Board of Governors of the Federal Reserve System

International Finance Discussion Papers

ISSN 1073-2500 (Print)
ISSN 2767-4509 (Online)

Number 1346

June 2022

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Please cite this paper as:
Caramichael, John and Andreas Rapp (2022). "The Green Corporate Bond Issuance Premium," International Finance Discussion Papers 1346. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/IFDP.2022.1346.

The Green Corporate Bond Issuance Premium

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May 2022

Abstract

We study a global panel of green and conventional bonds to assess the borrowing cost advantage at issuance for green bond issuers. We find that, on average, green bonds have a yield spread that is 8 basis points lower relative to conventional bonds. This borrowing cost advantage, or greenium, emerges as of 2019 and coincides with the growth of the sustainable asset management industry following EU regulation. Within this context, we find that the greenium is linked to two proxies of demand pressure, bond oversubscription and bond index inclusion. Moreover, while green bond governance appears to matter for the greenium, the credibility of the underlying projects does not have a significant impact. Instead, the greenium is unevenly distributed to large, investment-grade issuers, primarily within the banking sector and developed economies. These findings have implications for the role of green bonds in incentivizing meaningful green investments throughout the global economy.

Keywords: Green bonds, corporate bonds, green finance, sustainable finance, climate finance, green bond premium, bond issuance

JEL Classifications: C33, G15, G18, G23, G28, Q54, Q56

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For helpful discussions and valuable comments we thank Ricardo Correa, Michele Dathan, Anil Jain, Yuriy Kitsul, Gordon Liao, Andrew McCallum, Viktors Stebunovs, Emre Yoldas, Tony Zhang, and participants at the Division of International Finance Policy Workshop and the Georgetown-IDB Green Bond Methods Seminar. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or any other person associated with the Federal Reserve System. First draft: October 2021. Final draft: May 2022.

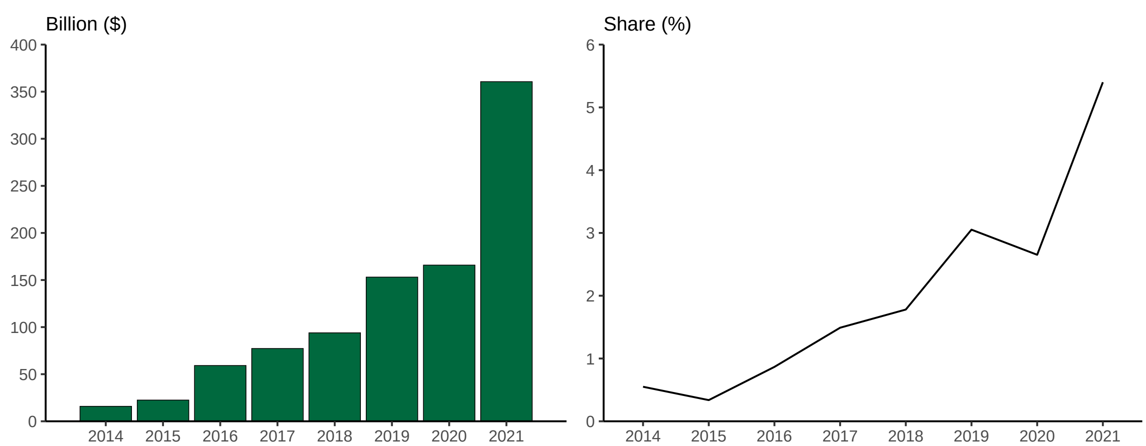
1 Introduction

According to intergovernmental organizations and research institutes worldwide, to slash greenhouse gas emissions to net zero by 2050, it will be necessary to invest up to $275 trillion in physical assets over the next thirty years.[1] A substantial part of this investment will likely come from the private sector. One prominent instrument for financing this private sector investment is the green corporate bond, a long-term fixed income debt security that is rapidly gaining popularity. Green corporate bonds are similar to conventional corporate bonds, but they contain provisions that direct the funding raised from the bond's issuance towards environmental (green) projects.

The issuance of green corporate bonds has grown rapidly in recent years, totaling almost $400 billion in 2021 (see Figure 1a). As of 2021, green corporate bonds account for nearly six percent of global corporate bonds outstanding, up from less than one percent in 2014 (see Figure 1b). During this period of rapid growth, green bonds have been cited as a potential driver of large-scale, rapid climate investment. They have been criticized, however, for their lack of standardization, high cost of issuance, and the potential for "greenwashing", or misusing a green label for a bond that does not finance eligible green projects. Furthermore, it remains unclear if green bonds actually incentivize green investment, or if they are an instrument that merely identifies green investments that otherwise would have been made and financed with a conventional bond.

Figure 1: Growth in green corporate bonds

(a) Annual issuance volume (b) Share of corporate bonds outstanding



Panel (a) is the annual issuance volume of the global green corporate bond market. Panel (b) is the notional share of green corporate bonds relative to the notional size of the total corporate bond market at year-end. Source: Bloomberg Finance LP (2021).

[1] See, for example, McKinsey (2022) as well as the Global Financial Markets Association and Boston Consulting Group (2020). For the energy sector specifically, which accounts for a large portion of emissions, estimates include those from the Energy Transitions Commission (2021), the International Energy Agency (2021), and BloombergNEF (2021) at $50 trillion, $100 trillion, and $92 to $173 trillion respectively.

In this paper, we investigate whether green bonds offer a direct incentive to corporations that wish to invest in green projects. The potential direct incentive is in the form of a borrowing cost advantage (lower yield spread at issuance) for green bonds versus conventional bonds, also called the "greenium". Our analysis focuses on three main questions: First, is there empirical evidence for an average greenium at issuance that is statistically significant? And, if so, is this average greenium economically meaningful so as to constitute a direct economic incentive for green investment? Second, does the greenium vary over time, and if so, how does this time variation connect with the development of the green bond market? Third, how is the greenium distributed across bond-level and issuer characteristics?

In addressing these questions, we leverage a comprehensive global sample of the primary bond market, containing 1,169 green and 129,043 conventional corporate bonds over a sample period from 2014 to 2021. We analyze our sample with a detailed and well-specified fixed effects regression specification that accounts for potential nonlinearities, issuer- and bond-specific time-variation, and the pricing dynamics of the global corporate bond market. Our analysis relies on traditional financial securities data, such as the price, rating, and maturity of each bond, as well as metrics specific to green bonds, such as whether a green bond experienced strong investor demand at issuance or whether it adheres to voluntary green bond standards. We contribute to the literature by using a well-specified empirical approach to understand the primary market pricing of green corporate bonds in a global context, with an eye towards the differentiated pricing of the quality and credibility of green corporate bonds and the differences between various market segments.

Our main findings are as follows: On average, US dollar- and euro-denominated green corporate bonds offer a small borrowing cost advantage of about 8 basis points over our sample period. This advantage is distinct from a green bond issuer effect, or "green halo", which is a hypothesized benefit from issuing a green bond that lowers an issuer's overall borrowing costs across all bonds, both green and conventional (see Section 2). A significant greenium emerges only in 2019, when corporate bond investors and European Union officials began to embrace the green bond market. We find that the greenium is linked to two proxies of demand pressure, oversubscription and green bond index inclusion, highlighting mechanisms through which the greenium can be allocated as demand for the bonds outpaces supply. While US dollar- and euro-denominated green bonds capture comparable greeniums, the greenium is, on average, allocated primarily to local euro and foreign US dollar issuers. Lastly, the greenium is unevenly distributed to large, investment-grade issuers, primarily within the banking sector and developed economies.

With these findings, we argue that the issuance premium of green corporate bonds likely plays a limited role in incentivizing rapid, large-scale green investment. Instead, green corporate bonds may indirectly incentivize green investment by signaling the environmental credentials of the issuer. However, the signaling effect from green corporate bonds may be relatively suboptimal compared to alternative solutions, such as certain regulatory requirements or financing instruments based on green performance targets rather than green projects. Situated within the critical need for investment to avert the worst potential outcomes of climate change, overreliance on green corporate bonds as an incentive may lead to an undersupply of green investment.

The remainder of the paper proceeds as follows: In Section 2, we discuss the growth of the green bond market, the potential motivations for issuing and investing in green bonds, and the existing body of literature on green bonds. In Section 3, we describe our dataset, regression methodology, and the limitations of our empirical approach. In Section 4, we present and analyze our empirical results. In Section 5, we discuss the broader significance of our results and conclude the paper.

2 Background: Green bonds and the greenium

Before we begin our analysis of green corporate bonds, we first review key concepts and developments within the green bond market at large. Green bonds have been one of the most recognized instruments for the financing of green projects. While the stock of green loans is also growing, most green debt is in the form of green bonds. Like conventional bonds, green bonds are long-term fixed income debt instruments. They generally have the same seniority, recourse, and rating as an issuer's conventional bonds. The main difference between green and conventional bonds is that the proceeds of a green bond are earmarked for climate- and environment-friendly projects.[2] This typically includes investments into clean energy, energy efficiency, green buildings, or electrified transportation.[3] Green bonds rely on third-party certification or the trust of investors to assure that the bonds' proceeds are channeled toward the intended green investments. In short, green bonds are essentially a conventional bond packaged with a "green promise".[4]

Green bonds currently lack a universal global regulatory framework. Instead, green bonds are customarily structured to align with the Green Bond Principles published by the International Capital Markets Association (ICMA).[5] The principles provide voluntary best-practice guidelines for the selection, management, evaluation, and disclosure of green projects when issuing a green bond. The principles recommend (but do not require) third-party certification for green bonds. As alignment with the principles is voluntary, the proceeds of some green bonds may not be invested in meaningful green projects, a process that reflects broader trends of greenwashing, or misusing the green label, in the sustainable finance industry.[6]

[2] Conventional bonds can still be used to finance green projects. Green bonds are distinguished by the specification of the use of proceeds in the bond prospectus.

[3] While this paper focuses on the reduction of greenhouse gas emissions to mitigate climate change, green bonds may pledge investment to achieve a variety of aims not only limited to reducing emissions, such as increasing water efficiency or supporting biodiversity.

[4] See Levine (2019).

[5] See International Capital Markets Association (2021).

[6] For further discussion of greenwashing in green bonds, see Wirz (2022). For greenwashing in ESG investment funds, see Fletcher and Oliver (2022). For general greenwashing concerns, see Mundy (2022), The Economist (2021), and Fancy (2021).

The overall green bond market has grown rapidly in recent years, with issuance reaching $556 billion in 2021. This is a substantial increase from only $31 billion in 2014, reflecting a compound annual growth rate of about 50% for the entire market. Green bonds are poised for continued rapid growth, with some market participants forecasting significant growth in green bond issuance in 2022.[7] While green bonds have been issued in many countries, European issuers have been the most active, followed by US issuers, Chinese issuers, and supranational issuers. About three-quarters of annual green bond issuance is denominated in the euro or the US dollar.

2.1 Green corporate bonds

Green bonds were first issued in the late 2000s by supranational organizations such as the European Investment Bank and the World Bank. Supranationals (and governments) still issue green bonds, but corporations now account for about two-thirds of global issuance. Private-sector issuers of green bonds tend to be large, mature firms or firms with strong access to debt capital markets. This is especially true of firms issuing green bonds in a foreign currency to tap international green capital markets. Issuers also tend to be from relatively less carbon-intensive industries and greener than their industry peers.[8]

About half of green corporate issuance is concentrated in financial firms. The majority of this financial firm issuance is from banks, which use green bond proceeds to extend loans to firms that need financing for green projects. Alternatively, banks may first extend green loans, and then securitize the loans into a green bond.[9] The remaining portion of financial firm issuance is mostly from real estate financing vehicles such as real estate investment trusts (REITs), which typically finance the development of green buildings. The electric utility sector accounts for an additional quarter of green corporate bond issuance. The remaining quarter of green corporate bond issuance is distributed among a variety of sectors with growing issuance, such as alternate energy, automobiles, and heavy industry. Notably, issuance from fossil fuel companies is negligible.

During the recent period of remarkable growth in green bond issuance, policymakers, market participants, and financial journalists have acknowledged the potential for green bonds to fund green investments. However, while certain individual green bonds may have a discernible positive impact, the broader green bond market has several shortcomings. Key issues include greenwashing, the lack of a universal governance and certification framework, and the significant compliance costs associated with certification, issuance and reporting.[10] Critics further question if the green bond market actually influences firms'

[7] See, for example, Kuchtyak and Bruce (2022).

[8] See Flammer (2021).

[9] In either case, this financial engineering can lead to the banking sector overstating its green investments relative to actual capital expenditure. The double-counting occurs when the bondholder and the lender both claim to be funding green investments (Ritchie & Rocha, 2021). We further discuss this refinancing issue in a later section.

[10] For further discussion on the shortcomings of green bonds, see Ritchie, Ward, Kishan, and Gledhill (2021) and Stubbington and Nauman (2020). For discussion on greenwashing in the sustainable finance industry, see

investments, or if green bonds instead fund green projects that would have otherwise received funding through conventional channels. The unanswered question is: Is the green bond market *as a whole* incentivizing meaningful green investment?

2.2 Motivation for issuing and investing in green bonds

2.2.1 The greenium

Firms that issue a green bond may receive several direct and indirect benefits that potentially incentivize green investment. Issuing a green bond may directly lower the interest rate paid on the bond relative to conventional bonds. If a firm chooses to issue a green bond, it may attract new investors interested in sustainable investment, thereby increasing demand for the bond. Should the added demand push the green bond's yield lower than that of a comparable or hypothetical conventional bond, this yield difference is called the green premium, or "greenium".[11] That said, even if a green bond issue offers a greenium, it may still be costlier to issue a green bond compared to a conventional bond. The process of certifying, issuing, monitoring, and reporting over the lifetime of the bond is high, especially for complex green projects and small or first-time issuers. For some issuers, it may take several green bond issues or a very large greenium for the borrowing cost advantage of the greenium to break even against the significant compliance and issuance costs.

From the investor's perspective, there are several explanation for why one would accept a lower yield on a green bond relative to a comparable conventional bond. The most common explanation for the greenium is that investors are willing to sacrifice immediate financial returns in exchange for an environmental benefit.[12] According to this framework, because a green bond is effectively comprised of a conventional bond and a green promise, investors assign a positive value to the green promise and are willing to pay a higher price for a bond at issuance, which means they accept a lower yield. Under this working model, the marginal green bond investor is understood to be concessionary (as opposed to full-return), meaning they are willing to accept lower investment returns to finance high-quality green projects.[13] By optimizing the trade-off between returns and environmental impact, these investors are supposed to exert a demand pressure that produces

Quinson (2021a), Quinson (2021b), The Economist (2021), Fancy (2021), and Temple-West and Palma (2022). For a critical assessment of the changes in carbon emissions from green bond issuers see Ehlers, Mojon, and Packer (2020).

[11] Alternatively, the issuer may respond to the increased demand by issuing more debt at a the same interest rate, rather than lowering the interest rate. In practice, this is constrained by the limited number of green projects that are available to the issuer.

[12] See Section A1 in the Appendix for discussion of the two main alternative explanations for the greenium: higher risk-adjusted returns and the "green crisis premium".

[13] A recent draft methodology released by the Partnership for Carbon Accounting proposes that green bond investors should be able to claim a reduction to their Scope 3 Category 15 (investment-related) greenhouse gas emissions in accordance with their investment in a given green bond. This accounting methodology could potentially increase the incentive to pay a higher price for a given green bond (concede lower expected returns) by effectively allowing green bond investors to purchase an emissions reduction by buying a green bond (Partnership for Carbon Accounting Financials, 2021). Some market participants are reportedly already using this methodology (Edwards et al., 2022).

a ”smart greenium”, rewarding credible, high-impact green bonds with an incrementally lower interest rate.

Our research is not the first to focus on the greenium at issuance. Previous studies have delivered mixed empirical results.[14] Several papers, using different empirical methodologies and green bond samples, have quantified greeniums in the primary market that are ranging from a strict 0 to up to 19 basis points. See, for example, Ehlers and Packer (2017), Gianfrate and Peri (2019), Partridge and Medda (2020), Larcker and Watts (2020), Baker, Bergstresser, Serafeim, and Wurgler (2022), and Kapraun, Latino, Scheins, and Schlag (2021). However, it can be difficult to parse and compare the results across the papers because they differ widely in their sample period, green bond market segment, focus on primary and/or secondary markets, and empirical methodologies. In addition, some papers implement a matching approach that confines samples to a small set of issuers with a large number of bonds outstanding in order to establish meaningful matches, while other papers use fixed-effect regression approaches that require large, global panels and a host of control variables to meaningfully account for issuer- and bond-level differences. Therefore, the existence and robustness of a potential corporate greenium at issuance is inconclusive. In this paper, we aim to be careful in selecting the most appropriate empirical approach, given the global corporate green bond sample at our hands, in an attempt to gauge the greenium for a specific set of green bonds.

2.2.2 *The green halo*

Besides the direct benefit of the greenium, green bonds may provide additional indirect benefits for the issuer. For instance, by highlighting the environmental credentials of an issuer, green bonds offer a marketing benefit, potentially lowering the firm’s cost of capital by attracting new investors, or potentially improving business performance by attracting new customers. This hypothesized indirect effect is called the green halo.

Empirical research on the green halo has only emerged recently. The existing literature highlights short-term increases in issuers’ stock prices or decreases in issuers’ secondary market bond yields upon announcement of the first green bond issue. See, for example, Flammer (2021), Tang and Zhang (2020), NatWest Markets (2019), Baulkaran (2019), and Forfot and Fosse (2021). These announcement returns are captured by stockholders and bondholders, but they do not necessarily impact the firm’s actual cost of capital beyond the short-term window. The green halo is not a focus of our paper, but we do look to understand whether the benefits of issuing a green bond are distinct from any potential long-term improvements to a firm’s cost of capital.

[14] See Lau, Sze, Wan, and Wong (2022) for a summary of the empirical evidence on the greenium, covering both primary and secondary market results.

The argument for issuing green bonds to capture a green halo can be situated within the theoretical context of signaling problems.[15] Firms possess asymmetric information about their environmental credentials, such as future plans to reduce emissions. If this information is not or cannot be communicated effectively to investors with a preference for sustainability, firms may suffer from suboptimal costs of capital. Issuing a green bond may serve as (potentially costly) solution to address the signaling problem and achieve a more optimal capital cost.

3 Data and empirical approach

For the period from 2014 to 2021, we compile a global panel of 129,043 conventional corporate bonds and 1,169 green corporate bonds. These bonds have been issued by 12,736 corporations.

Our primary source of data to construct this sample is bond-level data from Bloomberg Back Office. For the bonds in our sample, Bloomberg Back Office data provides detailed information on the characteristics of each bond, such as the issue price, issue and maturity date, the history of the par amount outstanding, credit ratings, the bond's currency, as well as a variable to identify green bonds Bloomberg Finance LP (2021). The Bloomberg green bond identifier strictly requires referenced bonds to be aligned with the first principle of the Green Bond Principles, which states that the green bond's use of proceeds for environmental projects should be "appropriately described in the legal documentation of the security". We supplement the Bloomberg data with additional data from Refinitiv Workspace (Refinitiv, 2021).

To construct our sample, we begin by selecting conventional and green corporate bonds and medium-term notes (MTNs) from both green and conventional issuers. We further require a bond to be a fixed- or zero-coupon bond with a notional amount of at least $500,000 issuance. We only consider bonds issued by private-sector corporations but allow state-owned enterprises in our sample.[16] We do not consider bonds directly issued by supranational entities or municipalities.

We require green bonds to be issued in either the euro or US dollar because these green bond markets are the deepest and most liquid. We drop green bonds if their ultimate parent does not have at least one conventional bond in our sample.[17] For conventional

[15]See Daubanes, Mitali, and Rochet (2021), which develops a theoretical model of signaling by green bond issuers. See Maltais and Nykvist (2020) for further discussion of potential indirect, non-financial benefits to issuing green bonds, such as alleviating institutional pressures, seeking social legitimacy (the "license to operate"), and attracting or retaining valued employees.

[16]Many large emerging market issuers with consistent access to international bond markets have some form of government backing; this includes state-owned enterprises (SOEs). We retain SOEs because excluding them would reduce our global sample by roughly 20%. This does not qualitatively affect our results. Moreover, we add regression controls on the issuer- and issuer-times-country level to account for potential differences in SOEs bonds.

[17]We obtain data on issuers' ownership structure from Bloomberg Capital Structure (CAST) (Bloomberg Finance LP, 2021).

bonds, we include only bonds denominated in currencies where issuers of the selected green bonds have issued at least one additional bond and where there is at least $10 billion in total issuance in the currency over the sample period. Our goal is to compare euro and US dollar green bonds issued by firms outside the US and euro area to the conventional bonds in the issuers' domestic markets, provided the market has sufficient issuance volume for a robust, meaningful comparison. The end result is that we include conventional bonds from 23 currencies. A breakdown of our sample by currency is provided in the Appendix in Table A1.

After constructing this initial sample of bonds, we calculate the exact yield to maturity of each bond at issuance using each bond's issue price, coupon rate, coupon frequency, and day-count convention. We focus on the primary market yield (the yield at issuance), instead of the secondary market yield, because it determines the actual interest rate paid by the issuer to borrow funds.[18] Additionally, because the global corporate bond market is relatively illiquid and has substantial transaction costs, many investors have a preference for purchasing bonds in the primary market (Flanagan, Kedia, & Zhou, 2021). When investors are considering where to allocate their bond portfolio, they are often more likely to select one of several comparable bond offerings in the primary market rather than choose between a given issuer's new primary market issue and their outstanding bonds trading in the secondary market. This means it is often more appropriate to compare an issuer's primary market yields to the primary market yields of other issuers in a given period, rather than compare an issuer's primary market yields to their secondary market yields.

We then calculate each bond's yield spread at issuance by taking the difference between the yield to maturity and the linearly interpolated maturity-matched government bond yield curve for the given bond's currency on its date of issuance. Lastly, we take several steps to eliminate outliers and data errors. We drop bonds with yield spreads greater than ten percent, as these bonds are generally considered distressed. We also drop bonds with prices at issuance of less than 90 and greater than 250, as these are likely distressed, data errors, or very large outliers. By focusing on yield spreads, we are able to control for the differences in interest rate environments across currencies. By comparing yield spreads between bonds denominated in different currencies without accounting for currency hedging, we are assuming that exchange rates follow a random walk. Summary statistics for yield spread, yield to maturity, and amount issued across the bonds in our sample are provided in the Appendix in Table A2.

3.1 Variable construction

For bonds included in our sample, we construct composite credit ratings by taking the mean of the bond's credit rating, where available, from Moody's, Standard & Poor's, and

[18]Secondary market yields may not accurately reflect borrowing costs in the primary market for corporate issuers without a broad, liquid set of outstanding bonds that can be used to construct a yield curve. Liquidity conditions may also vary significantly across international markets and interest rate environments, which can further distort secondary market yields.

Fitch, and then rounding down. We aggregate the composite ratings into rating buckets. We provide a breakdown of the bond sample by rating bucket in Table A4.

Sector categories are based on the Global Industry Classical Standard (GICS) codes and used to analyze green bonds by industry. We tailor our sector categories to the major segments of the green bond market. Our green bond sector categories are: alternate energy; banks; electric utilities and fossil fuels; industry and materials; non-bank financials; real estate, transportation, and other.[19] We provide a breakdown of the green bond sample by industry in Table A5.

We construct a refinancing variable, which is equal to one if some portion of the bond was used to refinance an existing liability. Otherwise, this variable has a value of zero. We are able to construct this variable for 706 green bonds and 40,794 conventional bonds in our sample. Within this subset, 200 (28%) of the green bonds are used for refinancing, compared to 4,028 (10%) of conventional bonds.

3.1.1 Green bond variables

Where data is available, we calculate each green bond's oversubscription from a textual variable that contains additional information on the bond issue. A bond is oversubscribed if the investment bank underwriting a bond issuance receives excess orders relative to the actual amount of debt being issued. High oversubscription rates can indicate strong demand for a bond issuance, relative to supply. Relative to the typical demand seen for conventional bonds, green bonds have been well-received by investors, with some issues being several times oversubscribed, a fact that is often noted in the financial press. For a given bond, we calculate oversubscription as the ratio of the notional amount of orders to the actual amount of debt that is issued. Data on investment bank order books for the corporate bond market is very limited, but we are able to construct this variable for 474 of our 1,169 green bonds.

We also construct a variable reflecting each bond's adherence to the Green Bond Principles. At a minimum, green bonds must adhere to the first component of the Green Bond Principles, Use of Proceeds, to be identified as a green bond by Bloomberg. The remaining three components of the Green Bond Principles are optional to be considered a green bond and reflect the quality of the green bond's governance.[20] For each green bond, our Green Bond Principles variable is equal to zero if a green bond is not fully aligned with the Green Bond Principles and one if the bond is fully aligned. We construct a variable reflecting if the

[19] Transportation firms include firms in the transportation and auto manufacturing industry groups. Firms in the oil and gas sectors issue very few green bonds, so they are included with electric utilities.

[20] The remaining three components of the Green Bond Principles are: (1) Process for Evaluation and Selection, which indicates if the issuer has clearly communicated the eligibility, objectives, and potential risks of the bond's green projects; (2) Management of Proceeds, which indicates if the green bond's proceeds are transferred to a sub-account or sub-portfolio or otherwise managed in an "appropriate manner"; and (3) Reporting, which indicates if the issuer produces an annual report until the bond's proceeds are fully allocated. See International Capital Markets Association (2021).

green bond was subject to a pre-issuance external review by a third party. While external review is not a component of the Green Bond Principles, it is considered ”recommended”.

Finally, we construct a triple index inclusion indicator variable that is equal to one if a green bond was a constituent of three major green bond indices in our sample: the ICE Green Bond Index (542 bonds in the sample), the Solactive Green Bond Index (505) and the JP Morgan JESG Green Bond Index (436).[21] The triple index inclusion variable is equal to one for 365 bonds in our sample.

3.2 Empirical approach

The regressions in this paper are in spirit of Baker et al. (2022) in that we estimate a fixed-effects regression across an unbalanced panel of corporate bonds, with a given bond's yield spread at issuance as the dependent variable. In doing so, we allow our regression specification to account for potential nonlinearities as well as issuer- and bond-specific time variation.

We chose a fixed effects regression approach over a matching approach for two reasons. First, the matching approach generally requires a triplet of bonds from the same issuer: one green bond and two comparable conventional bonds that are used to interpolate a localized conventional yield curve. This requirement drastically reduces the number of green bonds that can be investigated and biases the sample to issuers with strong capital market access and the ability to frequently issue comparable bonds. Issuers that cannot frequently issue comparable bonds, such as small- and medium-sized enterprises (SMEs) and issuers in emerging markets, will be underrepresented. Second, the matching approach reduces the sample to only green bond issuers. This biases the control group of conventional bonds to those issued by green bond issuers, which is problematic because green bond issuers have been shown to be different from grey issuers (Flammer, 2021). In contrast, the regression approach allows us to estimate the greenium by regressing yield spreads on bond, issuer, and macro characteristics of bonds issued by both green and conventional-only bond issuers.

In our regression approach, we compare the borrowing costs of green and conventional bonds using an indicator variable that flags green bonds, while holding other factors constant. Our empirical baseline model is as follows:

$$\text{Yield spread}_{i,f} = \alpha\ \text{Green}_i + \beta\ \text{Controls}^T_{i,r,t} + \mu^T_{i,r,m,f} + \epsilon_{i,f} \qquad (1)$$

for bond i of ultimate parent company f issued in currency region r on date t in year-month m. In Equation (1), the key variable of interest is the indicator variable Green_i, which takes the value of one if bond i is a green bond. The coefficient on this indicator

[21] The JP Morgan index was launched in November 2020. Before November 2020, we rely on JP Morgan's simulated index constituents, which reflects what the index constituents would have been if the index methodology was retroactively applied to historical data.

variable, α, captures the average difference in primary market yield spreads for green and conventional bonds, holding other factors constant. A negative α indicates a lower yield spread for green bonds, and therefore a borrowing cost advantage over conventional bonds (or a positive greenium). The vector $\text{Controls}_{i,t,r}^{T}$ contains bond-level numeric and macro-level controls, observed for bond i in currency region r on issue date t, and their interactions $i \times r$ and $i \times t$. The vector $\mu_{i,m,f}^{T}$ contains bond-level, firm-level, and time-level fixed effects for bond i, ultimate parent f, and year-month m, as well as an interaction of year-month and currency region, $m \times r$. Standard errors are clustered on the issuer ultimate parent and year-month levels and are thus robust to both cross-sectional dependence and serial correlation.

Specifically, our vector of controls includes the following variables: We have two bond-level numeric variables, the log years to maturity and log notional amount issued. We further control for multiple variables that capture the general condition of credit markets in different currencies: The level, slope, and curvature of the sovereign yield curve for a given bond's currency region, calculated between 1 and 10 years to maturity using a principal component analysis; and the 30-day realized volatility of the 10-year sovereign bond for a given bond's currency region. To add a dimension for aggregate credit risk, we control for the option-adjusted spread (OAS) of the ICE BofA global investment grade corporate bond index (G0BC) and the difference in the OAS between the ICE BofA global high-yield corporate bond (HW00) and the investment grade corporate bond indexes.

In addition to the numeric controls, we include several fixed effects to capture potential nonlinearities: the issuer ultimate parent, the rating bucket, seniority, whether a bond is callable, whether a bond is putable, whether a bond is sinkable, the year-month of issuance, and the currency of issuance interacted with year-month, as well as country of issuance interacted with an indicator variable marking state-owned enterprises.

Lastly, to control for potential bond-specific time variation in the maturity risk, the credit risk, and the potential call-option feature, we allow for interactions of the numeric controls and the fixed effect. That is, we include interactions between the slope of the yield curve and log maturity; the rating bucket and the high yield minus investment grade index; and whether a bond is callable and the level, slope, curvature, and realized volatility of the sovereign yield curve.[22]

In its current version, the potential shortcomings of our empirical analysis may be rooted in our lack of firm-level metrics for ESG outcomes and balance sheet data. Nevertheless, our baseline results remain robust to the inclusion of time-varying issuer fixed effects, such as issuer ultimate parent interacted with year-quarter. Balancing the granularity of the time-varying issuer fixed effects and the associate reduction in sample size due to the elimination of singleton observations (Correia, 2015), we ultimately adopt a regression specification that interacts issuer and annual fixed effects. There is possibly some addi-

[22]See Gilchrist and Zakrajšek (2012) for the importance of controlling for interactions between the yield curve and whether a bond is callable

tional bias from our lack of data on expected liquidity. We further discuss this potential shortcoming in the Appendix in Section A2.

4 Empirical results

In this section, we present our empirical results. We start with the baseline estimate of the greenium for our sample. We then continue to account for the time-variation in the greenium over our sample period, relating it to the rapid growth of the sustainable asset management industry. Within the context of a growing demand from the asset management industry, we connect the greenium to two proxies for demand pressure, namely oversubscription and bond index inclusion, and document a relation particularly for euro-denominated green bonds. The latter motivates us to differentiate the greenium by currency and whether or not corporations are local or foreign currency issuers. We conclude by relating the greenium to the "greenness" of the bonds as well as to specific bond- and firm-level characteristics.

4.1 Baseline results: 8 bp greenium, not from green halo

We present our baseline results on the greenium and the green halo in Table 1. In Columns (1) to (3), we find negative and highly significant coefficients on the green bond indicator variable from Equation (1). The negative coefficient indicates that, on average, there is a greenium holding other factors constant. In Column (1), we estimate Equation (1) without time-varying issuer fixed effects, finding a greenium of about 11 basis points. In Columns (2) and (3), we control for time-varying issuer fixed effects at the annual and quarterly frequency, respectively, finding a greenium of about 8 and 9 basis points, respectively.

We select the regression specification of Column (2), which uses annual time-varying issuer fixed effects, as our baseline estimate of the greenium. This is motivated by the following consideration: It is important that our regressions account for issuer-specific time-variation, but there is a trade-off between the granularity of the fixed effects and the sample size due to our elimination of singleton observations.[23] As shown in Column (3), increasing the granularity of the time-varying issuer fixed effects to the quarterly frequency does not meaningfully impact the regression estimate, but it causes a sharp drop in our sample size by 12,755 bonds. This reduction in the sample most impacts the bonds issued by smaller issuers, which are more likely to issue a single bond in a given quarter, which would be counted as a singleton.

Taking Column (2) as our baseline regression, the green bonds in our sample receive an average yield spread at issuance that is about 8 basis points lower relative to conventional bonds. This indicates that, on average, corporate bond issuers pay a lower interest rate on their green bonds, holding other factors constant. Relative to the average yield spread of our sample, this reflects a roughly 5% decrease in the borrowing cost to the issuer. This

[23]See Correia (2015) for discussion of singleton observations.

borrowing cost advantage is economically meaningful, but at the same time it is reduced by green bonds' compliance costs (certification, monitoring, reporting) and a longer issuance process, particularly for complex green projects and small or first-time issuers.[24] However, anecdotal evidence suggests the costs of issuance may decrease as firms issue multiple green bonds, which is when an average 5% borrowing cost advantage may start to accumulate.

[INSERT TABLE 1]

In Columns (4) and (5), we test whether green bond issuers receive a borrowing cost advantage across all of their bonds, both green and conventional. As described in Section 2, this potential benefit to a firm's overall cost of capital is called the green halo. We construct an indicator variable that is equal to one for a given bond if its issuer has previously issued a green bond (or if the given bond is the issuer's first green bond). The coefficient on the green issuer variable is neither economically meaningful nor statistically significant. That is, relative to conventional issuers, green issuers do not capture an overall borrowing cost advantage across all of their bonds. Next, in Columns (6) and (7), we test if the borrowing cost advantage of the greenium is distinct from any potential green halo benefits for green bond issuers. We include both the green bond and green bond issuer indicator variables. While the greenium coefficient remains significant at about 8 basis points, the coefficient on the green issuer indicator variable is not statistically significant.

In combination the results in Columns (4) to (7) suggest that the greenium is a separate phenomenon from any potential green halo benefit to the bonds of green bond issuers. Admittedly, this test does not constitute an exhaustive invalidation of the green halo, as there are other possible channels by which issuing green bonds could lower a firm's cost of capital (for instance, through higher stock prices as documented by Flammer (2021) and Tang and Zhang (2020).

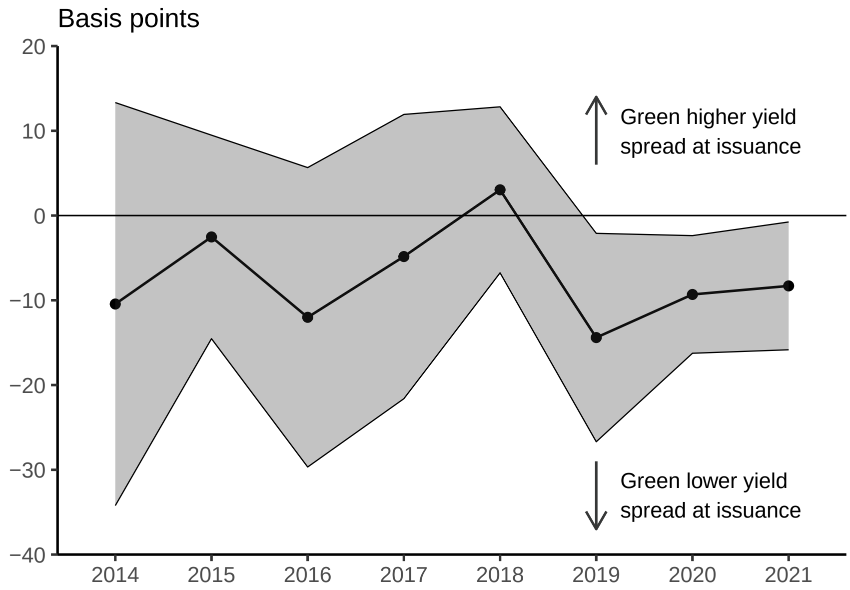
4.2 Accounting for time-variation: Greenium emerges in 2019

In Figure 2, we use a similar regression specification to Equation (1) to construct a time series of the greenium at issuance at an annual frequency. We interact the green bond indicator variable with a yearly time fixed effect; the regression estimates are detailed in Table A6 in the Appendix. In Figure 2, black dots reflect the greenium coefficient for each year, and the gray ribbon reflects a 95% confidence interval. We find that a statistically significant average greenium in our sample only emerges in 2019 at about 14 basis points, and then tightens to about 9 and 8 basis points in 2020 and 2021, respectively.

The emergence of an average greenium in 2019 follows a discrete jump in the maturation of the green bond market over the period from 2018 to 2019. During this time, green bonds

[24] In unreported results that go beyond the scope of this analysis, we find that, on average, underwriters charge lower fees for underwriting green bonds relative to conventional bonds. This might reflect underwriters' incentives to establish a foothold in the nascent market for issuing green bonds.

Figure 2: Time series of corporate bond greenium at issuance



Regression estimate of the average annual yield spread of green corporate bonds versus conventional corporate bonds, holding other factors constant. Negative values indicate green corporate bonds have a lower yield spread than conventional corporate bonds, and therefore a borrowing cost advantage. Shaded ribbon indicates a 95% confidence interval. Source: Regression estimation from Table A6.

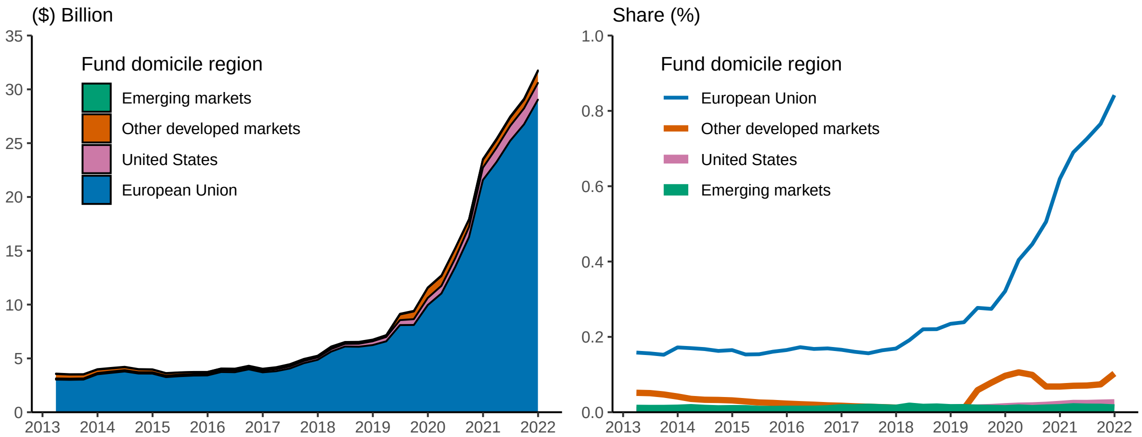
gained acceptance from investors and regulators as a mainstream investment vehicle, particularly in Europe. For regulators, this period marked a substantial development with the release of the European Union Sustainable Finance Action Plan (EU SFAP) by the European Commission in March 2018. The plan reflected a broad commitment to reorient capital flows towards a more sustainable economy, with specific commitments to standardize and regulate green securities through regulations such as the EU Green Bond Standard. The plan included a regulation to mandate and standardize the sustainability disclosures of financial market participants (or SFDR) in an effort to increase transparency. Following the release of the action plan by the European Commission, the SFDR was eventually adopted by the European Parliament on April 18, 2019 and signed into law on November 27, 2019.

This period of regulatory crystallization coincided with the uptake of green bonds by investors and asset managers. This uptake is reflected in the growth in assets under management (AUM) by green bond funds beginning in 2018, as charted in Figure 3a using data from Morningstar (Morningstar, Inc., 2021). The growth is driven almost exclusively by green bond funds domiciled in Europe, which account for more than 90% of green bond fund AUM.

It appears plausible that the increased appetite by investors, combined with a push for disclosures and standardization, contributed to the emergence of the average greenium in 2019. We test this conjecture in Table 2a by creating an indicator variable $SFDR_t$, which

Figure 3: Green bond fund assets under management (AUM)

(a) Green bond fund AUM (b) Green share of total fixed income AUM



Panel (a) is the assets under management (AUM) of green bond funds by fund domicile region. Panel (b) is the share of green bond fund AUM relative to each domicile region's total fixed income fund AUM. The data extends from 2014-Q1 through 2021-Q4 at a quarterly frequency. Source: Morningstar, Inc. (2021).

is equal to zero before and one on and after April 18, 2019, the date the EU Parliament adopted the SFDR. In Column (1), we estimate the greenium in the pre-SFDR and post-SFDR periods. In line with our results from Figure 2, we find a significantly negative greenium of about 13 basis points in the period following the EU regulation. In Column (2), we show that this post-SFDR greenium is little changed by the inclusion of annual time-varying issuer fixed effects, remaining significantly negative at about 10 basis points.

[INSERT TABLE 2a]

In Columns (3) and (4), we adopt a difference-in-differences specification, including the green bond indicator variable in combination with the post-SFDR interaction term. The coefficient on the interaction term should capture the response in the greenium following the regulatory change.[25] In Column (3), without controlling for time-varying issuer fixed effects, we still find a significantly negative coefficient on the interaction term. However, in Column (4), controlling for annual time-varying issuer fixed effects, the interaction term is no longer significant, suggesting that issuer-specific time-variation rather than just the regulatory change contributed to the significant greenium as of 2019 in Figure 2.

In Columns (5) and (6), we differentiate the greenium into the pre- and post-SFDR periods with further segmentation by currency. Consistent with Columns (1) through (4), we find significant negative greenium coefficients for euro and US dollar green bonds in Column (5), but these coefficients become insignificant in Column (6) with the addition of time-

[25] The baseline effect for the post-SFDR indicator is partialled out due to our year-month fixed effects in our regressions.

varying issuer fixed effects. Segmentation by region, as captured in Table 2b Panel (b) Column (1), suggests that only issuers from the EU and the United States captured significant greeniums following the introduction of the SFDR. Other developed market issuers as well as emerging market issuers appear not to capture a significant average greenium as of 2019. With time-varying issuer fixed effects, Column (2), this effect only holds weakly for US issuers.

[INSERT TABLE 2b]

From this mixed empirical evidence we cannot conclude that the SFDR regulation caused the emergence of a significant greenium as of 2019. This is not to say that the EU SFAP and the SFDR have been supportive to the overall development of the green bond market and in particular its strength in Europe.

4.3 Oversubscription and index inclusion

In the two subsections above, we documented a significant average greenium and differentiated this greenium across time. We showed that the emergence of a significant greenium coincides with the growth of the sustainable asset management industry. In this subsection, we focus on the impact of supply and demand imbalances for green bonds and how excess demand pressure relative to a green bond's fundamentals could drive the greenium. We examine two proxies for excess demand that could contribute to the allocation of the greenium: Oversubscription and bond index inclusion.

We link the greenium to a green bond's excess demand at issuance using bond oversubscription rates in Table 3. Anecdotally, market participants and financial journalists have reported that green corporate bonds can be heavily oversubscribed, indicating excess demand for a bond in the primary market.[26] Holding other factors constant, excessive demand from investors relative to the notional size of a green bond may allow an underwriter to lower the bond's yield on behalf of the issuer. Our hypothesis is therefore that oversubscription rates are negatively correlated with yield spreads.

We argue that oversubscription rates are a good proxy for excess demand in the case of green bonds. The notional size of a green bond is constrained by the opportunities for green investment available to an issuer. If there is very strong demand for a given issuer's green bond, it is difficult to increase the amount of debt issued without degrading the greenness of the bond. It is more feasible for the issuer to capture the high demand with a lower bond yield rather a larger supply of debt.

In Table 3 Column (1), we estimate the effect of green bonds' log oversubscription rates on yield spreads. We find a statistically significant negative coefficient, suggesting that higher green bond oversubscription rates are associated with a borrowing cost advantage.

[26] For discussion of green bond oversubscription in the primary market, see Climate Bonds Initiative (2021).

In our estimation, a 1% increase in oversubscription is associated with a 0.058 basis point increase in the greenium. For the average sample log oversubscription of 1.48, this would indicate an average greenium of about 8 basis points, consistent with our baseline results in Table 1 Column (2). Admittedly, one could argue that underwriters of issuers with oversubscribed bonds are more likely to report oversubscription data. In Column (2), in an attempt to tackle such a selection issue, we assume that if underwriters did not report an oversubscription rate, the green bond was neither over- nor undersubscribed, and assign an oversubscription ratio of one. These *imputed* oversubscription rates serve as a lower bound, as markedly undersubscribed bond offerings are typically not brought to the market. The coefficient retains its sign and significance and increases by a little more than a basis point, suggesting that green bonds without reported oversubscription data and an imputed oversubscription rate of one still capture an average greenium. That is, Column (1) is not necessarily biased toward bonds that capture a greenium. In Column (3), we continue our analysis by controlling for the green bond indicator. Despite some collinearity between the two variables, we find that the oversubscription effect remains weakly significant and negative, while the coefficient on the green bond indicator turns insignificant.

[INSERT TABLE 3]

In Column (4), we explore a potential nonlinear relationship between oversubscription and the greenium, breaking the green bond sample into terciles we form on oversubscription rates. We find that only highly oversubscribed green bonds receive an statistically significant average greenium at about 17 basis points. In Column (5), we confirm this effect even when controlling for the green bond indicator variable, finding statistically significant differences in the coefficients for low, medium, and high oversubscription rates. In Columns (6) and (7), we refine our result by segmenting the green bonds by currency. While controlling for the green bond indicator variable, we find that oversubscription in euro-denominated green bonds leads to a statistically significant greenium; for dollar green bonds, the effect is insignificant.

Another potential proxy for excess demand relative to a green bond's fundamentals is whether the green bond is included in a green bond index. Index inclusion is either known in advance or can be anticipated based on inclusion criteria and the inclusion or prior issues. Previous literature shows that demand from mutual funds and exchange-trade funds (ETFs) benchmarked to a given bond index can impact the pricing of bonds included in the index (Dannhauser, 2017; Holden & Nam, 2019; Ye, 2019). This phenomenon of additional demand for index constituents has been shown to encourage bond issuers to alter the characteristics of their bonds in order to meet index inclusion criteria (Dathan & Davydenko, 2020). Index inclusion may plausibly drive the greenium by forcing demand for constituent green bonds from green bond funds that are benchmarked against the indexes.[27]

Our hypothesis is that green bond index inclusion is negatively related to yield spreads at issuance. In Table 4 Column (1), we confirm that green bonds capture a significant average greenium of about 9 basis points when they are included in any of the three green bond indexes that we consider (ICE, Solactive, JP Morgan).[28] In Column (2), we control for the green bond indicator to test if the greenium for index constituent green bonds is distinct from the advantage for excluded green bonds. We find that index inclusion is not, on average, associated with a statistically significant greenium relative to excluded bonds. However, in Columns (3) and (4), we segment the index inclusion effect by currency. We find that euro green bonds included in the green bond indexes receive a large, statistically significant greenium of about 12 basis points, while excluded euro green bonds do not. On the other hand, included US dollar green bonds do not receive a greenium, while excluded dollar green bonds receive a sizeable, statistically significant greenium. Notably, most of the excluded US dollar green bonds have been issued by foreign dollar issuers, a green bond feature we study in more detail in the next subsection.

[INSERT TABLE 4]

In combination, the results in Tables 3 and 4 suggest that oversubscription and bond index inclusion are relevant proxies for how the greenium is allocated. Our results point to a more pronounced greenium through demand pressures in euro-denominated green bonds and US dollar green bonds of foreign issuers. One possible explanation for this effect could be the more stringent transparency requirements that European issuers and financial service providers are subjected too. Anecdotally, European issuers are more transparent about the governance and impact of their green projects, making it easier for investors to justify and disclose their green bond purchases. This may create additional demand for the respective green bonds. At this point, however, we cannot back up this notion empirically.

4.4 Euro greenium more robust

Next, we examine the effect of currency denomination and issuer geography on the greenium in Table 5. In Column (1), we show that euro-denominated green corporate bonds capture an average greenium of about 6 basis points, while US dollar-denominated green bonds capture an average greenium of 12 basis points. Both estimates are significant at the 5% significance level. In Column (2), we show that the roughly 7 basis point difference in

[27] Institutional investors with buy-and-hold strategies prefer to purchase bonds with a primary market allocation to avoid the substantial transaction costs associated with buying the same position in the secondary bond market (Flanagan et al., 2021). As green bonds are anecdotally reported to be less liquid than conventional bonds in the secondary market, this rationale should exacerbate the competition for green primary market allocations among the ESG asset management industry.

[28] We do not report the results from regressions using each green bond index separately, but the results are similar.

the greenium for euro and US dollar green bonds is not statistically significant from zero, meaning the bonds capture statistically comparable greeniums when the point estimates' confidence intervals are taken into account.

[INSERT TABLE 5]

We further segment the green bond sample by currency and whether a bond was issued by a domestic or foreign firm relative to the currency region. In Columns (3), our findings suggest that, on average, the greenium for US dollar green bonds is conferred to foreign issuers, not American issuers. This is consistent with our results from Table 4 Column (3), as most of the dollar green bonds excluded from green bond indexes are issued by foreign firms. In Column (4), we show that the 15 basis point difference between local and foreign issuers in the US dollar green bond market is significant at the 5% significance level. On the other hand, the euro greenium appears to be conferred primarily to local issuers, see Column (3). However, in comparison to the US dollar green bond market, we cannot confirm a statistically significant difference in the greenium of local and foreign euro green bond issuers, see Column (4).

In Column (5), we examine the impact of issuer geography on the greenium. We split the green bond market into five segments: the euro area, the United States, other developed markets, China, and other emerging markets.[29] We find statistically weak evidence of a 6 basis point average greenium for euro area issuers, but weak to no statistical evidence, respectively, of a greenium for other developed market issuers and from the United States. As shown in Column (6), we cannot confirm that these differences in the greenium across regions are statistically significant.

Overall, the results from Table 5 suggest that, on average, euro area firms issuing local currency bonds as well as foreign-currency dollar borrowers appear to receive a significant average greenium, while there appears to be no average greenium in the domestic dollar market, and in the non-euro area market more generally.

4.5 Mixed results on governance, external review, and credibility

In Table 6, we analyze whether the "greenness" of a green bond has a measurable impact on its yield. We begin by assessing the impact of a green bond's governance and alignment with voluntary international standards. In Column (1), we separate the green bond sample into those that are aligned and not aligned with the Green Bond Principles (GBP). In our sample, 82% of green bonds are aligned with the GBP (that is, 839 vs. 190 green bonds). We find that on average, GBP-aligned green bonds capture a robust statistically significant greenium of 7 basis points, while non-GBP-aligned green bonds also show a weakly significant coefficient of about 20 basis points at the 10% significance level. In Column (2), we

[29]The issuer country is the country of the issuer's ultimate parent as of 2021. Issuer country groupings are based on classifications from International Monetary Fund (2021).

check whether there is a statistically significant or measurable difference between the two groups of bonds, which we cannot confirm. The lack of a statistically significant difference between the two groups suggests that their pricing is not inherently different and green bonds with poor governance frameworks may still receive a comparable borrowing cost advantage.

Next, we separate the green bonds into those that do and do not receive an external review (also known as third-party verification). In our sample, 78% of green bonds have received an external review (that is, 800 vs. 229 green bonds). In Column (3), we find that, on average, green bonds with an external review capture a statistically significant greenium of 8 basis points, while green bonds without an external review capture a statistically insignificant estimate of about 9 basis points. Again, as shown in Column (4), we do not find a statistically significant difference in the greenium of green bonds with and without external review. This suggests that green bonds without external review may still capture a borrowing cost advantage, even though it is, on average, not significantly different from zero.

Lastly, in Columns (5) and (6), we separate green bonds by whether the bond has been used to refinance a firm's existing debt. For green bonds used for refinancing, we estimate a weakly significant greenium of about 6 basis points; for green bonds not used for refinancing, the greenium is a weakly significant at about 13 basis points at the 5% significance level. We show in Column (6) that this 7 basis point difference between refinancing and non-refinancing green bonds is not statistically significant, indicating no measurable impact of the refinancing variable on the greenium. This result is notable because it suggests that whether a green bond drives additional environmental impact from new green projects, as opposed to refinancing existing projects, is not priced in the primary market.[30]

In combination, the results from Table 6 suggest that the greenium is primarily allocated to green bonds that are sufficiently green beyond some minimum threshold. That is, on the margin, it appears that what determines the greenium is not the credibility of the green promise, but rather the requirements that make bonds "green enough" (full or partial GBP alignment and external review) to be included in a conventional ESG or green bond portfolio.

4.6 Bond- and firm-level characteristics

In this last subsection, we analyze the connection between bond and firm-level characteristics and the greenium. Table 7 presents the impact on the greenium by bond size, firm capital market access, and bond rating. In Column (1), we do not find that the size of the green bond itself has an impact on the greenium. However, in Column (2), we estimate the greenium while controlling for the average size of an issuer's bonds within the same year.

[30] Green investments are said to have an additional environmental impact (in ESG jargon, "additionality") when they produce beneficial outcomes that would not have occurred without the investment. For a review of environmental and social impact investing, see Brest and Born (2013).

We find that, on average, firms that are able to place larger bonds (a proxy for access to debt capital markets) capture a larger greenium. Specifically, the coefficient on the green bond indicator decreases in the average size of an issuer's bonds. Taking the average of the issuer log average bond size, 18.8 (about $152 million), the greenium is about 7 basis points (58.4 minus 3.5 times 18.8).

In Column (3), we assess the impact of a green bond's rating on the greenium, segmenting the sample into investment grade (AAA to BBB), high yield (BB to C), and not rated bonds. We find that only investment grade green bonds capture a statistically significant average greenium of about 10 basis points. In contrast, the greenium coefficients for high yield and not rated green bonds are not statistically significant. In Column (4), we do not find significant differences in the greenium between rating classes, despite the differences in group means. In a one-sided t-test between investment grade and not rated bonds we need to reject the null hypothesis that the estimated difference of -8 basis points is positive (p-value: 0.051), suggesting that, on average, investment grade bonds have a larger greenium relative to no rated bonds. This finding indicates that firms which cannot afford to have their bonds rated or firms not covered by ratings agencies (for instance, SMEs and EM issuers) may not capture a greenium.

The results from Table 7 are consistent with our findings in Table 4 in that they point to a greenium for firms that are able to meet typical index inclusion criteria, namely issuers with an ability to regularly issue large, investment-grade rated bonds.

[INSERT TABLE 7]

In Table 8a, we analyze how the greenium is allocated by issuer sector. In Column (1), we find that only issuers from the banking sector receive a statistically significant average greenium of about 9 basis points. A possible explanation for the banking greenium could be that banks receive a compensation for the costs of certifying, extending, and monitoring green loans to their customers, or that they capture a potential borrowing cost advantage that may be passed through to the banks' green debtors. What's more, in an attempt to prepare for anticipated climate-related financial disclosure the banking sector has increased their climate disclosure efforts, which may increase the attractiveness of banks' bonds to investors who are subject to sustainability-related reporting requirements. Most other sectors receive a statistically insignificant negative coefficient estimate. The notable exception is the high-emission industry and materials sector, for which we estimate a positive yet statistically insignificant coefficient.

In Column (2), we show that we do not find statistically significant differences in the greenium between banks and issuers in other sectors, suggesting that other sectors show statistically comparable greeniums when the estimates' confidence intervals are taken into account. The notable exception is the difference in the greenium between banks and industry and materials. This difference is about 23 basis points and weakly significant.

[INSERT TABLE 8a]

Finally, in Table 8b, we break down the greenium in the banking sector by region. We find that it is primarily banks from emerging markets (EM), in particular China, as well as banks from the European Union that are, on average, able to capture a significant greenium.[31] The significant greenium estimate for EU banks lines up with our overall results on a robust euro greenium for large, investment-grade issuers. And, it is in line with the idea that increased climate disclosures, in particular in Europe, increase the attractiveness of the region's bonds relative to other developed markets. For emerging markets, where information asymmetries can be large and access to issuers can be limited, the explanation that the estimated greenium could be compensating banks for their monitoring costs and access to green debtors applies well. Lastly, nearly all of the EM and Chinese banks' green bonds have full GBP alignment, external review, and a high credit rating, which can make the bonds attractive for portfolio diversification for a sustainable asset manager.

[INSERT TABLE 8b]

5 Conclusion

According to intergovernmental organizations and research institutes worldwide, hundreds of trillions of dollars of investment is required to achieve global net zero emissions by 2050. About two-thirds of this investment is expected to come from private sector investments in climate- and environment-friendly projects. Currently, one of the most recognized instruments for financing this type of investment is the green corporate bond, a long-term fixed income debt instrument that has its proceeds earmarked for green projects.

In this paper, we study a large global panel of corporate bonds to understand the potential for green corporate bonds to incentivize green investments. To do so, we investigate whether green bonds offer lower borrowing costs for issuers relative to conventional bonds. We find that, on average, dollar- and euro-denominated green corporate bonds have a primary market credit spread that is eight basis points lower compared to conventional corporate bonds, reflecting a 5% reduction relative to the average credit spread in our sample. This greenium is distinct from a green bond issuer effect, or so-called "green halo". It emerges, on average, only as of 2019, coinciding with the growth of the sustainable asset management industry following EU regulation. While this EU regulation appears to have been supportive for the development of the green bond market and its strength in Europe, our results do not establish a causal link between the regulation and the emergence of the greenium in 2019. However, the excess demand from green bonds, possibly from the sustainable asset management industry, appears to be an important driver of

[31] Besides the bond rating, our regression specification controls for whether an issuer is an SOE through the issuer fixed effect. It also accounts for differences in state ownership across jurisdictions with a country-times-SOE interaction. In unreported results, this effect remains qualitatively similar when we drop all SOEs from the sample.

the green bond borrowing cost advantage. In fact, we show that the greenium is linked to two proxies for excess demand pressure, bond oversubscription and bond index inclusion. While U.S. dollar- and euro-denominated green bonds capture comparable greeniums, we find that the greenium is allocated primarily to local euro and foreign U.S. dollar issuers. While green bond governance and external review appear to matter for the greenium, the credibility of the underlying projects does not have a significant impact. Instead, the greenium is unevenly distributed to large, investment-grade issuers, primarily within the banking sector and developed economies.

Our findings have implications for the role of corporate green bonds in incentivizing meaningful green investments throughout the global economy. The empirical evidence suggests that a greenium exists, but it primarily favors large, rated European firms, does not necessarily reward high-quality green projects, and is small or potentially negative when taken net of fees and compliance costs. Part of the funding advantage of green corporate bonds may be driven by potentially temporary supply and demand imbalances between green bond issuers and the growing sustainable asset management industry.[32] Furthermore, questions of additionality−whether green bonds incentivize additional green investment, or simply reward green investments that would have occurred anyway−remain unresolved.

For these reasons, the borrowing cost advantage of green corporate bonds likely plays a limited role in incentivizing global, large-scale climate investment. Instead, the potential benefit of issuing a green bond would likely be an indirect signaling benefit that improves the environmental credentials of the issuer. This raises questions about the potential quality of the signal from issuing a green bond. While issuing a green bond may indicate that a firm is more green than its peers, the potential for greenwashing is high and there is no guarantee that the green projects of a green bond are linked with a long-term, meaningful commitment for green investment.

Mandated, standardized reporting on environmental metrics such as greenhouse gas emissions, as well as required disclosure of climate-related risks and future corporate development, may provide a more effective signaling solution. Financial instruments that are linked to firm-level environmental metrics, such as sustainability-linked bonds, rather than specific green projects (like green bonds), may be more effective for connecting sustainability minded investors with firms making credible, systemic green investments. Situated within the need for substantial, rapid investments to reach net zero emissions by 2050, an over-reliance on the potentially limited incentives conferred from issuing green bonds could lead to an undersupply of green investment if green bonds are not complemented by other sources of private sector funding.

[32] Continued growth in green corporate bond issuance could therefore lead to a dilution of the greenium, should supply catch up with demand. That is, an exhaustion at the margin of the direct financial benefit to green issuance. This potential dilution has already been noted anecdotally by market participants and financial journalists (see, for example, Bahceli (2021) and Stubbington (2021)).

References

Bahceli, Y. (2021). *Analysis: 'Greenium' shrinks as climate bond sales swell to record.* Reuters.

Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2022). The pricing and ownership of US green bonds. *Annual Review of Financial Economics, forthcoming*.

Baulkaran, V. (2019). Stock market reaction to green bond issuance. *Journal of Asset Management*, *20*(5), 331–340.

Bloomberg Finance LP. (2021). *Bloomberg Back Office Credit Risk Data.*

BloombergNEF. (2021). *New Energy Outlook.*

Brest, P., & Born, K. (2013). Unpacking the impact in impact investing. *Stanford Social Innovation Review*, *11*.

Climate Bonds Initiative. (2021). *Green Bond Pricing in the Primary Market: January - June 2021.*

Correia, S. (2015). Singletons, cluster-robust standard errors and fixed effects: A bad mix. *Technical Note, Duke University*, *7*.

Dannhauser, C. D. (2017). The impact of innovation: Evidence from corporate bond exchange-traded funds (ETFs). *Journal of Financial Economics*, *125*(3), 537–560.

Dathan, M., & Davydenko, S. (2020). Debt issuance in the era of passive investment. *Available at SSRN 3152612*.

Daubanes, J. X., Mitali, S. F., & Rochet, J.-C. (2021). Why do firms issue green bonds? *Swiss Finance Institute Research Paper*, *21*.

Döttling, R., & Kim, S. (2020). Sustainability preferences under stress: Mutual fund flows during COVID-19. *VoxEU.org*, *19*.

Edwards, C., Harju, J., Aksu, C., Foux, M., & Herold, F. (2020). *Green is but a colour.* Barclays.

Edwards, C., Rekrut, D., Boulanger, C., Elias, K., O'Neal, M., Boyipadu, P., … Pobjoy, J. (2022). *A compilation of ESG bond trade ideas.* Barclays.

Ehlers, T., Mojon, B., & Packer, F. (2020). Green bonds and carbon emissions: Exploring the case for a rating system at the firm level. *BIS Quarterly Review, September*.

Ehlers, T., & Packer, F. (2017). Green Bond Finance and Certification. *BIS Quarterly Review September 2017*.

Energy Transitions Commission. (2021). *Making Mission Possible: Delivering a Net-Zero Economy.*

Fancy, T. (2021). *Tariq Fancy on the failure of green investing and the need for state action.* The Economist.

Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, *142*.

Flanagan, T., Kedia, S., & Zhou, X. A. (2019). Secondary market liquidity and primary market allocations in corporate bonds. *Available at SSRN 3449431*.

Flanagan, T., Kedia, S., & Zhou, X. A. (2021). Assessing gains from primary market allocations in corporate bonds. *Available at SSRN 3859063*.

Fletcher, L., & Oliver, J. (2022). *Green investing: The risk of a new mis-selling scandal.* Financial Times.

Forfot, J. S., & Fosse, H. G. (2021). The green halo debt effect. *Norwegian University of Science and Technology: Master's Thesis*.

Gianfrate, G., & Peri, M. (2019). The green advantage: Exploring the convenience of issuing green bonds. *Journal of Cleaner Production, forthcoming*.

Gilchrist, S., & Zakrajšek, E. (2012). Credit spreads and business cycle fluctuations. *American Economic Review*, *102*.

Global Financial Markets Association and Boston Consulting Group. (2020). *Climate Finance Markets and the Real Economy.*

Holden, C. W., & Nam, J. (2019). Market accessibility, corporate bond ETFs, and liquidity. *Kelley School of Business Research Paper*, *3083257*.

International Capital Markets Association. (2021). *Green Bond Principles: Voluntary Process Guidelines for Issuing Green Bonds.*

International Energy Agency. (2021). *World Energy Outlook 2021.*

International Monetary Fund. (2021). *World Economic Outlook October 2021.*

Kapraun, J., Latino, C., Scheins, C., & Schlag, C. (2021). (In)-credibly green: Which bonds trade at a green bond premium? In *Proceedings of Paris December 2019 Finance Meeting EUROFIDAI-ESSEC.*

Kuchtyak, M., & Bruce, E. (2022). *Sustainable bonds to hit record $1.35 trillion in 2022.* Moody's.

Larcker, D. F., & Watts, E. M. (2020). Where's the greenium? *Journal of Accounting and Economics*, *69*.

Lau, P., Sze, A., Wan, W., & Wong, A. (2022). The economics of the greenium: How much is the world willing to pay to save the earth? *Environmental & Resource Economics*, *81*.

Levine, M. (2019). *Green Bonds Without the Bonds.* Bloomberg.

Maltais, A., & Nykvist, B. (2020). Understanding the role of green bonds in advancing sustainability. *Journal of Sustainable Finance & Investment*, 1–20.

Marsh, A. (2020). *Green Bond Crisis Premium Theory Debunked by Covid, Manager Says.* Bloomberg.

McKinsey. (2022). *The economic transformation: What would change in the net-zero transition.*

Morningstar, Inc. (2021). *Morningstar Direct.* Retrieved from http://corporate.morningstar.com/US/asp/subject.aspx?xmlfile=40.xml

Mundy, S. (2022). *'Greenwashing' warnings accelerate drive for business sustainability standards.* Financial Times.

NatWest Markets. (2019). *Green halo 2.0.*

Partnership for Carbon Accounting Financials. (2021). *Draft: New methods for public consultation: For financial institutions measuring and reporting scope 3 category 15 emissions.*

Partridge, C., & Medda, F. R. (2020). Green bond pricing: The search for greenium. *The Journal of Alternative Investments*, *23*.

Quinson, T. (2021a). *How Wall Street is Gaming ESG Scores.* Bloomberg.

Quinson, T. (2021b). *Regulators Intensify ESG Scrutiny as Greenwashing Explodes.* Bloomberg.

Refinitiv. (2021). *Workspace.*

Ritchie, G., & Rocha, P. A. (2021). *A $180 Billion Green-Debt Boom Grows Faster Than Its Impact.* Bloomberg.

Ritchie, G., Ward, J., Kishan, S., & Gledhill, A. (2021). *Bond Investor Revolt Brews Over Bogus Green Debt Flooding Market.* Bloomberg.

Stubbington, T. (2021). *Squeeze on 'greenium' as ESG bond investors demand more value.* Financial Times.

Stubbington, T., & Nauman, B. (2020). *Investors probe ESG credentials of bond sellers on 'greenwashing' fears.* Financial Times.

Tang, D. Y., & Zhang, Y. (2020). Do shareholders benefit from green bonds? *Journal of Corporate Finance*, *61*.

Temple-West, P., & Palma, S. (2022). *SEC prepares to crack down on misleading ESG investment claims.* Financial Times.

The Economist. (2021). *Sustainable finance is rife with greenwash. Time for more disclosure.*

Wirz, M. (2022). *Bond Investors Challenge Wall Street Greenwashing.* Wall Street Journal.

Ye, S. (2019). How do ETFs affect the liquidity of the underlying corporate bonds. *Chinese University of Hong Kong Working Paper*.

Table 1: Greenium and green halo baseline regressions

	Yield spread						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Green	-11.35***	-8.232***	-9.020***			-9.782***	-8.350***
	(2.388)	(2.527)	(2.532)			(2.696)	(2.688)
Green issuer				-4.781*	-1.493	-3.876	0.521
				(2.516)	(3.976)	(2.600)	(4.157)
Controls	✓	✓	✓	✓	✓	✓	✓
Firm × Year FE		✓			✓		✓
Firm × Quarter FE			✓				
Observations	126,373	114,879	102,124	126,373	114,879	126,373	114,879
R^2	0.783	0.842	0.872	0.783	0.842	0.783	0.842
Adjusted R^2	0.762	0.809	0.833	0.762	0.809	0.762	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond and *Green issuer* indicator variables. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *Green issuer* is equal to one for a given bond if its issuer has previously issued a green bond (or if the given bond is the issuer's first green bond). All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 2: Greenium and EU regulation

(a) Baseline results and segmentation by currency

	Yield spread					
	(1)	(2)	(3)	(4)	(5)	(6)
Green			-2.660	-4.385		
			(3.511)	(3.748)		
Green × Pre-SFDR	-2.660	-4.385				
	(3.511)	(3.748)				
Green × Post-SFDR	-14.39***	-9.687***	-11.73***	-5.302		
	(3.180)	(3.136)	(4.439)	(4.525)		
Green × EUR					-0.711	-2.357
					(3.273)	(3.017)
Green × EUR × Post-SFDR					-10.38**	-4.406
					(4.003)	(3.740)
Green × USD					-4.855	-6.672
					(6.406)	(7.063)
Green × USD × Post-SFDR					-15.37*	-8.666
					(8.259)	(8.597)
Controls	✓	✓	✓	✓	✓	✓
Firm × Year FE		✓		✓		✓
Observations	126,373	114,879	126,373	114,879	126,373	114,879
R^2	0.783	0.842	0.783	0.842	0.783	0.842
Adjusted R^2	0.762	0.809	0.762	0.809	0.762	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond indicator variable and EU regulation indicator variables. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *Pre-SFDR* is equal to one before April 18, 2019 and zero afterwards. *Post-SFDR* is equal to zero before April 18, 2019 and one afterwards. *EUR* and *USD* are indicator variables that flag euro and US dollar green bonds. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

(b) Segmentation by region

	Yield spread	
	(1)	(2)
Green × China	8.355	7.717
	(12.70)	(10.95)
Green × EU	-3.002	-5.778*
	(3.612)	(3.027)
Green × USA	10.40*	9.311*
	(5.712)	(5.293)
Green × Other DM	-25.27**	-24.18
	(12.61)	(16.93)
Green × Other EM	4.683	2.811
	(17.02)	(25.61)
Green × China × Post-SFDR	-17.11	-24.98
	(15.37)	(15.45)
Green × EU × Post-SFDR	-10.14**	-1.025
	(4.448)	(4.321)
Green × USA × Post-SFDR	-29.64***	-15.51
	(10.54)	(11.55)
Green × Other DM × Post-SFDR	11.45	6.712
	(10.28)	(12.90)
Green × Other EM × Post-SFDR	-30.31	-23.10
	(23.59)	(28.83)
Controls	✓	✓
Firm × Year FE		✓
Observations	126,373	114,879
R^2	0.783	0.842
Adjusted R^2	0.762	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond indicator variable and EU regulation indicator variables. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *Post-SFDR* is equal to zero before April 18, 2019 and one afterwards. *Euro area*, *USA*, *Other DM*, *China*, and *EM* are indicator variables reflecting issuer geography. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3: Greenium and oversubscription

	Yield spread						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Green × Oversubscription	-5.791***		-10.76*				
	(2.109)		(6.386)				
Green × Imputed oversubscription		-7.145***					
		(2.067)					
Green			7.826		-17.81***		10.95
			(8.450)		(5.679)		(8.713)
Green × Low oversubscription bucket				-4.397	13.41**		
				(3.036)	(6.221)		
Green × Medium oversubscription bucket				-2.490	15.32**		
				(4.905)	(6.529)		
Green × High oversubscription bucket				-17.81***			
				(5.679)			
Green × EUR × Oversubscription						-8.597***	-15.84**
						(2.933)	(7.339)
Green × USD × Oversubscription						-2.454	-9.067
						(3.129)	(6.137)
Controls	✓	✓	✓	✓	✓	✓	✓
Firm × Year FE	✓	✓	✓	✓	✓	✓	✓
Observations	114,168	114,879	114,168	114168	114,168	114,168	114,168
R^2	0.842	0.842	0.842	0.842	0.842	0.842	0.842
Adjusted R^2	0.808	0.809	0.808	0.808	0.808	0.808	0.808

Regressions of corporate yield spreads at issuance on the *Green* bond indicator and bond oversubscription variables. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *Oversubscription* is the ratio of the notional amount of orders to the actual amount of issued debt. *Low/medium/high oversubscription bucket* represent terciles formed on bonds' oversubscription ratios. *EUR* and *USD* are indicator variables that flag euro and US dollar green bonds. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 4: Greenium and bond index inclusion

	Yield spread			
	(1)	(2)	(3)	(4)
Green × Triple index inclusion	-10.04***	-4.549		
	(2.869)	(4.697)		
Green		-5.610		
		(3.814)		
Green × EUR × Triple Index Inclusion			-11.81***	-12.52**
			(3.340)	(4.880)
Green × USD × Triple Index Inclusion			-7.847	12.58
			(5.065)	(10.75)
Green × EUR				0.696
				(3.047)
Green × USD				-20.93**
				(10.34)
Controls	✓	✓	✓	✓
Firm × Year FE	✓	✓	✓	✓
Observations	114879	114879	114879	114879
R^2	0.842	0.842	0.842	0.842
Adjusted R^2	0.809	0.809	0.809	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond indicator and the bond index inclusion indicator variables. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *Triple index inclusion* is equal to one if a green bond was a constituent of three major green bond indices (ICE, Solactive, JP Morgan). *EUR* and *USD* are indicator variables that flag euro and US dollar green bonds. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 5: Greenium and currency denomination and region

	Yield spread					
	(1)	(2)	(3)	(4)	(5)	(6)
Green × EUR	-5.734***			-5.404		
	(2.155)			(5.357)		
Green × USD	-12.36**	-6.625		-14.94**		
	(5.081)	(5.451)		(6.195)		
Green		-5.734***				-6.203**
		(2.155)				(2.406)
Green × Local EUR			-5.823***	-0.419		
			(2.175)	(5.428)		
Green × Foreign EUR			-5.404			
			(5.357)			
Green × Local USD			-4.218	10.72		
			(9.893)	(12.12)		
Green × Foreign USD			-14.94**			
			(6.195)			
Green × China					-10.03	-3.824
					(9.005)	(8.974)
Green × Euro area					-6.203**	
					(2.406)	
Green × USA					-0.846	5.357
					(7.635)	(8.089)
Green × Other DM					-19.67**	-13.47
					(8.929)	(9.155)
Green × Other EM					-12.36	-6.155
					(16.53)	(17.00)
Controls	✓	✓	✓	✓	✓	✓
Firm × Year FE	✓	✓	✓	✓	✓	✓
Observations	114879	114879	114879	114879	114879	114879
R^2	0.842	0.842	0.842	0.842	0.842	0.842
Adjusted R^2	0.809	0.809	0.809	0.809	0.809	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond indicator and currency denomination indicator variables. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *EUR* and *USD* are indicator variables that flag euro and U.S. dollar green bonds. *Local* and *Foreign* differentiate currency denomination by local and foreign currency issuers. *China*, *Euro area*, *USA*, *Other DM*, and *Other EM* are indicator variables reflecting issuer geography. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 6: Greenium and bond Governance, external review, and proceed credibility

	Yield spread					
	(1)	(2)	(3)	(4)	(5)	(6)
Green × GBP aligned	-7.214***					
	(2.363)					
Green × GBP Not aligned	-20.25*	-13.04				
	(11.22)	(11.13)				
Green		-7.214***		-8.088***		-6.453**
		(2.363)		(2.585)		(2.726)
Green × External review			-8.088***			
			(2.585)			
Green × No external review			-9.317	-1.229		
			(8.113)	(8.385)		
Green × No refinancing					-6.453**	
					(2.726)	
Green × Refinancing					-13.73**	-7.281
					(5.676)	(5.651)
Controls	✓	✓	✓	✓	✓	✓
Firm × Year FE	✓	✓	✓	✓	✓	✓
Observations	114,879	114,879	114,879	114,879	114,403	114,403
R^2	0.842	0.842	0.842	0.842	0.842	0.842
Adjusted R^2	0.809	0.809	0.809	0.809	0.809	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond indicator and variables capturing green bond governance, external review, and credibility. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *GBP aligned* is equal to zero if a green bond is not fully aligned with the Green Bond Principles and one if it is fully aligned. *External review* is equal to one if a green bond was subject to a pre-issuance external review by a third party. *No refinancing* is equal to one if some portion of the bond was used to refinance an existing liability, otherwise it is zero. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 7: Greenium and bond- and firm-level characteristics

	Yield spread			
	(1)	(2)	(3)	(4)
Green	14.74	58.40**		-9.793***
	(26.70)	(28.18)		(3.063)
Green × Size	-1.201			
	(1.413)			
Green × Average issuer bond size		-3.473**		
		(1.489)		
Green × Investment grade			-9.793***	
			(3.063)	
Green × High yield			-23.99	-14.20
			(18.28)	(18.79)
Green × Not rated			-1.669	8.124
			(3.278)	(4.904)
Controls	✓	✓	✓	✓
Firm × Year FE	✓	✓	✓	✓
Observations	114,879	114,879	114,879	114,879
R^2	0.842	0.842	0.842	0.842
Adjusted R^2	0.809	0.809	0.809	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond indicator variable and variables capturing bond and issuer characteristics. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *Size* is the logarithm of the bond's notional amount issued. *Average issuer bond size* is the average size of an issuer's bonds issued within the same year of the green bond. *Investment grade*, *High yield*, and *No rated* are indicator variables that flag the respective bond ratings. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 8: Greenium and issuer industry

(a) Industry

	Yield spread	
	(1)	(2)
Green		-8.682***
		(2.970)
Green × Alternate energy	-26.40	-17.72
	(25.70)	(25.48)
Green × Banks	-8.682***	
	(2.970)	
Green × Electric utilities and fossil fuels	-14.88*	-6.195
	(7.826)	(8.725)
Green × Industry and materials	14.37	23.06*
	(11.33)	(11.83)
Green × Non-bank financials	0.209	8.891
	(15.35)	(15.37)
Green × Real estate	0.0330	8.715
	(9.577)	(10.10)
Green × Transportation	-15.27*	-6.591
	(8.699)	(9.618)
Green × Other	-8.064	0.618
	(5.744)	(6.400)
Controls	✓	✓
Firm × Year FE	✓	✓
Observations	114879	114879
R^2	0.842	0.842
Adjusted R^2	0.809	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond indicator and issuer industry indicator variables. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *Alternative energy*, *Banks*, *Electric utilities and fossil fuels*, *Industry and materials*, *Non-bank financials*, *Real estate*, *Transportation*, and *Other* are indicator variables that flag the respective issuer industries. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

(b) Banks by region

	Yield spread	
	(1)	(2)
Green		-27.61***
		(5.060)
Green × Banks × China	-27.61***	
	(5.060)	
Green × Banks × EU	-6.170***	21.44***
	(2.320)	(5.188)
Green × Banks × USA	11.89	39.50***
	(9.002)	(11.09)
Green × Banks × Other DM	-2.144	25.46**
	(8.864)	(10.99)
Green × Banks × Other EM	-66.40*	-38.79
	(37.03)	(37.06)
Green × Non-bank financials	-0.00835	27.60*
	(15.37)	(16.11)
Green × Non-financials	-8.558*	19.05***
	(5.031)	(6.450)
Controls	✓	✓
Firm × Year FE	✓	✓
Observations	114,879	114,879
R^2	0.842	0.842
Adjusted R^2	0.809	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond indicator and issuer industry and region variables. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *Banks*, *Non-bank financials*, and *Non-financials* are indicator variables that flag the respective issuer industries. *China*, *EU*, *USA*, *Other DM*, and *EM* are indicator variables reflecting issuer geography. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Appendix

A1 Alternate greenium theories

There are two main alternative explanations for the greenium. The first is that green bonds are more valuable because they are expected to achieve higher risk-adjusted returns relative to conventional bonds, as they are issued by firms that are reducing their exposure to climate- and other environment-related physical and transition risks. This explanation is problematic because the coupon and principal payments from green bonds are almost never paid out from cash flows generated by the green bond's underlying green projects. Instead, the credit risk of a green bond should be considered identical to the credit risk of a firm's conventional bonds, particularly when the bonds have the same recourse. Even if a firm's issuance of a green bond reduces its overall credit risk by lowering its exposure to sustainability risk factors, this would not necessarily improve the risk-adjusted returns expected for green bonds. Accordingly, we show in Table 1 Column (7) that green bonds receive a greenium distinct from the green halo benefits to a firm's overall cost of capital, suggesting this explanation is insufficient.

The second explanation for the greenium, called the crisis premium theory, is that green bonds offer better returns during crisis periods, because environmentally conscious investors are less likely to sell green bonds during market distress. For this explanation to hold, it would have to be true that green investors are, at the margin, less risk averse than conventional investors. This seems plausible for institutional investors, who may trade off selling sustainable assets against the perceived penalty to their cost of capital from failing to hit their sustainable investment goals, typically articulated in an ESG shareholder engagement. However, this seems less plausible for retail investors, who are typically more risk averse and may view green investments as a luxury preference that withers under financial or economic stress.[33] While the crisis premium theory should be considered, the limited available market participant commentary suggests this theory is not widely held. See, for example, Edwards, Harju, Aksu, Foux, and Herold (2020) and Marsh (2020).

A2 The greenium and liquidity

Our regression specifications use controls, such as firm, rating, and time fixed effects, that may proxy for the impact of expected secondary market liquidity on pricing in the primary market. However, data availability limits our ability to construct measure of expected liquidity to directly control for it at issuance. As such, it is possible that we are not fully capturing the impact of expected liquidity on the greenium. In this section, we briefly

[33] For example, Döttling and Kim (2020) find evidence that the sustainability preferences of retail investors deteriorated relative to institutional investors during the market crash of March 2020.

outline how the role of buy-and-hold investors in the green bond market may affect the greenium.[34]

A2.1 Expected secondary market liquidity

Assume the yield for a given bond can be decomposed into three components, such that

$$y = y_F + y_D + y_{EL} \tag{A1}$$

where y_F is the compensation for a bond's fundamental characteristics; y_D is the compensation for investor demand for the bond; and y_{EL} is the compensation for a bond's expected liquidity in the secondary market. The bond's fundamental characteristics, such as its credit rating and maturity, determine its risk profile across several dimensions, including credit risk, interest rate risk, and inflation risk. A given bond with riskier fundamentals will have higher values of y_F (lower price p_F). Beyond the fundamentals, excess investor demand for a given bond will exert further demand pressure on the bond, lowering the value of y_D (raising price p_D). Finally, lower expected liquidity in the secondary market should raise y_{EL} (lower the price p_{EL}), because bonds that are more difficult to sell or buy in the secondary market are less valuable or tied to high transaction costs.

When measuring the greenium in our regressions, we compare the yield on a green bond to that of a comparable conventional bond (observed or hypothetical) with the same fundamentals. In other words, we assume that for a comparable green bond, $y_F^{Green} = y_F^{Conventional}$. Therefore, the yield differential between a green bond and a comparable conventional bond is given by:

$$\underbrace{y^{Green} - y^{Conventional}}_{\text{Yield differential}} = \underbrace{\left(y_D^{Green} - y_D^{Conventional}\right)}_{\text{Greenium (-)}} + \underbrace{\left(y_{EL}^{Green} - y_{EL}^{Conventional}\right)}_{\text{Expected liquidity differential (+)}} \tag{A2}$$

We argue that $y_D^{Green} < y_D^{Conventional}$, because excess demand for the green bond lowers its yield relative to the yield for the conventional bond. Therefore the greenium term is negative. However, if a green bond has a lower expected liquidity than a comparable conventional bond, because green bond investors are more likely to be buy-and-hold investors, then $y_{EL}^{Green} > y_{EL}^{Conventional}$, and the expected liquidity term will be positive. Controlling for relevant bond characteristics, we find that the green bond yield differential, given by $y^{Green} - y^{Conventional}$, is negative. If there is an expected liquidity penalty for green bonds beyond their fundamentals, meaning the expected liquidity term is positive, then we may

[34]See Flanagan, Kedia, and Zhou (2019) for empirical evidence that links primary market allocations and secondary market liquidity for a subset of buy-and-hold investors.

be underestimating the magnitude of the "true" greenium by not controlling for differences in expected liquidity. However, even if this were the case, it would not impact the ultimate borrowing cost from the issuer's perspective, measured by the yield differential $y^{Green} - y^{Conventional}$.

A2.2 Near-term expected liquidity

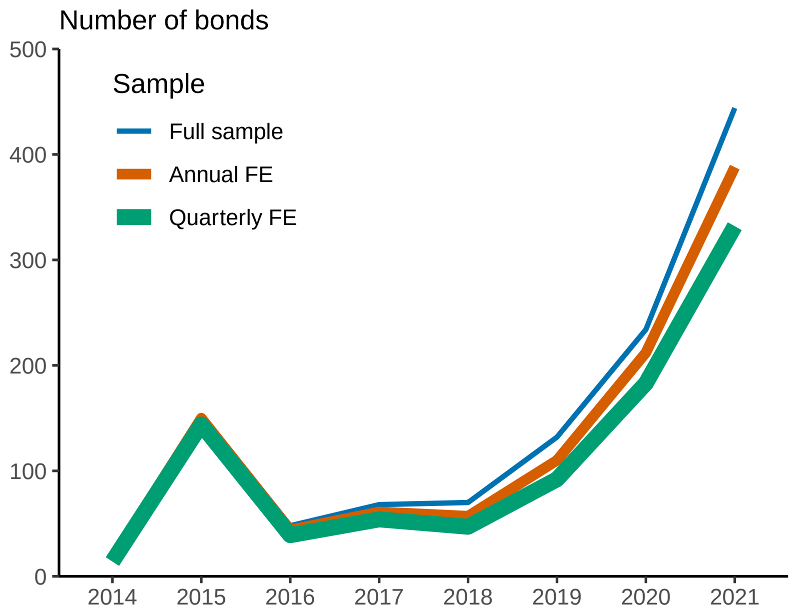
We can decompose the yield even further. First, note that y_{EL} refers to investor compensation for *long-term* expected secondary market liquidity, referring to the expected transaction costs of selling the bond before it matures. In this context, lower secondary market liquidity would reduce the overall price p_{EL} of the bond (raise yield y_{EL}). However, there is an additional factor in play – the *near-term* expected liquidity. If investors believe it will be costly to buy the bond in the secondary market, they may, at the margin, be willing to buy the bond in the primary market, driving further excess demand for a bond beyond its fundamentals. Let us denote the yield compensation from this primary market excess demand y_{PM}, where a stronger preference for a primary market allocation lowers y_{PM} (raises y_{PM}). Let us also relabel the residual demand uncorrelated with expected bond liquidity as y_{RD}. Thus, the yield differential from Equation A2 can be rewritten:

$$\underbrace{y^{Green} - y^{Conventional}}_{\text{Yield differential}} = \underbrace{\left(y_D^{Green} - y_D^{Conventional}\right)}_{\text{Greenium (-)}} + \underbrace{\left(y_{EL}^{Green} - y_{EL}^{Conventional}\right)}_{\text{Expected liquidity differential (+)}} + \underbrace{\left(y_{PM}^{Green} - y_{PM}^{Conventional}\right)}_{\text{Primary market demand (-)}} \tag{A3}$$

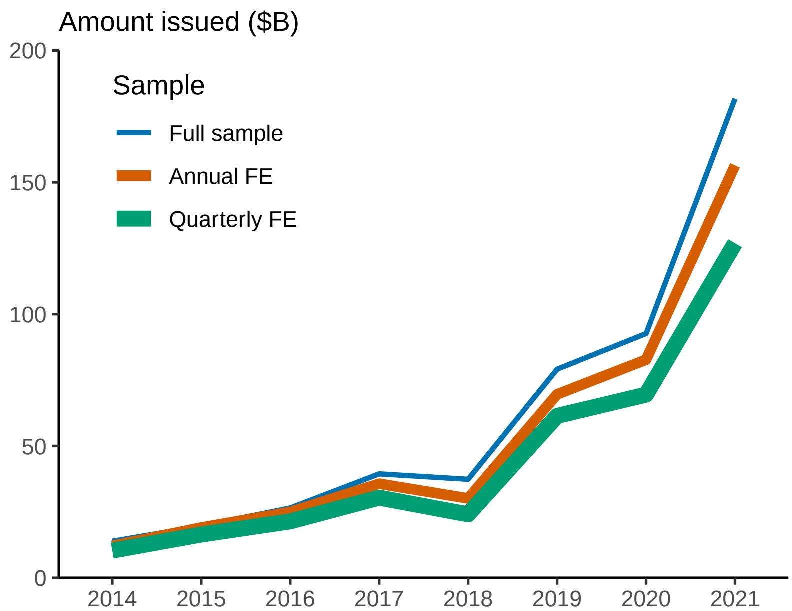
If a green bond has a lower expected liquidity in the secondary market than a comparable conventional bond, this should increase the preference to buy the green bond in the primary market. This means $y_{PM}^{Green} < y_{PM}^{Conventional}$, so the additional primary market term will still be negative. As in the previous subsection, note that while this may impact the estimation of the greenium term in Equation A3, it ultimately does not impact the borrowing cost of the issuer to the extent that the additional primary market demand is driven by the green label itself.

Figure A1: Impact of time-varying fixed effects on green bond sample size

(a) Number of green bonds



(b) Notional amount of green bond issuance



Panel (a) is the number of green bonds in our sample. Panel (b) is the notional amount of green bond issuance in our sample. The data is reported at an annual frequency. *Full sample* is the sample when we do not include time-varying fixed effects. *Annual FE* and *Quarterly FE* are the samples when we include annual or quarterly time-varying fixed effects, respectively.

Table A1: Bond sample by currency

Currency	Amt. issued ($B)	N
AUD	243.0	2,109
BRL	13.5	361
CAD	605.4	2,386
CHF	397.3	1,763
CNY	4,161.0	21,572
DKK	24.7	313
EUR	6,708.6	22,094
GBP	542.1	1,222
HKD	67.7	1,226
IDR	54.3	1,572
ILS	40.7	304
INR	515.5	9,146
JPY	897.6	6,583
KRW	824.3	14,440
MXN	25.8	191
MYR	126.4	2,191
NOK	69.6	874
NZD	37.0	476
RUB	61.7	660
SEK	311.6	790
SGD	57.5	451
USD	17,768.9	39,239
ZAR	9.3	249
Total	33,563.6	130,212

Table A2: Bond sample summary statistics

	Mean	S.D.	Min.	25th	Median	75th	Max.
Green bonds							
Yield spread (bp)	149.8	128.3	-212.3	75.3	100.3	190.1	959.1
Coupon (%)	2.0	1.9	0.0	0.5	1.5	3.0	12.0
Years to maturity	7.8	4.1	1.0	5.0	7.0	10.0	30.0
Amount issued ($M)	419.4	488.3	0.6	29.0	370.2	598.2	7,030.2
Observations	1,169						
Conventional bonds							
Credit spread (bp)	137.3	168.3	-499.5	43.0	97.8	198.4	997.5
Coupon (%)	3.5	2.8	0.0	1.4	3.0	5.0	20.8
Years to maturity	6.1	4.7	1.0	3.0	5.0	8.0	30.0
Amount issued ($M)	256.3	623.9	0.5	16.9	76.0	300.0	111,639.5
Observations	129,043						

Table A3: Green bond sample oversubscription summary statistics

	Mean	S.D.	Min.	25th	Median	75th	Max.
Oversubscription	3.8	2.1	1.0	2.2	3.3	4.7	15.0
Observations	474						

Table A4: Bond sample by rating

Rating	Amt. issued ($B)	N
Green bonds		
AAA	64.5	47
AA	36.8	63
A	154.5	256
BBB	157.4	260
BB	39.0	73
B	14.3	35
C	0.4	1
Not rated	23.5	434
Total	490.3	1,169
Conventional bonds		
AAA	2,360.5	3,467
AA	2,485.0	6,109
A	6,955.2	14,557
BBB	7,059.1	12,634
BB	3,122.6	4,946
B	2,351.5	3,789
C	396.8	699
Not rated	8,342.6	82,842
Total	33,073.3	129,043

Table A5: Green bond sample by sector

Sector	Amt. issued ($B)	N
Alternate energy	19.7	170
Banks	162.4	450
Electric utilities and fossil fuels	121.3	188
Industry and materials	31.1	75
Non-bank financials	24.4	47
Real estate	74.9	156
Transportation	20.6	29
Other	35.8	54
Total	490.3	1,169

Table A6: Greenium and time variation

	Yield spread
	(1)
Green × 2014	-10.44
	(11.98)
Green × 2015	-2.525
	(6.049)
Green × 2016	-12.01
	(8.898)
Green × 2017	-4.837
	(8.448)
Green × 2018	3.036
	(4.934)
Green × 2019	-14.40**
	(6.193)
Green × 2020	-9.312***
	(3.497)
Green × 2021	-8.302**
	(3.799)
Controls	✓
Firm × Year FE	✓
Observations	114,879
R^2	0.842
Adjusted R^2	0.809

Regressions of corporate yield spreads at issuance on the *Green* bond indicator variable interacted with annual indicator variables. The sample period covers green and conventional bond issues from 2014 to 2021 (Section 3 details the sample construction). The dependent variable *Yield spread* refers to a bond's yield spread on its date of issuance over the maturity-matched government bond yield for the given bond's currency region. The independent variable *Green* takes the value of one for green bonds and zero otherwise. *2014* to *2021* are indicator variables that flag the respective calendar year. All other control variables and fixed effects are detailed in Section 3. Standard errors, reported in parentheses, are clustered on the issuer ultimate parent and year-month levels. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.