the best proxy of a bond's liquidity and the underlying transaction cost (Fleming, 2003). The bid-ask spread can be defined as the difference between the maximum price an investor is willing to pay (bid) and the minimum price its counterpart is willing to accept (ask). The bigger the difference (or spread) is, the higher is the transaction cost and the less liquid the underlying bond. A few working papers have questioned the reliability of this indicator. Hong and Warga (2000) use a data set composed of transactions on the NYSE Automated Bond System (the exchange market) and those reported to the National Association of Insurance Commissioners (the dealer market) for about two years (1995–1997). They conclude that the effective bid-ask spreads for investment-grade bonds and those with high-yield credit ratings, and for bonds with different issuance sizes, tend to be quite similar, confirming the reliability of the bid-ask spread as a liquidity proxy.

Chakravarty and Sarkar (1999) analyze whether a bond's intrinsic characteristics affect its bid-ask spreads. Using a sample of U.S. corporate and municipal bonds from 1995 to 1997, the paper suggests that, for corporate bonds, the bid-ask spread increases when the bond is approaching its maturity date and when its credit risk is high. For municipal bonds, spreads particularly increase when bond yield has been subject to taxation.

Other researchers use volume-based measures instead of price-based ones. Alexander, Edwards, and Ferri (2000) perform a regression analysis of the relationships between three measures of trading volume and key attributes of the issue and issuer. The authors propose an

estimation model that expresses bond liquidity as a function of a number of bond-specific characteristics. Their conclusions are quite similar to those of Chakravarty and Sarkar (1999). Hong and Warga (1998) also conclude that bonds' intrinsic characteristics are associated with bid-ask spreads. Hotchkiss and Jostova (2007) analyze twelve potential determinants of the trading volume and liquidity of corporate bonds, including both bond-related and equity-related information and issuer characteristics—the widest set of potential determinants assessed so far. In accord with the existing literature, the authors find that the bond's issuance size and age remain the most important determinants of its liquidity. They also conclude that bonds issued by companies with publicly traded equity are more likely to trade than those of private-equity firms, a point also demonstrated by Alexander et al. (2000).

Macroeconomic events and market conditions might also affect a bond's liquidity. Galliani, Petrella, and Resti (2014) explain that a bond's liquidity is driven mainly by its intrinsic characteristics, notably its duration, rating, amount issued, and time to maturity, especially when the market is under stress. From the opposite perspective but still focusing on crisis and market stress, Friewald, Jankowitsch, and Subrahmanyam (2012) demonstrate that a bond's liquidity can account for up to one-third of the variation in its yield spread in unstressed periods, and up to half during the subprime crisis. Dick-Nielsen, Feldhütter, and Lando (2012) also look at the subprime crisis and arrive at basically the same conclusion, but they use a novel approach: they proxy liquidity as an equally weighted sum of four (normalized) measures of liquidity and liquidity risk (the Amihud measure of price impact, a measure of roundtrip trading costs, and the variabilities of these two measures).

Another set of studies examines how processes and relations within a company affect its bond liquidity. Lee and Cho (2016), using a dataset of 959 corporate bonds traded in Korea between 2003 and 2007, first demonstrate (in line with most of the existing literature) that issue size and age are the most important determinants of bond liquidity. More interestingly,

using corporate governance evaluation scores from the Korea Corporate Governance Service, the authors conclude that better corporate governance increases the liquidity of corporate bonds, enabling companies to lower their debt transaction costs by improving transparency and reducing information asymmetry.

Most of these studies examine how the liquidity of corporate bonds can be affected either by internal company factors or by external shocks from the global economic context, and their focus is mainly financial or managerial. We expand the existing literature by addressing the environmental dimensions of information disclosure.

2.4 Theoretical background and hypothesis development

The financial literature has focused on the "narrative quality" of financial information published by companies, and it frames the narratives in two competing ways: as incremental information and as impression management (Merkl-Davies & Brennan, 2007). The incremental information perspective argues that managers voluntarily provide narrative disclosure to mitigate information asymmetries. The impression management perspective argues that managers opportunistically exploit information asymmetries between them and firm outsiders to manipulate the outsiders' perceptions and decisions.

Several studies have addressed the relation between information asymmetry and stock liquidity. Lower information asymmetries reduce transaction costs and increase stock liquidity (Copeland & Galai, 1983; Demsetz, 1968; Diamond & Verrecchia, 1991; Epps, 1976; Glosten & Milgrom, 1985). Diamond and Verrecchia (1991) propose that a credible commitment by managers to improve disclosure quality reduces information asymmetry and increases liquidity of the firm's stock. In contrast, higher information asymmetries are likely to increase transaction costs, which discourage trading and reduce stock liquidity.

From the incremental information perspective, one would expect that easy-to-read documentation would reduce information asymmetry and decrease the bond spread. From the

impression management perspective, one would expect that readable documentation might manipulate investors' perceptions of the "greenness" of the projects funded, thus increasing information asymmetry and bond spreads.

These considerations lead to the following three testable hypotheses:

Hypothesis 0. The issuance documentation associated with green bond issuances has no impact on the underlying green bond's liquidity.

Hypothesis 1. The issuance documentation associated with green bond issuances increases the underlying green bond's liquidity.

Hypothesis 2. The issuance documentation associated with green bond issuances decreases the underlying green bond's liquidity.

3. Data and variables

3.1. Green bond data

Because there was no widely accepted definition of "green" between 2007, the first climate bond issuance, and 2014, the publication of the Green Bond Principles from the International Capital Market Association (ICMA), the definition of a "green" asset or project has depended on the issuer's and investor's visions. Therefore, for around seven years, it was impossible to build a commonly accepted green bond database.

Still today, most market participants build their own green bonds databases. Indeed, institutional investors and large commercial banks that underwrite green bond issuances have pioneered the collection and exploitation of green bond data. In section 3.4, we provide details about our sample selection process.

3.2. Readability data

3.2.1. The Green Bond Framework

To comply with commonly accepted market practices, a green bond issuer must disclose publicly, before or, at least, at the time of the issuance, a document explaining transparently how it will use the proceeds, how it will select and evaluate the green assets or projects, how it will manage the proceeds during the bond's lifetime, and how it will report on both the allocation and the environmental impact of the proceeds.

As the framework is likely to evolve over time along with the issuer's environmental strategy and objectives and the pool of eligible green assets, an issuer may publish updated green bond frameworks over the years. Any new issuances would then follow the newly disclosed framework.

3.2.2. Green bond annual reports

Again, according to commonly accepted market practice, the issuer is supposed to communicate publicly and annually, mostly to the investors but also to any other stakeholder, information on the allocation of the green bond's proceeds and its environmental impact. Regarding the allocation of proceeds, the issuer usually reports the amounts allocated to each of the projects and assets; their nature (either listing them one by one or describing them by category, such as renewable energy, clean transportation, green building, biodiversity preservation, etc.); their location (by country, region, city, etc.); and the proceeds that have not yet been allocated, if any. Regarding the environmental impact, the issuer reports, either qualitatively or quantitatively, the environmental benefits associated with the projects or assets. Most often, the reports use quantitative indicators, either for the whole pool of projects or at the project level (one by one). The reports prorate the benefits according to the share of the project financed exclusively by the green bond, if the project or asset has also been financed from other sources.

We chose to measure the readability of the *green bond framework* and the *green bond annual reports* and to exclude *second opinion reports*. The green bond framework is the most

available documentation associated with a green bond issuance, and it is also the document most used by investors to reduce, at first sight, the risk of greenwashing. The green bond annual reports are the second most available form of documentation published by an issuer, and they are the best way to inform investors about the bond's environmental usefulness, in the same way as a financial report informs them about the expected financial returns. We decided not to analyze second opinion reports because we observed that, for a given ESG analysis company, the structure of the reports is approximately the same from one report to another, and this structural repetitiveness would have been a source of bias in our empirical study. Moreover, since the certification process makes the issuer the client of the analysis company, these reports may not be impartial. We also ignored investor presentations, because the information they contain is duplicated in the green bond framework and they incorporate financial information that would not have been relevant in this empirical study.

One limit of our research lies in the availability of this documentation and the effort made by the issuer. Indeed, an important number of issuers, mostly outside the European Union, did not disclose the required documentation at the time of the issuance. This omission was particularly significant in the early stages of the green bond market; new research on this topic might benefit from improved availability of such documentation.

3.3. Liquidity data

A bond is initially issued on the primary market, where issuers (corporations, financial institutions, governments) sell it to an investor who becomes the first holder. Afterwards, a bond can be bought and sold on the secondary market by any investor until it reaches its maturity. A bond's liquidity is then defined as the facility with which it is buyable or sellable on the secondary market. To measure this liquidity we use the bid-ask spread (BAS; see section 2.3).

3.4. Sample selection process

We construct our database by combining private access databases[3] and free online databases. Our initial sample consisted of 3,174 green bonds. From this initial sample, we removed all duplicates, identifying them through their ISIN codes. We then excluded securities (bank facilities and bank loans; commercial papers; private placements; green asset-backed securities; mortgage-backed securities) and sustainability bonds whose proceeds were to be used for both green and social purposes (as such dual-purpose bonds do not fit internationally recognized definitions of green bonds). Finally, we excluded issuances for which we lacked financial information. These filters reduced the database from 3,174 to 2,079 green bond issuances.

Because our full sample of green bonds is partly composed of small issuances and unquoted bonds whose liquidity is null or not calculable, we considered additional filters. We dropped bonds issued by governmental institutions and selected those issued by publicly listed financial and nonfinancial firms.[4] We then matched the resulting sample of green bond issuers with issuer-level annual accounting information obtained from Compustat North America and Compustat Global. We also merged our resulting green bonds sample with manually collected monthly readability data as well as monthly liquidity data retrieved from Bloomberg. Finally, we excluded observations with missing values for any variable used in this study. Our final sample contains 3,057 monthly observations corresponding to 274 green bonds issued by 102 unique firms across 23 countries during the period 2011–2018.

Table 1 compares the cross-country distributions of the initial green bonds sample and our final sample. Column 1 shows that the green bond market is largely driven by China,

[3] The private access is obtained through a partnership with *Amundi Asset Management* (an institutional investor).

[4] We define publicly listed issuers as those that are listed in a stock exchange, or whose parent company is so listed.

which issued 677 green bonds over our sample period. This number even exceeds the number of green bonds issued by supranational organizations, the most frequent issuers until 2013, when the market started growing rapidly. Also, the green bond market has recently been dominated by European countries and the United States, as well as Asian countries—especially since 2015, the year of the release of the Green Bond Endorsed Project Catalogue, a newly recognized local market standard for issuing green bonds. Column 2 shows that the country distribution of our final sample is quite similar to that of the original green bonds sample; specifically, the bulk of our final sample is also concentrated in the U.S., Europe, and Asia.

[Insert Table 1 about here]

3.5. Variables

3.5.1. Disclosure and readability

To proxy for the information asymmetry between the issuer and investors, we use the disclosure and the readability of the green bond-related documents. On the premise that the absence of documentation represents the severest possible information asymmetry, we assign a value of zero to issues for which no disclosures have been made. To measure readability, we calculate Gunning Fog Indexes for the green bond frameworks (GBFs) and green bond annual reports (GBRs) associated with each green bond issue in our sample. The Gunning Fog Index reflects the years of education that an individual requires to understand a text at first reading; thus, the index is inversely related to readability. For ease of interpretation, we create an inverse measure of readability (*Inv_Fog_Index*) calculated as (1/fog-index), so that higher values indicate better readability. We average the *Inv_Fog_Index* measure across the two types of documents (GBF and GBR) for a given issue to obtain the *Avg_Inv_Fog_Index*. A high value of *Avg_Inv_Fog_Index* means that the issuer discloses easy-to-read documentation about the green issuance, which reduces the information asymmetry with investors. A low

value means that the issuer discloses hard-to-read documentation. Finally, a zero value of *Avg_Inv_Fog_Index* means that the issuer does not disclose green documentation and its information asymmetry with investors is severe.

3.5.2. Liquidity

In accord with the extant literature (see section 2.3), we consider an indirect measure of liquidity: the bid-ask spread (*BASpread*). It is the ratio of the difference between ask and bid prices to the mean of the two. A higher level of the *BASpread* is associated with a higher information asymmetry and therefore a lower liquidity of the green bond.[5]

3.5.3. Control variables

We control for an array of bond-specific and issuer-specific characteristics that are deemed to be important in explaining bond liquidity. Specifically, we control for the following variables: (1) *Issue_size*, the natural logarithm of the USD-equivalent amount issued; (2) *Age_of_bond*, the natural logarithm of the number of months since issuance; (3) *Rating_dummy*, a dummy variable that takes a value of zero if the bond's credit rating is below BB; (4) *Interest_rate_risk*, the natural logarithm of the time remaining to maturity; (5) *Bond_price_volatility*, the ratio of the difference between the highest and lowest prices to the monthly average price of the individual bonds traded each month; (6) *Issuer_size*, the natural logarithm of the issuer's total assets; (7) *Leverage*, the issuer's ratio of debt to total assets; and (8) *Europe_dummy*, a dummy variable that takes a value of one for European countries and zero otherwise.

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[5] There exist other measures of liquidity/illiquidity, such as the end-of-day high and low prices or trading volumes (see, e.g., Amihud, 2002; Corwin & Schultz, 2012; Downing & Zhang, 2004; Lesmond, Ogden, & Trzcinka 1999). For a review of literature about the multifaceted dimension of liquidity, see Díaz and Escribano (2020). We could not use additional liquidity measures because we lacked access to the necessary data.

3.6. Descriptive statistics

The green bond market has grown significantly since its inception in mid-2007. Indeed, more and more companies have entered the market since the European Investment Bank issued the first green bond, which amounted to about 674 million dollars. Figure 1 plots the total amount of green bonds issued over the past few years. The green bond market grew slightly during its first 7 years, but since 2014 it has seen phenomenal growth in both the value and the number of issuances, reaching about 70 billion dollars in 2018—mostly owing to the arrival of commercial banks and corporations as a consequence of the release of the ICMA's Green Bond Principles.

[Insert Figure 1 about here]

Table 2 provides summary statistics of our variables. The mean and median values of *BASpread* are 0.480 and 0.360, respectively. *Disclosure_dummy* is a dummy variable that takes a value of one if the issuer has disclosed at least one GBF or GBR for a specific green bond by a specific year, and zero otherwise. On average, about 52% of our sample green bonds have at least one GBF or GBR. *Avg_Inv_Fog_Index,* our measure of disclosure and readability, has a mean (median) value of 0.021 (0.026). For GBFs the mean is 0.029; for GBRs, it is 0.013. Issuers disclose more green bond frameworks than green bond reports.[6]

The average amount issued is about 956 million dollars, the average bond age is about 21 months, and about 33% of our sample green bonds are rated above BB grade. The issuers in our sample are large and exhibit an average leverage ratio of about 29%. These statistics are largely in line with those reported in previous studies.

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[6] Previous studies on annual financial report readability show slightly higher average values of the Fog index than those we find for green bond frameworks (16.07) and green bond annual reports (15.37). For instance, Li (2008) reports a mean Fog index of 19.39. Similarly, Ertugrul et al. (2017) find that 10-K files of U.S. firms have an average Fog index of 19.55.

[Insert Table 2 about here]

Table 3, which reports the matrix of Pearson pairwise correlations between the main variables, highlights two interesting points. First, *Avg_Inv_Fog_Index* is negatively correlated with *BASpread*, with significance at less than the 1% level. This preliminary finding is consistent with the prediction that both disclosure and the readability of green bond documents (GBF and/or GBR) tend to reduce the bid-ask spread and hence increase green bond liquidity. Another notable point is that the correlation coefficients are relatively small, mitigating the concern that our multivariate regressions might involve multicollinearity problems.

[Insert Table 3 about here]

4. Model and results

To examine the impact of the disclosure of GBF and/or GBR on the bid-ask spread, we use the estimation model proposed by Alexander et al. (2000), expanded with additional variables that reflect readability and issuer-specific characteristics:

$$BASpread_{it} = \beta_0 + \beta_1 * Disclosure_dummy_{iy} + \sum_k \beta_k * Controls + Month_FE + Industry_FE + \varepsilon_{it}, \quad (1)$$

where subscripts *i* and *t* denote individual bond and trading month, respectively. The dependent variable (*BASpread*) is the bid-ask spread of each green bond *i* in month t. The independent variable (*Disclosure_dummy*) is a dummy variable that takes the value of one if a GBF and/or GBR has been disclosed for green bond *i* by year y. *CONTROLS* are the set of green bond and issuer characteristics described above: *Issue_size*, *Age_of_bond*, *Rating_dummy*, *Interest_rate_risk*, *Bond_price_volatility*, *Issuer_size*, *Leverage*, and *Europe_dummy*, all of which affect liquidity. *Month_FE* and *Industry_FE* are trading month and industry dummy variables that control for the residual variation in green bond liquidity caused by month and industry differences. These controls mitigate endogeneity issues driven

by omitted variables (e.g., issuer characteristics, industry characteristics) that might influence both liquidity and the readability of green bond–related documents. Finally, ε is an error term. Standard errors are adjusted for heteroskedasticity and clustered by month and industry.

We estimate equation (1) using several specifications and report the results in Table 4. Model (1) includes only the independent and control variables of interest. The significant negative coefficient on *Disclosure_dummy* suggests that green bonds for which a GBF and/or GBR has been disclosed have lower bid-ask spreads and hence better liquidity. Models (2), (3), and (4) additionally control for trading month fixed effects, industry fixed effects, and both month and industry fixed effects to account for observable and unobservable factors that are fixed over time and within industries. The negative coefficient on *Disclosure_dummy* continues to hold in Models (3) and (4) and is significant at the 1% level. In Model (5), we further control for country fixed effects to capture any institutional or macroeconomic variables that may also affect green bond liquidity. The results remain qualitatively unchanged, with a slightly higher magnitude of the negative coefficient on *Diclosure_dummy*, and a statistical significance that remains at the 1% level. The economic impact of these results also appears to be meaningful. Indeed, as Table 4 shows, the disclosure of a green bond–related document (GBF/GBR) decreases the bid-ask spread by about 7 to 11 percentage points. These findings are consistent with hypothesis one, that the disclosure of a green bond framework and regular green bond reports is positively correlated with the bond's liquidity.

We interpret this result as implying that the issuance of such documents demonstrates the issuer's willingness to comply with green bond market practices and standards and also the transparency of its green credentials. Compliance and transparency are particularly sought after by portfolio managers whose investment strategy is based on environmental considerations.

Turning to control variables, we find that *Issue_size* has a negative and significant (at the 1% level) effect on *BASpread*. This result matches with the well-known market phenomenon that bigger bond issuance volumes increase the number of transactions, thus increasing liquidity. Additionally, the bond's age has a significantly positive impact on *BASpread*. The older the bond is, the closer it is to its maturity: a portfolio manager holding it will have more financial interest in holding it until it matures (and finally being reimbursed at the nominal amount) than in trading it, so its liquidity lessens over time. The results also demonstrate that credit rating is an important determinant of bid-ask spreads. The coefficient on *Rating_dummy* is negative and significant at the 1% level, implying that bonds rated above BB have lower spreads and thus better liquidity. Bonds with a higher interest rate risk (longer time to maturity) and those with a higher price volatility tend to be less liquid. Another notable finding is the difference in bond liquidity between European and non-European countries. The coefficient on *Europe_dummy* is negative and significant in four out of five model specifications, suggesting that bonds issued by European issuers are likely to have lower bid-ask spreads, and hence better liquidity, than those issued by non-European entities. This result can be explained by the difference in market size, the important presence of an institutional investor base, and the lack of reliable and consistent trade data with which to evaluate the real level of liquidity in the secondary market outside the European Union. Finally, the results in Table 4 also show that the liquidity of green bonds is not significantly affected by issuer size or leverage.

Overall, the results reported in Table 4 corroborate the idea that GBF and/or GBR disclosures are likely to convey valuable environmental information to investors in the green bond market, making the issuers' green credentials more transparent and finally improving the green bond's liquidity.

[Insert Table 4 about here]

We next examine how the readability of green bond–related documents affects the green bond's liquidity, by introducing the variable *Avg_Inv_Fog_Index*, which combines disclosure and readability:

$$BASpread_{it} = \beta_0 + \beta_1 * Avg_Inv_Fog_Index_{iy} + \sum_k \beta_k * Controls + Month_FE + Industry_FE + \varepsilon_{it}, \quad (2)$$

where the subscripts *i* and *t* denote individual bond and trading month, respectively. The dependent variable (*BASpread*) is the bid-ask spread of each green bond *i* in month *t*. The independent variable (*Avg_Inv_Fog_Index*) is the inverse fog index averaged across the two types of green bond-related documents (GBF and GBR) disclosed for green bond *i* by year *y* (with a value of zero in the case of no disclosure). The *CONTROLS* are the set of green bond and issuer characteristics described above. *Month_FE* and *Industry_FE* are trading month and industry dummy variables that control for the residual variation in green bond liquidity caused by month and industry differences. ε is an error term. Standard errors are adjusted for heteroskedasticity and clustered by month and industry.

We estimate equation (1) using several specifications and report the results in Table 5. As in Table 4, we begin by estimating equation (2) with no fixed effects in Model (1). We then include trading month fixed effects, industry fixed effects, and both month and industry fixed effects in Models (2), (3), and (4), respectively. In Model (5), we further control for country fixed effects. Across all model specifications, the coefficient on *Avg_Inv_Fog_Index* is negative and significant at the 1% level, indicating that when the issuer discloses easy-to-read green bond–related documents (lower information asymmetry), the bid-ask spread will be lower (better liquidity). Reflecting the economic importance of our results, given a one-standard-deviation change in *Avg_Inv_Fog_Index* (0.023), the bid-ask spread changes by about 0.0377 (1.640*0.023 for Model (5)) to 0.042 (1.840*0.023 for Model (3)). In other

words, a one-standard-deviation increase in disclosure and readability leads to a decrease that is 8% to 9% of the bid-ask spread's average (0.480).

[Insert Table 5 about here]

5. Sensitivity checks and additional analyses

As our results may suffer some limitations, in this section we address potential endogeneity concerns and use alternative econometric regression methods. We also perform additional analyses to dig deeper into the relations among disclosure, readability, and green bond liquidity.

5.1. Sensitivity checks

Our core findings could be driven by unobserved omitted variables (e.g., issue or issuer characteristics) that simultaneously influence the readability of green bond-related documents and green bond liquidity, leading to spurious causal inferences. To address this potential problem we adopt a two-stage instrumental variable (IV) technique. We instrument for readability using the one-year lagged value of our main variable (*Avg_Inv_Fog_Index*). In the first stage, we regress the index (*Avg_Inv_Fog_Index*) on its instrument and other control variables, controlling for month and industry fixed effects. In the second stage, we reestimate our baseline regression after replacing *Avg_Inv_Fog_Index* with its fitted values obtained from the first stage.

Table 6 summarizes the results. The first stage regression, reported in column 1, shows that the lagged fog index is positively and significantly related to Avg_Inv_Fog_Index, suggesting that our instrument is a good predictor of the readability of green bond–related documents. The F-statistic is highly significant at better than the 1% level, disproving the null hypothesis of weak identification. Moreover, the Shea (1997) partial R^2 from the first-stage regression is well above the suggested threshold of 10%, confirming the relevance of our instrument in explaining the variation in readability. The second-stage regression reported in

column 2 shows corroborating evidence that green bond liquidity increases with improved disclosure and readability of green bond–related documents: the coefficient on the instrumented value of *Avg_Inv_Fog_Index* is negative and statistically significant, in accord with our baseline regression results. In columns 3 and 4, we replicate these same IV regressions using a different instrument for our *Avg_Inv_Fog_Index*, i.e., industry-year averages. The regression results remain qualitatively the same. Overall, we conclude that our inferences are unlikely to be driven by endogeneity issues.

[Insert Table 6 about here]

In a second set of sensitivity checks, we test the soundness of our results using alternative estimation techniques. In particular, we reestimate our baseline regression model using the Fama-MacBeth (1973) regression procedure as a way to alleviate cross-sectional dependence. This two-step procedure consists of running a series of cross-sectional regressions for each time period, and then estimating the average value of the coefficients obtained in the first stage. The results, reported in column 1 of Table 7, corroborate our baseline finding that the disclosure and readability of green bond–related documents decrease bid-ask spreads. We further account for potential serial correlation of standard errors using the Newey and West (1987) specification and find consistent results (column 2 of Table 7). In another specification, we use the weighted least squares (WLS) estimation. Our sample is dominated by specific industries in which the issuance of green bonds is more prevalent (e.g., electric power, transportation), so our numbers of observations vary significantly across industries. To address this issue, we use a WLS regression in which the weight is the inverse number of observations per industry (Sassi et al., 2019) as a way to attribute a higher weight to industries with a smaller number of observations. The results, shown in column 3 of Table 7, remain qualitatively the same as our main findings. Finally, to alleviate issues associated with extreme values or measurement error in our variables, we use the decile rank

regression (Boubaker et al., 2019). In this regression, our variables are ranked into deciles from 1 to 10 in each sample year. Again, our results, reported in column 4 of Table 7, continue to show a negative and significant impact of disclosure and readability on bid-ask spreads of green bonds. In sum, we conclude that our findings are robust to various estimation procedures.

[Insert Table 7 about here]

5.2. Additional analyses

In additional analyses, we further examine how the relation between readability and liquidity varies according to several country-level, issuer-level, and bond-level characteristics. We perform five subsample analyses by reestimating Model (2) for (1) European vs. non-European countries; (2) financial issuers vs. nonfinancial issuers; (3) large issues vs. small issues; (4) long-maturity bonds vs. short-maturity bonds; (5) investment-grade bonds vs. high-yield bonds.

5.2.1. European vs. non-European countries

The results displayed in Table 8 show that our previous inferences hold for both European and non-European countries. Early in the market's development, non-European issuers and investors reached European green bond market standards, practices, and levels of transparency, rapidly harmonizing standards across the world. Consequently, for a given green bond, from a European or non-European issuer, traded inside or outside Europe, it is generally easy to find a counterparty among portfolio managers, no matter what their location.

[Insert Table 8 about here]

5.2.2. Financial vs. nonfinancial issuers

We define financial firms as banks, insurance companies, and diversified financial companies. Table 9 shows that the negative impact of our measure of disclosure and readability on bid-ask spreads is even more pronounced for nonfinancial firms. More

importantly, the difference is significant at the 1% level. This result could be interpreted as evidence that disclosure and readability are more important for nonfinancial firms, perhaps because financial firms have more disclosure requirements and hence are less subject to market imperfections. Moreover, environment-friendly investments are, by nature, more important for nonfinancial corporations (e.g., utilities companies). Their direct exposure to the green assets and projects that the bond finances intensifies investors' need for transparency. Therefore, the role of disclosure and readability in mitigating market frictions is weaker for financial firms, and rather stronger for nonfinancial ones.

[Insert Table 9 about here]

5.2.3. Large issues vs. small issues

We define green bond issues as large if the amount issued exceeds 500 million dollars. Issues below 500 million are considered small. The results displayed in Table 10 show that our baseline inferences hold for both large and small issues. Since its inception, the green bond market has shown significantly more demand than offerings—unlike the standard bond market, where bigger issuances attract more investors than smaller ones, for liquidity reasons. Furthermore, the level of readability mostly depends on the issuer's willingness to be transparent about environmental issues and commitments, and not on a contingent, market-determined funding strategy.

[Insert Table 10 about here]

5.2.4. Long-maturity vs. short-maturity bonds

We define short-maturity bonds as those that mature within 10 years. Table 11 shows that readability affects green bond liquidity differently for short-maturity and long-maturity bonds, and the difference is significant at the 1% level. In column 1, the coefficient on *Avg_Inv_Fog_Index* is positive and significant at the 1% level, suggesting that greater disclosure and readability lead to higher bid-ask spreads, and hence lower liquidity, for long-

maturity bonds. In contrast, column 2 shows a negative and significant coefficient on *Avg_Inv_Fog_Index*, indicating that more readability leads to lower bid-ask spreads, and hence higher liquidity, for short-maturity bonds. This result is consistent with the idea that green investors tend to adopt a "buy and hold" approach. However, this result must be considered carefully because the sample contains few long-maturity bonds.

[Insert Table 11 about here]

5.2.5. Investment-grade vs. high-yield bonds

When we separately analyze investment-grade bonds (rated above BB+) and high-yield bonds (rated at or below BB+), the results, displayed in Table 12, show that the coefficient on *Avg_Inv_Fog_Index* is negative and significant at the 1% level only for high-yield bonds. The difference between the two subgroups is significant at the 1% level. This result is consistent with our prediction that lower-rated bonds are generally more exposed to informational frictions, and hence their liquidity is more likely to be affected by the readability of disclosures.

[Insert Table 12 about here]

6. Conclusion and interpretations

We demonstrate that both the mere disclosure of documentation and the disclosure in conjunction with the documents' readability increase the liquidity of green bonds. In general, this evidence is more pronounced for bonds from nonfinancial issuers, those with shorter maturities, and those with lower ratings. In contrast, the issuer's geographical location and the issue size—traditionally considered important determinants of liquidity—do not moderate the effect of disclosure and readability on liquidity for green bonds.

Our findings have both managerial and policy implications. First, for green bond issuers, we bring strong arguments that transparency efforts pay off in the liquidity of this investment tool on the secondary bond market. Second, our findings also have important policy

implications for investors, as they inform asset owners and managers about the tradability of such bonds. Finally, the policy implications of this study could help regulators and market standards bodies make more stringent and relevant recommendations on green bond issuance practices, helping them bring more clarity to investors and, eventually, streamline green bond daily market trades.

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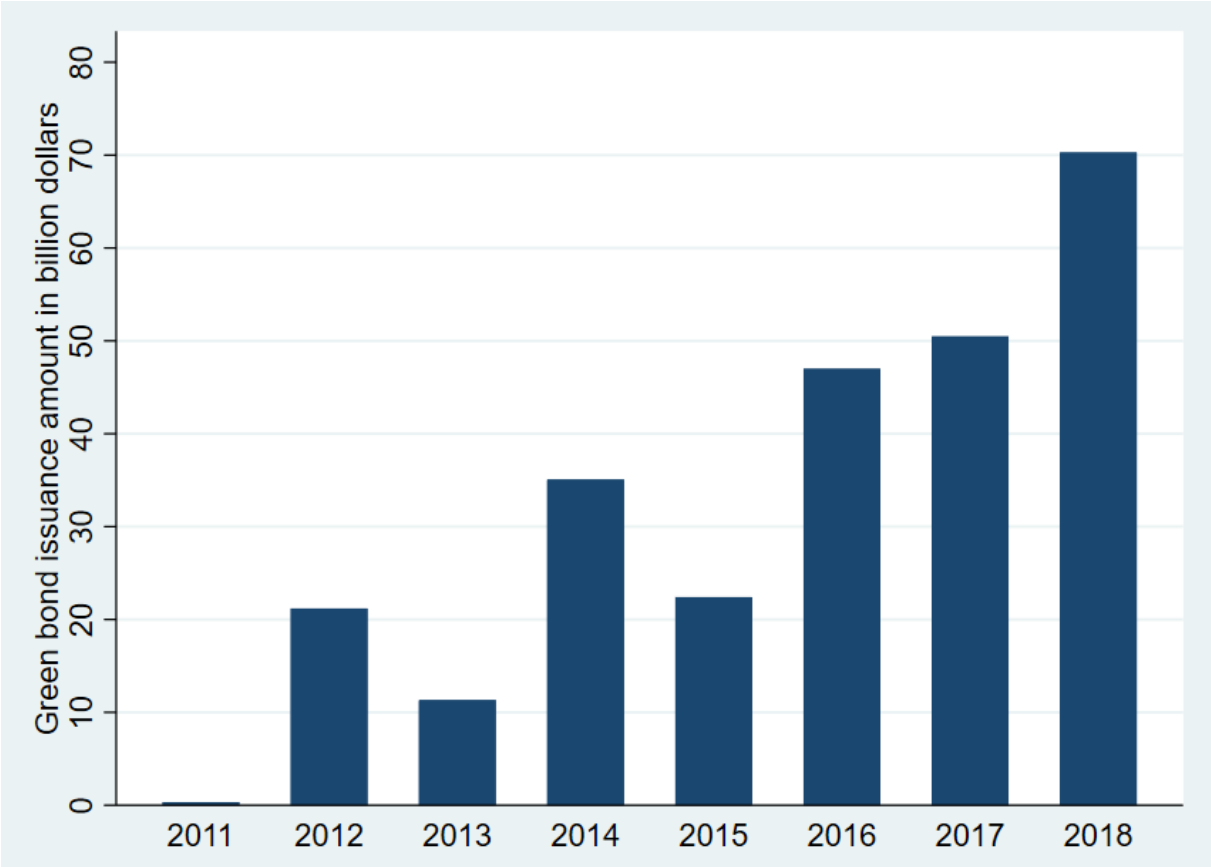

Fig. 1. Corporate green bonds over time. This figure plots the total issuance amount (in $B) of corporate green bonds per year, for our sample of corporate green bonds from 2011 to 2018.

Table 1

Green bonds by country.

Country	Full sample	# of bonds issued by public issuers included in our final sample
Supranational (SNAT)	348	N.A.
China	677	123
France	191	40
Japan	46	17
Sweden	197	16
United States	164	14
Canada	31	8
Spain	23	7
India	34	7
Norway	31	7
Brazil	13	6
Australia	20	4
Italy	13	4
New Zealand	5	4
Germany	50	3
Austria	5	2
Belgium	4	2
United Kingdom	17	2
Hong Kong	13	2
Korea	16	2
Switzerland	7	1
Denmark	7	1
Finland	11	1
Turkey	1	1
Others	155	0
Total	2,079	274

Table 2

Summary statistics.

Variables	N	Mean	Median	Standard deviation	Q1	Q3
BASpread	3,057	0.480	0.36	0.425	0.192	0.602
Disclosure_dummy	3,057	0.520	1	0.500	0	1
Avg_Inv_Fog_Index	3,057	0.021	0.026	0.023	0	0.033
Inv_FOG_Index_GBF	3,057	0.029	0	0.032	0	0.063
Inv_FOG_Index_GBR	3,057	0.013	0	0.027	0	0
Issue_size	3,057	19.763	20.147	1.851	18.816	21.123
Age_of_bond	3,057	2.604	2.708	1.056	1.946	3.367
Rating_dummy	3,057	0.330	0	0.470	0	1
Interest_rate_risk	3,057	4.067	4.111	0.671	3.738	4.595
Bond_price_vol	3,057	0.018	0.007	0.103	0.002	0.014
Issuer_size	3,057	12.368	13.434	2.291	10.654	13.756
Leverage	3,057	0.293	0.240	0.160	0.191	0.383
Europe_dummy	3,057	0.338	0	0.473	0	1

Notes: The full sample includes 3,057 monthly observations from 23 countries between 2011 and 2018.

Table 3

Correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) BASpread	1.000									
(2) Avg_Inv_Fog_Index	-0.187***	1.000								
(3) Issue_size	-0.121***	-0.274***	1.000							
(4) Age_of_bond	-0.046**	-0.022	0.170***	1.000						
(5) Rating_dummy	-0.239***	0.358***	0.069***	0.093***	1.000					
(6) Interest_rate_risk	0.310***	-0.078***	0.159***	-0.210***	0.159***	1.000				
(7) Bond_price_vol	0.209***	-0.053***	-0.021	0.024	-0.043**	0.108***	1.000			
(8) Issuer_size	-0.036**	-0.023	0.067***	-0.126***	-0.385***	-0.179***	-0.114***	1.000		
(9) Leverage	0.106***	-0.012	-0.008	0.001	0.099***	0.123***	0.278***	-0.584***	1.000	
(10) Europe_dummy	0.015	0.418***	-0.470***	-0.068***	0.159***	0.090***	0.094***	-0.178***	0.025	1.000

Table 4

The impact of disclosure of GBF and GBR on green bond liquidity.

Variables	No fixed effects	Month fixed effects	Industry fixed effects	Month & industry fixed effects	Month & industry & country fixed effects
	(1)	(2)	(3)	(4)	(5)
Disclosure_dummy	-0.078**	-0.077**	-0.091***	-0.090***	-0.116***
	(2.26)	(2.21)	(2.79)	(2.72)	(3.31)
Issue_size	-0.056***	-0.056***	-0.048***	-0.048***	-0.048***
	(9.97)	(10.61)	(9.48)	(9.44)	(4.77)
Age_of_bond	0.033***	0.033***	0.037***	0.037***	0.018*
	(3.64)	(3.68)	(3.84)	(3.89)	(1.71)
Rating_dummy	-0.229***	-0.228***	-0.244***	-0.244***	-0.212***
	(10.17)	(10.62)	(8.07)	(7.96)	(4.94)
Interest_rate_risk	0.240***	0.240***	0.267***	0.268***	0.233***
	(12.99)	(13.58)	(14.28)	(14.36)	(15.25)
Bond_price_vol	0.570**	0.566***	0.608***	0.604***	0.484***
	(2.60)	(2.65)	(2.68)	(2.71)	(2.68)
Issuer_size	-0.003	-0.003	-0.004	-0.004	-0.008
	(0.78)	(0.74)	(0.96)	(0.94)	(1.02)
Leverage	0.112	0.117	0.046	0.053	0.117
	(1.14)	(1.19)	(0.42)	(0.48)	(1.06)
Europe_dummy	-0.056*	-0.056*	-0.075***	-0.074**	0.171*
	(1.99)	(1.95)	(2.65)	(2.62)	(1.83)
Intercept	0.652***	0.659***	0.328***	0.332***	0.635**
	(5.52)	(5.46)	(2.94)	(2.78)	(2.41)
Month fixed effects	No	Yes	No	Yes	Yes
Industry fixed effects	No	No	Yes	Yes	Yes
Country fixed effects	No	No	No	No	Yes
Observations	3,057	3,057	3,057	3,057	3,057
Adjusted R^2	0.25	0.25	0.26	0.26	0.34

Notes: The dependent variable is the bid-ask spread. The independent variable is a dummy variable that takes the value of 1 if an issuer discloses at least one GBF or GBR for the issue. All reported absolute t–values in parentheses are based on robust standard errors adjusted for heteroskedasticity and clustered by month and industry. *, **, and *** refer to significance at the 10%, 5%, and 1% levels, respectively.

Table 5

The impact of GBF/GBR disclosure and readability on green bond liquidity.

Variables	No fixed effects	Month fixed effects	Industry fixed effects	Month & industry fixed effects	Month & industry & country fixed effects
	(1)	(2)	(3)	(4)	(5)
Avg_Inv_Fog_Index	-1.756***	-1.752***	-1.840***	-1.836***	-1.640***
	(3.56)	(3.54)	(4.72)	(4.57)	(3.57)
Issue_size	-0.052***	-0.052***	-0.043***	-0.043***	-0.043***
	(8.79)	(9.45)	(8.87)	(8.87)	(4.37)
Age_of_bond	0.034***	0.034***	0.038***	0.038***	0.018*
	(3.86)	(3.90)	(4.02)	(4.08)	(1.70)
Rating_dummy	-0.227***	-0.226***	-0.253***	-0.253***	-0.239***
	(11.17)	(11.92)	(9.42)	(9.27)	(6.39)
Interest_rate_risk	0.241***	0.241***	0.269***	0.269***	0.237***
	(13.73)	(14.45)	(15.03)	(15.13)	(15.67)
Bond_price_vol	0.577***	0.572***	0.618***	0.613***	0.506***
	(2.64)	(2.69)	(2.72)	(2.75)	(2.68)
Issuer_size	-0.002	-0.002	-0.004	-0.003	-0.007
	(0.68)	(0.63)	(0.83)	(0.80)	(0.82)
Leverage	0.096	0.102	0.032	0.040	0.127
	(1.09)	(1.14)	(0.31)	(0.39)	(1.10)
Europe_dummy	-0.050*	-0.049*	-0.072***	-0.071***	0.186*
	(1.80)	(1.78)	(2.66)	(2.64)	(1.77)
Intercept	0.567***	0.584***	0.214**	0.225**	0.486*
	(4.69)	(5.07)	(2.02)	(2.03)	(1.85)
Month fixed effects	No	Yes	No	Yes	Yes
Industry fixed effects	No	No	Yes	Yes	Yes
Country fixed effects	No	No	No	No	Yes
Observations	3,057	3,057	3,057	3,057	3,057
Adjusted R^2	0.25	0.25	0.26	0.26	0.33

Notes: The dependent variable is the bid-ask spread. The independent variable is the average inverse fog index for GBF and GBR. Avg_Inv_Fog_Index takes the value of 0 for issues with missing GBF/GBR. The higher the Avg_Inv_Fog_Index, the more the issuer discloses readable GBF/GBR. All reported absolute t–values in parentheses are based on robust standard errors adjusted for heteroskedasticity and clustered by month and industry. *, **, and *** refer to significance at the 10%, 5%, and 1% levels, respectively.

Table 6

Addressing endogeneity: instrumental variable regression.

Variables	Lagged Fog index		Industry-year average	
	1st stage	2nd stage	1st stage	2nd stage
Avg_Inv_Fog_Index		-1.616***		-5.138***
		(3.95)		(3.97)
Issue_size	0.000	-0.046***	0.001***	-0.040***
	(0.39)	(8.50)	(3.75)	(8.16)
Age_of_bond	-0.000	0.049***	0.000	0.041***
	(1.56)	(4.01)	(0.16)	(4.57)
Rating_dummy	0.000	-0.245***	0.004**	-0.233***
	(0.93)	(9.37)	(2.42)	(8.31)
Interest_rate_risk	0.000	0.268***	0.001	0.266***
	(0.70)	(14.31)	(1.41)	(14.98)
Bond_price_vol	-0.000	0.598***	-0.006***	0.591***
	(0.24)	(2.75)	(3.19)	(2.76)
Issuer_size	0.000	-0.001	0.002***	0.002
	(1.30)	(0.28)	(7.54)	(0.28)
Leverage	-0.001	0.076	0.005	0.044
	(1.08)	(0.70)	(1.32)	(0.45)
Europe_dummy	0.000	-0.078***	0.014***	-0.015
	(0.41)	(2.93)	(8.87)	(0.49)
IV of Avg_Inv_Fog_Index	0.974***		0.937***	
	(97.47)		(18.11)	
Intercept	0.009**	0.176	-0.046***	0.212*
	(2.35)	(1.55)	(4.87)	(1.90)
Month fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	2,783	2,783	3,057	3,057
Adjusted R^2	0.98	0.28	0.57	0.25
F-test of excluded instruments	9,499.86***		327.98***	
Shea's partial R^2	0.95		0.17	

Notes: In the first two columns, we report first- and second-stage regression results where lagged fog index is used as an instrument for readability. In the second two columns, we present first- and second-stage regression results where the industry-year average fog index is used as an instrument for readability. All reported absolute t–values in parentheses are based on robust standard errors adjusted for heteroskedasticity and clustered by month and industry. *, **, and *** refer to significance at the 10%, 5%, and 1% levels, respectively.

Table 7

Robustness to alternative estimation techniques.

Variables	Fama-MacBeth	Newey-West	Weighted least squares	Decile-rank regression
	(1)	(2)	(3)	(4)
Avg_Inv_Fog_Index	-1.062**	-1.062**	-1.837***	-0.059***
	(2.13)	(2.13)	(4.70)	(3.22)
Issue_size	0.015	0.015	-0.043***	-0.198***
	(1.05)	(1.04)	(8.46)	(5.49)
Age_of_bond	0.008	0.008	0.037***	0.125***
	(1.32)	(1.34)	(5.37)	(5.59)
Rating_dummy	0.093*	0.093*	-0.251***	-1.832***
	(1.85)	(1.84)	(10.76)	(10.01)
Interest_rate_risk	0.016	0.016	0.268***	0.323***
	(1.54)	(1.52)	(22.07)	(9.63)
Bond_price_vol	3.626**	3.626**	0.610***	0.181***
	(2.57)	(2.58)	(8.86)	(3.86)
Issuer_size	0.008	0.008	-0.003	0.010
	(0.43)	(0.43)	(0.77)	(0.24)
Leverage	0.522***	0.522***	0.044	0.006
	(2.68)	(2.68)	(0.70)	(0.16)
Europe_dummy	0.091**	0.091**	-0.070***	-0.200
	(1.99)	(1.99)	(3.78)	(1.02)
Intercept	2.151***	-0.296	0.228*	3.961***
	(2.86)	(1.27)	(1.66)	(4.83)
Month fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	3,057	3,057	3,057	3;057
Adjusted R^2	0.98	0.98	0.26	0.27

Notes: This table shows the results of reestimating our baseline regression using alternative estimation techniques: in column 1, the Fama-MacBeth regression procedure; in column 2, the Newey-West technique; in column 3, weighted least squares regression; in column 4, decile-rank regression. The dependent variable is the bid-ask spread. The independent variable is the average of the inverse fog index for GBF and GBR. Avg_Inv_Fog_Index takes the value of 0 for issues with missing GBF/GBR. The higher the Avg_Inv_Fog_Index, the more the issuer discloses readable GBF/GBR. All reported absolute t–values in parentheses are based on robust standard errors adjusted for heteroskedasticity and clustered by month and industry. *, **, and *** refer to significance at the 10%, 5%, and 1% levels, respectively.

Table 8

The impact of GBF/GBR disclosure and readability on green bond liquidity: European vs. non-European countries.

Variables	European countries	Non-European countries
	(1)	(2)
Avg_Inv_Fog_Index	-1.503***	-1.640***
	(3.10)	(2.91)
Issue_size	-0.029***	-0.038***
	(2.82)	(2.64)
Age_of_bond	0.020	0.052***
	(1.46)	(4.33)
Rating_dummy	-0.203***	-0.271***
	(4.10)	(7.80)
Interest_rate_risk	0.243***	0.290***
	(8.08)	(14.86)
Bond_price_vol	0.420**	4.246***
	(2.50)	(3.33)
Issuer_size	0.030***	0.006
	(2.87)	(0.76)
Leverage	0.259	-0.131
	(1.48)	(1.41)
Intercept	-0.433*	-0.032
	(1.66)	(0.10)
Month fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Observations	1,033	2,024
Adjusted R^2	0.327	0.287
Difference test for coefficients	0.03	

Notes: The dependent variable is the bid-ask spread. The independent variable is the average inverse fog index for GBF and GBR. Avg_Inv_Fog_Index takes the value of 0 for issues with missing GBF/GBR. The higher the Avg_Inv_Fog_Index, the more the issuer discloses readable GBF/GBR. All reported absolute t–values in parentheses are based on robust standard errors adjusted for heteroskedasticity and clustered by month and industry. *, **, and *** refer to significance at the 10%, 5%, and 1% levels, respectively.

Table 9

The impact of GBF/GBR disclosure and readability on green bond liquidity: financial vs. corporate issuers.

Variables	Financial	Corporate
	(1)	(2)
Avg_Inv_Fog_Index	-0.300	-2.862***
	(0.66)	(4.72)
Issue_size	-0.021**	-0.017*
	(2.33)	(1.79)
Age_of_bond	0.042***	0.015
	(5.17)	(1.04)
Rating_dummy	-0.327***	-0.167***
	(11.43)	(3.44)
Interest_rate_risk	0.270***	0.177***
	(10.67)	(5.74)
Bond_price_vol	8.963***	0.307**
	(5.78)	(2.37)
Issuer_size	-0.016***	-0.008
	(3.31)	(0.94)
Leverage	-0.478***	0.539***
	(9.28)	(4.71)
Europe_dummy	-0.104***	0.027
	(3.21)	(0.78)
Intercept	0.151	-0.142
	(0.86)	(0.72)
Month fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Observations	1,091	1,966
Adjusted R^2	0.427	0.261
Difference test for coefficients	11.49***	

Notes: The dependent variable is the bid-ask spread. The independent variable is the average inverse fog index for GBF and GBR. Avg_Inv_Fog_Index takes the value of 0 for issues with missing GBF/GBR. The higher the Avg_Inv_Fog_Index, the more the issuer discloses readable GBF/GBR. All reported absolute t–values in parentheses are based on robust standard errors adjusted for heteroskedasticity and clustered by month and industry. *, **, and *** refer to significance at the 10%, 5%, and 1% levels, respectively.

Table 10

The impact of GBF/GBR disclosure and readability on green bond liquidity: high issues vs. low issues.

Variables	High issues	Low issues
	(1)	(2)
Avg_Inv_Fog_Index	-3.567***	-1.839**
	(5.64)	(2.33)
Issue_size	0.115**	-0.055***
	(2.00)	(4.72)
Age_of_bond	0.040***	0.037***
	(2.77)	(2.63)
Rating_dummy	-0.395***	-0.254***
	(8.74)	(5.92)
Interest_rate_risk	0.296***	0.297***
	(11.61)	(14.47)
Bond_price_vol	0.360	0.506**
	(0.36)	(2.52)
Issuer_size	-0.014	-0.004
	(1.48)	(0.71)
Leverage	-1.081***	0.162
	(4.80)	(1.36)
Europe_dummy	0.134**	-0.114*
	(2.10)	(1.92)
Intercept	-2.201*	0.225
	(1.83)	(0.84)
Month fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Observations	1,534	1,523
Adjusted R^2	0.25	0.32
Difference test for coefficients	1.90	

Notes: The dependent variable is the bid-ask spread. The independent variable is the average inverse fog index for GBF and GBR. Avg_Inv_Fog_Index takes the value of 0 for issues with missing GBF/GBR. The higher the Avg_Inv_Fog_Index, the more the issuer discloses readable GBF/GBR. All reported absolute t–values in parentheses are based on robust standard errors adjusted for heteroskedasticity and clustered by month and industry. *, **, and *** refer to significance at the 10%, 5%, and 1% levels, respectively.

Table 11

The impact of GBF/GBR disclosure and readability on green bond liquidity: long maturity vs. short maturity.

Variables	Long-maturity bonds	Short-maturity bonds
	(1)	(2)
Avg_Inv_Fog_Index	12.177***	-1.392***
	(3.92)	(3.50)
Issue_size	-0.014	-0.037***
	(0.14)	(6.91)
Age_of_bond	-0.154*	0.035***
	(1.80)	(4.15)
Rating_dummy	-0.911	-0.227***
	(0.73)	(8.04)
Interest_rate_risk	-0.002	0.241***
	(0.00)	(13.85)
Bond_price_vol	0.143*	4.268***
	(1.66)	(3.84)
Issuer_size	-0.340	-0.004
	(1.45)	(0.84)
Leverage	0.565	-0.225**
	(1.40)	(2.52)
Europe_dummy	0.296	-0.094***
	(0.27)	(4.49)
Intercept	4.230	0.281***
	(0.72)	(2.63)
Month fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Observations	146	2,911
Adjusted R^2	0.56	0.25
Difference test for coefficients	19.83***	

Notes: The dependent variable is the bid-ask spread. The independent variable is the average inverse fog index for GBF and GBR. Avg_Inv_Fog_Index takes the value of 0 for issues with missing GBF/GBR. The higher the Avg_Inv_Fog_Index, the more the issuer discloses readable GBF/GBR. All reported absolute t–values in parentheses are based on robust standard errors adjusted for heteroskedasticity and clustered by month and industry. *, **, and *** refer to significance at the 10%, 5%, and 1% levels, respectively.

Table 12

The impact of GBF/GBR disclosure and readability on green bond liquidity: investment-grade bonds vs. high-yield bonds.

Variables	Investment-grade bonds	High-yield bonds
	(1)	(2)
Avg_Inv_Fog_Index	0.070	-3.203***
	(0.16)	(3.88)
Issue_size	-0.057***	-0.022**
	(2.58)	(2.52)
Age_of_bond	0.000	0.046***
	(0.05)	(3.97)
Interest_rate_risk	0.127***	0.302***
	(6.82)	(16.61)
Bond_price_vol	8.987***	0.578***
	(6.66)	(2.72)
Issuer_size	-0.018***	0.025***
	(3.39)	(2.63)
Leverage	0.150*	0.093
	(1.73)	(0.73)
Europe_dummy	-0.122***	0.079
	(4.77)	(1.47)
Intercept	0.846*	-0.852***
	(1.82)	(3.57)
Month fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Observations	981	2,076
Adjusted R^2	0.35	0.25
Difference test for coefficients	14.51***	

Notes: The dependent variable is the bid-ask spread. The independent variable is the average inverse fog index for GBF and GBR. Avg_Inv_Fog_Index takes the value of 0 for issues with missing GBF/GBR. The higher the Avg_Inv_Fog_Index, the more the issuer discloses readable GBF/GBR. All reported absolute t–values in parentheses are based on robust standard errors adjusted for heteroskedasticity and clustered by month and industry. *, **, and *** refer to significance at the 10%, 5%, and 1% levels, respectively.