Investor ESG Tastes and Asset Pricing: Evidence from the Primary Bond Market*

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Abstract

This study uses demand and dynamic pricing information in the primary bond market to examine investor tastes for ESG assets and their pricing effects. We find that green bonds are significantly more oversubscribed than their conventional counterparts offered by the same issuer. Anticipating a stronger demand for green bond offerings, underwriters and issuers propose lower initial offering spreads to investors, followed by more aggressively tightening offering spreads after bookbuilding. The resulting offering spread of green bonds is lower than their conventional counterparts (greenium). After controlling for investor demand, the offering spread of green bonds no longer statistically differs from conventional bonds, suggesting that greenium mainly stems from the higher demand for green bonds. Our findings support investor-tastes asset pricing models.

Keywords: Green bonds, primary market, ESG investing, investor demand, investor tastes, nonpecuniary motives, greenium
JEL classifications: G12, G14, G23, G24, G30

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1. Introduction

Sustainable investing, which applies environmental, social, and governance (ESG) criteria in investment decisions, has grown exponentially in recent years.[1] The emerging theoretical literature on sustainable investing predicts that financial assets with better ESG profiles should have lower *expected* returns because investors with ESG (green) tastes are willing to sacrifice financial returns for societal benefits (e.g., Pastor, Stambaugh, and Taylor (2021b), Baker, Bergstresser, Serafeim, and Wurgler (2020), Zerbib (2020)).[2] However, empirical studies on the impact of ESG tastes on equity returns provide mixed evidence to this prediction, likely due to the complexities of distinguishing between *ex ante* and *ex post* returns (Pastor et al. (2021b), Pastor et al. (2021a)). More surprisingly, empirical studies on bond offering yields, which are expected yields to maturity at issuance, also provide mixed evidence to the prediction. For example, Larcker and Watts (2020), Flammer (2020), and Tang and Zhang (2020) find no pricing difference between green and conventional bonds, but Baker et al. (2020), among others, show that green bonds have lower yields than conventional bonds (i.e., greenium). In this study, we exploit a unique setting that allows us to identify investor ESG tastes at the security level to quantify the impact of such tastes on asset prices. In particular, utilizing bookbuilding information from the primary bond market, we examine investor demand for and the pricing dynamics of green bonds and their conventional counterparts.

Our setting has several distinctive advantages. First, to the best of our knowledge, we are the first to directly measure investor tastes for ESG assets at the security level. During bookbuilding, bond underwriters invite all interested investors to express their tastes (i.e., demand) via submitting orders in a short window and record the aggregate order amount as the order book size. Newly available data on the order book size allows us to examine

[1]According to the Global Sustainable Investment Review, the total assets under management for sustainable investing are $35 trillion in 2020.

[2]These models can be applied to E, S, or G dimensions separately or in combination. Following the prior literature, we use ESG, green, and sustainability interchangeably in the paper.

the extent to which green securities attract greater investor demand than their conventional counterparts. Second, underwriters disclose the initial offering yield before bookbuilding and adjust the offering yield based on investor demand revealed during bookbuilding. Studying the pricing dynamics, rather than only relying on the offering yield, allows us to better understand how investor green tastes affect asset prices. Third, corporate and sovereign, supranational, and agency (SSA) green bond issuers are often large and frequent issuers that also offer conventional bonds, which provide otherwise unavailable non-green counterparts. Comparing green and conventional bonds offered by the same issuers allows us to isolate the pricing effect of investor tastes from differences in exposures to climate risk across issuers (e.g., Pedersen, Fitzgibbons, and Pomorski (2021), Seltzer, Starks, and Zhu (2020)). Last, using the bond offering yield, which is the expected yield to maturity, to study the pricing impact of ESG tastes is not subject to concerns about *ex ante* versus *ex post* returns as discussed in Pastor et al. (2021b) and Pastor et al. (2021a).[3] The above features of the primary bond market afford us a clean setting to examine whether and how investor ESG tastes affect *expected* returns.

Our sample includes 637 green and 4,271 conventional EUR and USD denominated corporate and SSA bonds offered by 306 unique green bond issuers during 1/1/2013 and 5/31/2021. We begin our analysis by showing that investor demand, measured by the oversubscription ratio (i.e., the size of the order book scaled by the proposed amount of offering), is significantly higher for green bond offerings than for conventional bond offerings. Specifically, the average oversubscription ratio of sample green bonds is 3.6, whereas that of sample conventional bonds is 2.6. Holding other factors constant, the oversubscription ratio of green bonds is 0.397 greater than conventional bonds issued by the same issuer on average, which accounts for about 15% of the average oversubscription ratio for the whole sample. These results are consistent with the annecdotal evidence that green bonds are often more oversubscribed than

[3]In particular, Pastor et al. (2021b) note that although their model predicts lower expected return for green assets, green assets could outperform conventional assets *ex post* because ESG tastes strengthen unexpectedly over the sample period. They state, “Disentangling alphas from ESG taste shifts is a major challenge for empirical work in this area.”

conventional bonds.[4]

While we argue that the greater demand for green bonds can be attributed to some investors' ESG tastes, an alterantive explanation could be that green bond issuers and their underwriters use a mometum-generating stratergy (e.g., Lowry and Schwert (2004)) to deliberately propose a higher initial offering yield with the hope of generating momentum and thereby attracting more investor demand. To differentiate between the two explanations, we examine the initial offering spread (i.e., initial offering yield over the government benchmark security rate) proposed before bookbuilding. We find that the initial offering spread is lower, albeit not statistically significant, for green bonds than for conventional bonds, with a difference of 2.804 basis points (bps) for the full sample. This result indicates that underwriters propose a lower offering spread for green bonds in anticipation of their greater demand, rather than proposing a higher offering yield to attract more demand.

Furthermore, the greater realized demand for green bonds enables underwriters and issuers to tighten their offering spread to a larger extent. Specifically, the compression from the initial offering spread to the offering spread (i.e., spread compression) is 2.352 bps tighter for green bonds than for conventional bonds on average. Because green bond offerings exhibit smaller initial offering spread and greater yield tightening, they should display greenium.

Consistent with the evidence on investor demand, initial offering spread, and the spread compression, greenium is present in our sample. First, in a panel regression with issuer and various other fixed effects, we find that on average the offering spread is 5.4 bps lower for green bond offerings than conventional bond offerings. These results are robust to a battery of alternative specifications, including controlling for issuer-year fixed effects and underwriter fixed effects. Second, we conduct a matching-sample analysis by finding a conventional counterpart of each green bond from its issuer based on various bond features, including rating, currency, seniority, maturity, and issue amount. Both the mean and median comparisons in the matched sample confirm that greenium exists.

[4]For example, Hurley, M. (April 06, 2021). Growing "greenium" in labeled bond market divides opinions. Environmental Finance.

Do investor tastes for green bonds, i.e., their demand for green bonds, exclusively explain greenium? To answer this question, we include both the oversubscription ratio and the green bond indicator as independent variables in the regression to explain the offering spread. If factors other than demand for green bonds contribute to greenium, we expect that both the green bond indicator and the oversubscription ratio are significantly negatively correlated with the offering spread. However, we note that investors tend to reach for yield and favor higher-yielding securities (Becker and Ivashina (2015), Choi and Kronlund (2017)), which may make the offering spread counter-intuitively positively correlated with the oversubscription ratio. To tease out the impact of reaching-for-yield, we regress the oversubscription ratio on the relative initial spread (i.e., the difference between the initial offering yield and the yield of the rating- and currency-matched Barclays' index) to obtain the residual oversubscription ratio, and refer to it as residual demand. Then, we examine if the green bond indicator remains a significant predictor of the offering spread after controlling for the residual demand. We find that the offering spread is strongly negatively associated with the residual demand: increasing the residual demand from the 25th percentile to the 75th percentile decreases the offering spread by 8.75 bps. However, the green bond indicator, albeit carrying a negative sign, is no longer a significant predictor of the offering spread. These results indicate that strong investor demand for green bond offerings is the main driver of greenium, supporting investor-tastes asset pricing models.

Finally, to shed some light on the heterogenous demand for green bonds, we examine the determinants of investor demand within the sample of green bonds. We present several interesting findings. First, we find evidence of ESG investors chasing for yield. Specifically, the oversubscription ratio increases significantly as the rating quality of the offering decreases from AA to BBB, suggesting that green bonds with higher expected returns are more appealing to institutional investors. These results are consistent with the objectives stated in the fund prospectus we have sampled.[5] Second, we find that an issuer's first green

[5]For example, the fund prospectus of TIAA-CREF Green Bond Fund states that it seeks favorable long-term total return while giving special consideration to certain environmental criteria by investing in a broad

bond offering attracts higher demand than subsequent green bond offerings, consistent with the notion that security offerings from new issuers add to portfolio diversification and, thus, receive greater demand. Lastly, we find that more recent green bond offerings receive greater investor demand. This result is consistent with the increasing trend of sustainable investing and helps reconcile the presence of greenium in our sample with previous studies that do not find greenium using corporate bond data before 2018 (e.g., Flammer (2020), Tang and Zhang (2020)).

We make several important contributions to the literature. First, we contribute to recent asset pricing literature that features investor tastes (e.g., Fama and French (2007), Pastor et al. (2021b), Baker et al. (2020), Zerbib (2020)). Several studies provide empirical support to the models via either survey evidence (e.g., Riedl and Smeets (2017), Bauer, Ruof, and Smeets (2021)) or use of mutual fund flows to proxy for investors' ESG tastes (e.g., Hartzmark and Sussman (2019), Zerbib (2020), and Pastor et al. (2021a)). To the best of our knowledge, none of prior studies *directly* measure investors' ESG tastes at the *security* level and examine their impact on expected returns. We fill this gap by providing bond-level empirical evidence on investor ESG tastes and the resulting pricing impact.

Second, we expand the growing literature on green bonds. The green bond market has an annual growth rate of about 95% and a cumulative offering amount of over $1 trillion dollars from its inception in 2007 to 2020.[6] Despite its importance, the empirical evidence on whether green bonds exibit greenium is mixed. Existing studies on greenium either examine the offering yield, an outcome determined after bookbuilding, or the secondary-market trade yield. Larcker and Watts (2020), Flammer (2020), and Tang and Zhang (2020) find that the offering yield of green bonds are not different from conventional bonds issued by the same issuers, but Zerbib (2019) and Baker et al. (2020) find that green bonds enjoy premium. Utilizing unique data on the order book size and the pricing dynamics in the primary market, we directly measure investor demand for each bond offering and its pricing

range of investment-grade bonds and fixed-income securities.

[6]See https://www.climatebonds.net/market/explaining-green-bonds

effects, enhancing our understanding of whether and why greenium exists.

Finally, our paper adds to a broader literature of environmental issues and a firm's cost of capital. One line of research examines how climate issues or green investments impact the cost of equity and provides mixed evidence. For example, Bolton and Kacperczyk (2021) find that firms with higher carbon emissions have higher stock returns. This finding and results from a few other recent studies (e.g., Ramelli, Wagner, Zeckhauser, and Ziegler (2018), Hsu, Li, and Tsou (2020)) suggest a risk premium for exposure to carbon emission risk. These findings support the predictions of Heinkel, Kraus, and Zechner (2001) and Pastor et al. (2021b) and are consistent with recent survey evidence that institutional investors consider carbon emissions a material risk (Krueger, Sautner, and Starks (2020)).[7] However, Berk and van Binsbergen (2021) argue that divesting has little impact on a firm's cost of capital in general. Aswani et al. (2022)show that there is no association between carbon emissions and stock returns. The second line of research focuses on the relation between environmental issues and cost of debt. Among others, Chava (2014), Correa, He, Herpfer, and Lel (2020), Degryse, Goncharenko, Theunisz, and Vadazs (2020), and Reghezza, Altunbas, Marques-Ibanez, dAcri, and Spaggiari (2021) show that exposure to climate change increases bank loan costs. While previous studies do not find greenium using corporate bond data before 2018 (e.g., Flammer (2020), Tang and Zhang (2020)), our study offers fresh evidence from the primary bond market that investor green tastes can lower firms' cost of public debt.

2. Related Literature

Our study is motivated by the tastes-based theoretical framework featuring a set of investors with a nonpecuniary component of utility, in addition to standard portfolio mean and variance (e.g., Pastor, Stambaugh, and Taylor (2021b), Baker, Bergstresser, Serafeim, and Wurgler (2020), Zerbib (2020), Pedersen et al. (2021)). In this theoretical framework,

[7] Among others, Dyck et al. (2019) and Gibson et al. (2020) examine how ESG motivated investing varies across countries around the world.

a security's expected return has the traditional CAPM beta term and a second term that reflects agents' tastes for an asset's environmental attributes. Assets with green profiles, or more generally better ESG scores, are expected to be priced at a premium and offer lower *expected* returns. In the setting of bond markets, these models predict that green bonds should exhibit greenium.

When applying tastes-based pricing models to fixed-income securities, we are aware of one institutional difference that may hinder the application of these models: fixed-income markets are mainly institutional markets, and institutional investors might not exhibit a non-pecuniary component of utility as assumed by the models. Empirical evidence on investors' willingness to trade off financial returns for societal benefits is mainly on fund investors and on the equity side. For example, Riedl and Smeets (2017) and Hartzmark and Sussman (2019) suggest that mutual fund investors value sustainability and are willing to accept lower returns for holding socially responsible mutual funds, and Barber et al. (2021) show that dual-objective venture capital fund investors sacrifice returns for nonpecuniary utility. On the fixed-income side, survey evidence suggest that institutional investors do not trade-off returns for non-pecuniary benefits. For example, the municipal bond institutional investors surveyed and interviewed by Chiang (2017) and Larcker and Watts (2020) and the four institutional investors with a focus on sustainable securities interviewed by Flammer (2020) stated that they would not invest in green assets if the returns were not competitive. Thus, the survey evidence questions the applicability of tastes-based pricing models on fixed-income securities. In this paper, we note that to the extent that institutional investors follow their investment mandate, ESG fund investors' tastes will translate into ESG fund managers' (almost) exclusive demand for green assets. Thus, by directly examining investor demand at the bond level and their pricing effects, we not only provide empirical support to the tastes-based asset pricing models, but also provide evidence that ultimate investors' tastes can manifest in asset prices when investment decisions are delegated to institutional managers.

Likely because green bonds are relatively new and half of the amount offered before 2020 occurs during 2019-2020, existing studies on green bonds mainly focus on municipal bonds and a small sample of corporate bonds. For example, Larcker and Watts (2020) study a sample of 640 green municipal bonds that have matched conventional bonds, with the median offering amount of $2.3 million; Baker et al. (2020) examine a sample of 3,983 municipal bonds with the median offering amount of $2.2 million and 51 corporate green bonds with the median offering amount of $350 million; Zerbib (2019) study 110 various type green bonds whose issuers have outstanding conventional bonds that could provide a benchmark to the yield of the green bonds. In this paper, we study non-municipal bonds because of the institutional differences between municipal and other bonds. In particular, both individual investors and institutional investors participate in municipal bond offerings, and different investors may pay different prices for the same offering.[8] But the primary market investors for non-municipal bond offerings are mainly institutional investors whose average allocation per bond is on the order of millions of dollars (Nikolova, Wang, and Wu (2020), Bessembinder, Jacobsen, Maxwell, and Venkataraman (2020)), and all investors pay the same price for the allocation.

Existing studies on corporate green bonds offer mixed evidence on greenium. For example, Tang and Zhang (2020) study a sample of 241 corporate green bonds issued by public firms and find no reliable difference between the offering yield spread of green and conventional bonds. However, they state, "[w]e note that only 41 firms have issued both regular corporate bonds and green bonds during our sample period. Such a relatively smaller sample may limit the power of the test." Flammer (2020) compares 152 pairs of corporate green and matched conventional bonds issued by the same issuers and finds no significant difference between the offering yield of these bond pairs, noting that "the market for corporate green bonds is still at a relatively early stage... my finding of no pricing differential need not

[8] For example, Schultz (2012) studies municipal bonds and states, "IRS rules require that a substantial fraction (interpreted by the courts as 10% or more) must be sold at the reoffering price, but additional bonds can be sold for higher prices. In many cases, a significant proportion of the bonds are sold with markups of 1%, 2%, or more above the reoffering price."

generalize to future years." Taking advantage of the fast-growing green bond market, we are able to use a relatively large sample of green bond offerings to examine their pricing. More importantly, unlike prior literature, which primarily focuses on the existence of greenium, we explore investor demand and the dynamic pricing process in the primary bond market, providing systematic evidence on why greenium exists.

Finally, if investors' green tastes affect bond yields, it may be more evident in the primary market than in the secondary market. New offerings attract the most attention and demand around the offering date and quickly turn illiquid in the secondary market. For example, Goldstein, Hotchkiss, and Nikolova (2019) show that the percentage of bonds traded declines from above 90% in the first week after the offering to 80% (65%) [46%] in 10 (60) [240] days after the offering date. Thus, unlike the secondary market where ESG investors arrive at the market in uncoordinated times, all investors submit their indications of interests in a short window during bookbuilding, allowing underwriters and issuers to observe the difference in investor demand for green and conventional bonds and set the prices accordingly. Furthermore, the secondary market price is affected by the bid-ask spread and liquidity premium, which vary across time and by security.[9] Because of the high trading cost and liquidity problem associated with bond trading, Zhu (2021) find that mutual funds prefer purchasing new offerings from the primary market to existing bonds in the secondary market when they experience positive fund flows. In this study, we take advantage of the rich information about investor demand and price adjustments to provide a comprehensive analysis of the performance of green bonds in the primary market.

[9]For estimates of trading costs in corporate bonds, see Schultz (2001), Bessembinder, Maxwell, and Venkataraman (2006), Edwards, Harris, and Piwowar (2007), and Goldstein and Hotchkiss (2020), among others.

3. Data

3.1. Sample construction

Since we focus on primary market activities in the green bond market, we obtain primary market information, such as the initial price talk (IPT; the initial offering yield or spread underwriters disclose to investors before bookbuilding commences) and order book size, from a leading fixed income data provider. We rely on Bloomberg to identify green bonds.[10] From Bloomberg, we extract 1,416 USD- and EUR-denominated government (non-municipal), financial, and industrial fixed- or variable-coupon non-perpetual green bonds that are announced between 1/1/2013 and 5/31/2021, with non-missing offering amount and positive coupon rate.[11,12] The data vendor covers 776 (88% in terms of the offering amount) of these 1,416 USD- and EUR-denominated green bonds. Next, we obtain USD- and EUR-denominated conventional bonds offered by green bond issuers.[13] Because we compare green bonds with conventional bonds offered by the same issuer, our final sample only includes issuers that have offered both green and conventional bonds. This criteria reduces the number of sample green bonds from 776 to 637.

Table 1 presents the comparison of the 637 sample green bonds with the 1,416 green

[10]Following the Green Bonds Principles (GBP) and other organizations' pioneering issuance and analysis, Bloomberg defines green bonds as fixed income instruments for which the proceeds will be applied towards projects or activities that promote climate change mitigation or adaptation or other environmental sustainability purposes. For more details, see https://data.bloomberglp.com/bnef/sites/4/2015/09/BNEF_Green-Bonds-Terminal-Guide_H2-2015-update.pdf.

[11]We focus on USD- and EUR-denominated green bonds, which account for 71% of total offering amount of green bonds of all currencies issued in the same period, because these two are the major types and many indexes tracked by passive green bond funds only include USD and EUR assets. Furthermore, the lack of liquid benchmark securities that span the whole yield curve for non-USD and non-EUR bond offerings makes it difficult to compare bonds of different currencies on the basis of yield spreads.

[12]Many green bonds are both Rule 144A eligible and Reg S eligible. When a bond is issued both to US investors through Rule 144A and non-US investors through Reg S, Bloomberg records two different bonds (e.g., with different ISIN, FIGI, and CUSIP) for the same issue. To avoid double counting, if two green bonds have the same issuer name, pricing date, maturity date, issuing amount, coupon, and currency, then we only keep one of these bonds.

[13]In particular, we keep the conventional bonds that can be found in Bloomberg and have identifiers (e.g., ISIN) available. Because we study the bond performance during bookbuilding, we also require the conventional bonds to have price update information available.

bonds extracted from Bloomberg by year and by currency. For ease of exhibition, we convert the offering amount of EUR-denominated green bonds to USD. Consistent with the general trend, there has been an exponential growth in the green bond market in the past few years. Most sample green bonds (60% both in the number and volume) are offered on or after 2019. The average offering amount of sample green bonds is USD 751 million, comparable to the size of the USD-denominated corporate bonds with price update information available from Bloomberg studied in Wang (2021).[14] The green bond offerings not covered by our sample are much smaller, with an average offering size of USD 196 million. This pattern holds for both USD- and EUR-denominated offerings. Because the offering amount of the green bond offerings not covered by our sample is small, they may not meet the inclusion threshold of green bond indexes. For example, the Bloomberg Barclays MSCI Global Green Bond Index requires the outstanding amount of a bond denominated in USD and EUR to exceed 300 million.[15] Because these smaller green bonds not covered by our sample might attract less investor demand, our findings may not necessarily generalize to them.

3.2. Variables

3.2.1. Oversubscription

At the beginning of the bookbuilding process, underwriters announce the preliminary terms of the offering, before the sales force starts to solicit indications of interest from potential investors. Appendix A provides an example of the typical pricing process using Apple Inc's $1 billion 10-year green bond announced and priced on June 13, 2017. The lead underwriters collect all indications of interest and record the aggregate order amount as the order book size. To measure the demand for a bond offering i, we calculate its oversubscription ratio, which is the dollar amount of the book size scaled by the initial

[14]We convert the offering amount of EUR-denominated bond offerings to USD using daily exchange rate downloaded from Bloomberg.

[15]https://www.msci.com/documents/10199/242721/Barclays_MSCI_Green_Bond_Index.pdf/6e4d942a-0ce4-4e70-9aff-d7643e1bde96

offering amount (i.e., the amount that the underwriters and issuers proposed to offer at the beginning of bookbuilding):[16]

$$Oversubscription_i = \frac{Dollar\ Amount\ of\ Book\ Size_i}{Initial\ offering\ amount_i}. \quad (1)$$

A larger oversubscription ratio indicates higher investor demand.

3.2.2. Spread compression

Underwriters disclose the IPT to investors before bookbuilding. The IPT is either in yield spread over a benchmark rate or yields. For our sample bonds, the IPT of 94% (4%) [2%] of bonds denominated in Euro are expressed as yield spreads over the mid-swap rates (yield spreads over the government security benchmark) [yields], and the IPT of 28% (63%) [9%] of bonds denominated in USD are expressed as yield spreads over the mid-swap rates (yield spreads over the Treasury benchmark) [yields]. For the bonds denominated in USD whose initial pricing is expressed as yield spreads over the the mid-swap rates, the issuers of all but five of these bonds are non-US entities. The differences in quoting conventions reflect the most liquid benchmark instruments denominated in respective currencies. Furthermore, as shown in Wang (2021), the IPT (or initial guidance when IPT is missing) could be expressed as a range (e.g., T +90-100 bps), an area (e.g., T +95 bps area), or just a number (e.g., T +95 bps). When IPT has a range, we use the midpoint of the range as the initial price. Based on the order book size, underwriters adjust the initial price to arrive at the offering price. The offering price typically follows the IPT in terms of whether it is expressed as yield spreads over the mid-swap rates, yield spreads over the Treasury benchmark, or yields.

To measure the price change from the initial price to the offering price, we calculate the changes in yield/yield spreads and refer to them as spread compression:

[16] As shown in Hotchkiss, Sun, Wang, and Zhao (2021), high investor demand often leads to bond upsizing, where the eventual offering amount is greater than the initial offering offering. Thus, scaling the book size by the offering amount underestimates the actual demand for upsized offerings. In our sample, 23 green bond offerings and 95 conventional bond offerings are upsized. We conduct robustness tests excluding these upsized bond offerings and report the results in Appendix C, Table A1.

$$
Spread\,compression_i = \begin{cases} Off\ Swap\ Spread_i - IPT\ Swap\ Spread\ Midpoint_i & IPT_i\ in\ swap\ spreads \\ Off\ Gov\ Spread_i - IPT\ Gov\ Spread\ Midpoint_i & IPT_i\ in\ gov\ spreads \\ Off\ Yield_i - IPT\ Yield\ Midpoint_i & IPT_i\ in\ yields \end{cases} \quad (2)
$$

where i indicates a bond. *Off Swap Spread*, *Off Gov Spread* and *Off Yield* refer to the offering yield spread over mid-swap rate, offering yield spread over the government security benchmark, and offering yield for bond i, respectively. *IPT Swap Spread Midpoint*, *IPT Gov Spread Midpoint*, and *IPT Yield Midpoint* refer to the midpoint of the IPT price when IPT is expressed as yield spread over mid-swap rate, yield spread over the government security benchmark, and yield, respectively.[17] A more aggressive tightening of the offering spread leads to a more negative value of spread compression.

3.2.3. Offering spread

In this paper, we use the offering yield spread over the government benchmark rate (offering spread hereafter) to measure the expected return of bond offerings.[18] The data vendor provides the offering spread over the government benchmark rate. When this variable is missing from the data vendor, we supplement it with the offering spread over government

[17] When the initial pricing is expressed as an area, some IPT includes expressions such as "high", "mid", or "low" (10.5% of sample bonds). For example, the IPT could be "High T +90 bps," followed by the offering price of "T +95 bps." In this case, omitting these adjectives in the IPT underestimate the magnitude of the spread compression. Thus, when the IPT includes the string of "very high", "high", "mid-high", "mid" (excluding the cases where the string stands for the mid-swap benchmark), "mid-low", "low", "very low", we add 8.75, 7.5, 6.25, 5, 3.75, 2.5, 1.25 bps to the number in the IPT price when the number is in 10s, respectively, to calculate the mid-point of the initial spreads/yields. For example, if the IPT is quoted as "High T +90 bps", we adjust the IPT to be T+97.5 bps. In a robustness test, we exclude offerings for which these adjectives exist in the IPT.

[18] We choose offering spreads rather than offering yields because it is difficult to control for the risk-free rate component from the offering yield with time fixed effects when bonds are issued in different currencies at different times. Robustness tests using offering yields rather than offering spreads are reported in Table A2, Appendix C. In general, using the offering yield to measure the expected return of offerings generates larger greenium than using the offering spread.

benchmark obtained from Bloomberg.[19]

3.2.4. Initial offering spread

To compare the initial prices of all bonds, which are quoted in different conventions as discussed in Section 3.2.2, we use the initial offering spread over the government benchmark rate, and refer to it as the initial offering spread. For offerings that are quoted as offering spreads over the mid-swap rate and yields, we calculate the initial offering spread by subtracting the spread compression (discussed in Section 3.2.2) from the offering spread over the government benchmark (discussed in Section 3.2.3).

3.3. Summary Statistics

Table 2, Panel A presents statistics of bond characteristics for the full sample, including both green bonds and their conventional counterparts. [20] We winsorize all continuous variables at 1st and 99th percentile of the sample. Variable definitions are available in Appendix B. Green bonds account for 13% of the sample. The average offering yield is 214.377 bps, and the average offering spread is 107.030 bps. The low offering spread reflects that most of our sample bonds (94%) are investment grade, consistent with the sample composition of Flammer (2020). The average oversubscription ratio of our sample bonds is 2.737, and the median is 2.2, meaning that the average (median) book size is 2.737 (2.2) times the proposed offering amount. This ratio is consistent with the underwriters' view that the book size should be at least 1.5 to 2 times the offering amount such that underwriters can have some room to tighten the offering yield and still get all bonds sold (Feldstein and

[19]We do not calculate the offering spread for bonds with missing values. Calculating the yield spread by subtracting the daily benchmark rates from the offering yield could be problematic because the daily benchmark rate could be different from the benchmark rate at the pricing time, especially when the market is volatile. We do not use i-spreads or other spreads from Bloomberg either, because Bloomberg often does not provide these spreads calculated on the pricing date, which is a few days before the offering date for our sample bonds. For example, 91% of sample bonds are priced on the announcement date, but the median interval between the pricing and the offering date is 7 days.

[20]Due to data availability, not all 4,908 sample bonds have offering yield, offering spread, order book size, and rating information.

Fabozzi (2008)). The average spread compression is -12.552 bps, indicating that an average bond experiences about 13 bps drop from the initial yield spread to the offering yield spread. The mean offering amount is about USD1.2 billion, and the average maturity is 8.7 years. Among the sample bonds, 71.7% are listed: 1.5% of USD-denominated bonds offered by U.S. companies and 85% of the EUR-denominated bonds are listed. Among the full sample, 99% of the bond offerings are rated, and the median rating of these bonds is A.

Panel B and Panel C of Table 2 display statistics for green and conventional bond subsamples, respectively. Notably, the offering sizes of green bonds are smaller than conventional bonds ($739 million vs. $1,281 million) on average, likely because the use of proceeds of green bonds is designated to specified green projects rather than general corporate purposes, limiting the size of green bonds. The sample green bonds also have slightly longer maturities than the conventional bonds (9.002 years vs. 8.656 years) on average. To account for potential differences in pricing that stem from these differences, we always control for the offering amount and maturity in our multivariate regressions. Moreover, we conduct a matched sample analysis by matching green bonds to their conventional counterparts along these dimensions.

4. Demand and dynamic pricing in the primary market

If green bond offerings attract significantly greater investor demand than their conventional counterparts, the oversubscription ratio should be greater for green bonds than conventional bonds. Furthermore, greater investor demand for green bond offerings should enable underwriters to tighten the offering spread more aggressively, resulting in a larger spread compression.

4.1. Demand

We first investigate whether green bonds experience higher demand than conventional bonds by examining the oversubscription ratio. Specifically, we estimate the following equation:

$$Oversubscription_i = \alpha + \lambda Green\,bond_i + \beta Control_i + FE + \epsilon_i, \tag{3}$$

where i indexes a bond. *Oversubscription* is the order book size scaled by the initial offering amount as defined in equation (1). *Green bond* is an indicator variable equal to one if an offering is labeled as a green bond by Bloomberg and zero otherwise. Control variables include bond characteristics and market conditions. Bond level controls include the natural logarithm of offering amount, the natural logarithm of maturity in years, whether the bond is listed on an exchange, indicators of the format of the bond (e.g., Rule 144A, Reg S, Public, and other), seniority indicators (senior unsecured, secured, subordinated/Jr subordinate secured), indicators of letter ratings (AAA, AA, A, BBB, BB, B, and unrated) and indicators of the denominated currency of the offering.[21] Market conditions include the 10-year swap rate of the denominated currency of the offering and the slope of the swap rate (i.e., 10-year - 1-year swap rate). FE includes issuer and year fixed effects. We estimate this equation using an ordinary least squares (OLS) regression and cluster the robust standard errors at the issuer level.

Table 3 presents the estimation results. Column (1) reports the results for the full sample. The coefficient on *Green bond* is 0.397, suggesting that on average, the oversubscription ratio of green bonds is 0.397 greater than otherwise similar conventional bonds issued by the same issuer. This difference is economically significant considering that the average oversubscription ratio for conventional bonds is 2.6. This finding is consistent with the anecdotal evidence that investors, especially those who target green bonds, are eager to get hold of green bonds in the primary market.

For control variables, larger offerings exhibit a smaller oversubscription ratio, consistent

[21] In untabulated tables, we show that our results are robust to using the offering amount, as opposed to the natural logarithm of offering amount, as a control variable. We assign the format Rule 144A to the bonds that are registered under both Rule 144A and Reg S.

with the findings in the literature that an average primary market investor typically purchases about USD 5 million in a new issue and larger offerings require a greater investor pool, leading to smaller oversubscription ratio (Nikolova et al. (2020), Bessembinder et al. (2020), Helwege and Wang (2021)). Longer maturity is associated with a higher oversubscription ratio, possibly because longer maturity bonds have higher yield spreads and investors reach for yield (at least partially by reaching for maturity) in the low interest rate environment (Murray and Nikolova (2021)) during our sample period.

In columns (2) and (3), we repeat our analysis of demand for corporate and SSA bonds separately. The coefficient on *Green bond* indicator is greater for the corporate than for SSA issues (0.538 vs. 0.302). For SSA bonds, the coefficient on *Green bond* remains positive but not statistically significant (mainly due to the increase in the standard error). One possible explanation is that SSA green bonds are typically larger than corporate green bonds ($998 million vs. $662 million), diluting the potential impact of green bond investors. These findings suggest that greenium, if exists, may be more prominent for corporate bonds than for SSA bonds.

4.2. Initial pricing and spread compression

We interpret the greater oversubscription for green bonds as evidence of more demand from institutional investors. If so, in anticipation of greater demand, underwriters might propose a lower initial yield for green bonds to avoid the need to tighten the offering yield too aggressively after bookbuilding, which annoys investors.[22] Alternatively, it is also plausible that the greater oversubscription for green bonds is a result of issuers and underwriters deliberately lowballing the initial price (i.e., proposing a higher initial yield) to attract more investors (Lowry and Schwert (2004)). Green bond issuers might have an incentive to do so to increase investor awareness of the company and improve reputation (Dimson, Karakaş, and Li, 2015). In addition, to the extent that green bonds are relatively new financial instruments

[22] Wilson, H, Vaughan, L, and Griffin, D. (November 2019), “Bond Investors Fume at Price Talk Some Call ‘Bait and Switch’,” Bloomberg.

compared to conventional bonds, underwriters may face more uncertainty in placing green bonds. Along this line, underwriters might also lowball the initial pricing of green bonds (Sherman and Titman (2002), Wang (2021)). If these are the cases, the initial offering spread of green bond offerings should be greater than their conventional counterparts. To differentiate between these cases, we estimate the following equation:

$$Initial\, offering\, spread_i = \alpha + \lambda Green\, bond_i + \beta Control_i + FE + \epsilon_i, \tag{4}$$

where i indexes a bond, and *Initial offering spread* is defined in section 3.2.4. Other model specifications are the same as in equation (3).

Table 4, columns (1)-(3), present the estimation results. In column (1), we report the results of the initial offering spread for the full sample. The initial offering spread of green bonds is lower (-2.804 bps, although not statistically significant) than conventional counterparts. The subsample analyses of corporate bonds in column (2) and SSA bonds in column (3) yield the same conclusion. These results are not consistent with the conjecture that issuers lowball the initial price, and provide some weak support to the argument that green bond underwriters propose lower initial offering yields.

We proceed to examine if the greater demand for green bond offerings leads to a more aggressive spread compression by estimating the following model:

$$Spread\, compression_i = \alpha + \lambda Green\, bond_i + \beta Control_i + FE + \epsilon_i, \tag{5}$$

where i indexes a bond, and *Spread compression* is defined in equation (2). Other model specifications are the same as in equation (3).

Table 4, column (4), suggests that the spread compression for green bond offerings exceeds their conventional counterparts. Specifically, the magnitude of the spread compression of green bonds is 2.352 bps larger than conventional bonds, supporting the notion that stronger investor demand enables underwriters to tighten the offering spreads to a greater extent. The subsample results in column (5) for corporate bonds and (6) for SSA bonds reach similar conclusions.

Because green bond offerings exhibit (statistically insignificantly) lower initial offering spreads before bookbuilding and experience a more aggressive spread tightening after bookbuilding, they should display lower offering spreads than their conventional counterparts. In other words, the combined evidence on investor demand, the initial offering spread, and the spread compression in the primary market suggests that greenium should exist.

5. Greenium

5.1. Does greenium exist?

In this subsection, we examine whether greenium exists. We first compare the offering yield spread of green bonds and conventional bonds issued by the same issuers using multivariate regressions. Then, we perform a match-sample analysis.

5.1.1. Multivariate regressions

We begin by estimating the following regression model:

$$Offer\,spread_i = \alpha + \lambda Green\,bond_i + \beta Control_i + FE + \epsilon_i, \tag{6}$$

where i indexes a bond, and *Offering spread* is the offering yield spread over the government benchmark rate. Other model specifications are the same as in equation (3).

Table 5 presents the regression results. These results suggest that greenium exists in our sample, lending support to the investor-tastes asset pricing model (e.g., Pastor et al. (2021b), Baker et al. (2020)). In particular, column (1) shows that the offering spread of green bonds is 5.419 bps smaller than that of similar conventional bonds offered by the same issuer on average, accounting for about 5% of the offering spread. Although the magnitude of the greenium is in the eyes of the beholder, we view it as reasonable. Fixed income securities exhibit high substitutability, so investors, especially ESG-neutral investors, could drop their interest and seek for alternatives when the yield spread of green bonds becomes too low.

Utilizing various dimensions of pricing information, including the initial offering spread, the spread compression, and the offering spread, we capture the dynamic formation of greenium. The greenium of green bonds (5.419 bps) is roughly distributed into a lower initial offering spread (2.804 bps as reported in Table 4 , column (1)) and a greater spread compression (2.352 bps as presented in Table 4, column (4)). That is, underwriters anticipate that green bonds are likely to have a larger order book size, so they set the initial offering spread lower, avoiding a too large spread compression after the bookbuilding that annoys investors. Underwriters do not appear to propose an initial offering spread that is low enough to absorb all the expected greenium, possibly because of the uncertainty associated with investor demand in the offering process (Bessembinder et al. (2020), Wang (2021)).

The control variables in Table 5 mostly show expected signs. For example, larger offerings exhibit greater offering spread, possibly because of the price pressure associated with finding a large number of investors at issuance (Helwege and Wang (2021)). Longer maturity is associated with a higher offering spread, and the offering spread increases with the 10-year swap rate. Because of our extensive list of control variables and fixed effects, the R-squared of the regressions is high: it is 83% in column (1).

In columns (2) and (3), we conduct the regression analysis for corporate and SSA bond offerings separately. Among the corporate sample, we observe an average greenium of 6.25 bps, statistically significant at 1% level. Among the SSA sample, the greenium is smaller at 4.19 bps and significant at 10% level. These findings are consistent with the patterns in the oversubscription ratio, the initial offering spread, and the spread compression discussed in Section 4.

5.1.2. Matching sample

To address the potential concern that the differences in pricing between green and conventional bonds arise from some uncontrolled factors (Larcker and Watts (2020)), we conduct a matching sample analysis following the spirit of Flammer (2020). Specifically, for each green bond, we first find the conventional bonds from the same issuer with the same rating, currency, seniority, maturity bucket, and offering amount bucket.[23] When a green bond is matched to multiple conventional bonds, we keep the conventional bond with the smallest distance to the green bond, calculated based on the offering amount, maturity, and the pricing date. These requirements yield 380 green and conventional bond pairs.

Table 6 reports the mean and median of the offering spread for green bonds and their matched conventional bonds, as well as the pairwise differences. Panel A shows that among the 380 matched pairs, the mean and median pairwise differences in the offering spread are -8.093 and -5.050 bps, respectively, both of which are significant at the 1% level. Panel B shows that for the 298 matched corporate green bonds, the mean and median pairwise differences in the offering spread are -9.636 and -6.45 bps, respectively, both of which are significant at the 1% level. Panel C shows that the mean and median pairwise differences in the offering spread are for the 82 green bonds issued by SSA are -2.488 and -3.000 bps, respectively, with the mean not significant and the median significant at the 10% level. Overall, the matching sample results are consistent with our multivariate regression results, suggesting that green bonds command a reasonable premium over their conventional counterparts. These results lend support to the theoretical prediction that green assets offer lower expected returns.

5.2. Investor demand and greenium

After showing the relation between demand and the green label and the relation between the offering spread and the green label separately, we next examine if investor demand

[23] We group bond maturities into four buckets, <=5, 5-10, 10-30 and >30 years. We group offering amount into four size buckets, <=USD 500, USD 500-USD 1,000, USD 1,000-USD 1,500, and >USD 1,500 (in millions).

exclusively explains greenium.

When using demand to explain the offering spread, we note that fixed-income investors reach for yield (Becker and Ivashina (2015), Choi and Kronlund (2017)), which can lead to a positive relation between investor demand and the IPT. Because IPT and the offering spread are highly correlated (Wang (2021)), the reaching-for-yield behavior could result in a positive relation between investor demand and offering spread, rather than a negative relation suggested by the downward sloping demand curve. To circumvent this issue, we use a two-stage approach to tease out the impact of reaching-for-yield. In particular, we estimate the following equation in the first stage:

$$Oversubscription_i = \alpha + \beta Relative\,initial\,spread_i + \epsilon_i, \tag{7}$$

where i indexes a bond, and *Relative initial spread* is the offering's initial offering yield over the yield of currency- and rating-matched Barclays' index. We expect *Relative initial spread* to be positively associated with the oversubscription ratio if investors reach for yield. We estimate this equation using OLS. Residuals from this regression capture investor demand orthogonal to the potential reaching-for-yield motive.

In the second stage, we augment equation (6) by including residuals from the first stage regression. Specifically, we estimate the following equation:

$$Offering\,spread_i = \alpha + \lambda Green\,bond_i + \theta Resi\,demand\,_i + \beta Control_i + FE + \epsilon_i, \tag{8}$$

where i indexes a bond. *Resi demand* is the percentile rank value of the residuals obtained from estimating equation (7). We use percentile ranks to mitigate the noise from the first stage regression and for ease of interpretation. We expect *Resi demand* to be negatively associated with the offering spread. If investor demand cannot fully explain greenium, the coefficient of G*reen bond* should remain negative and significant after controlling for demand.

Other model specifications are the same as in equation (6).

Column (1) of Table 7 displays the first-stage estimation results based on equation (7). As expected, the *Relative initial spread* is significantly positively associated with demand, suggesting investor chase yield. Columns (2)-(4) report the second-stage regression results. First, *Resi demand* is significantly negatively associated with the offering spread, consistent with the notion that higher demand enables underwriters and issuers to push down the financing cost. Specifically, column (2) suggests that increasing the residual demand from the 25th percentile to the 75th percentile decreases the offering spread by about 8.75 bps. Second, the *Green bond* indicator remains negative, but becomes insignificant after controlling for *Resi demand*, indicating that the greater demand attracted by the green label is the main driver for the greenium we observe.

6. Heterogeneous demand for green bonds

To shed some light on variations in investor demand for green bonds, we conduct a regression analysis using the green bond sample only. Because all green bonds meet the green investment mandate, this analysis helps us understand the investment preferences of ESG institutional investors in choosing green bonds. Specifically, we estimate the following model:

$$Oversubscription_i = \alpha + \lambda_1 Factors_i + \beta Control_i + FE + \epsilon_i, \tag{9}$$

where i indexes a bond. Factors include *Credit quality*, *First green, Year, Greenness, and Second party opinion. Credit quality* includes *Relative initial spread* and letter rating indicators. *Relative initial spread* is the offering's initial yield over the yield of currency- and rating-matched Barclays' index, and letter ratings refer to AAA, AA,..., and B. *First green* is an indicator variable that equals one if the green bond is the first offered by an issuer and zero for subsequent green offerings. *Year* refers to the calendar year when a bond is offered.

Greenness indicators include *Dark green* (the omitted group), which equals one if the ESG project category of the bond offering is renewable energy, and zero otherwise; *Medium green*, which equals one if the ESG project category is green buildings and infrastructure or energy smart technologies and energy efficiency, and zero otherwise; *Light green*, which equals one if the ESG project category is projects other than dark or medium green as defined above, and zero otherwise; and *Unclassified green*, which equals one if the ESG project category has a missing value, and zero otherwise. We obtain ESG project categories from Bloomberg. *Second party opinion* is an indicator variable that equals one if the green bond has an assurance provider, and zero otherwise. Controls and FEs are the same as in equation (6), except that we do not control for year fixed effects in this model due to the use of *Year* as a control variable. Also, non-rated bond offerings are excluded from the sample because we are interested in rating effects.

Table 8 reports the estimation results. Results in columns (1) and (2) differ in that the latter controls for firm-fixed effects, whereas the former does not. Several interesting findings emerge in column (1). First, there is strong evidence of chasing for yield. Specifically, within IG bond offerings (96% of this subsample), as the rating quality of the green bonds decreases from AAA to BBB, the oversubscription ratio steadily and significantly increases, suggesting that fund managers actively acquire assets that offer higher expected returns. Second, an issuer's first green bond offering attracts stronger investor demand than subsequent green bond offerings, consistent with the notion that ESG fund managers seek diversification in their portfolio. Third, more recent green bond offerings receive higher investor demand. This result suggests that our findings are stronger for the later years and helps reconcile our findings with the lack of greenium in previous studies that use corporate bond data before 2018 (e.g., Flammer (2020), Tang and Zhang (2020)). The *First green* and *Year* effects become even stronger after controlling for firm-fixed effects in column (2).

We do not find evidence that institutional investors factor in the shades of green when making their investment decisions. Specifically, the coefficients of *Medium green*, *Light Green*, and *Unclassified green* are not statistically different from that of *Dark green*, the omitted group. This finding could be due to the complexity of distinguishing between a firm's overall ESG profile and the profile of a specific security. For example, *Dark green* bonds for renewable energy can be issued by an automaker, which can have a quite low overall ESG score. This result is also consistent with Kim and Yoon (2020)'s findings of PRI funds' greenwashing. Furthermore, we do not find evidence that the second party opinion affects demand, which is likely due to the lack of heterogeneity: most (86%) of green bond issuers seek to get second party opinion, or third party review.

7. Robustness tests

In this section, we conduct an array of robustness analyses. First, we examine whether issuer characteristics explain the demand and pricing patterns we observe. We begin with re-examining equations (3) - (6) by including firm-level controls, such as total assets, leverage, and profitability. We obtain these firm-level accounting variables, measured at the year prior to the issuance date, from WorldScope. Because SSA issuers do not have firm-level controls, we only conduct these tests for corporate bonds. Also, we lose some observations because not all corporate issuers have accounting variables available. Table 9, columns (1)-(4) present the results and show that our main findings are robust to the inclusion of firm level accounting variables. More profitable firms have larger book size. Firms with higher leverage, other things equal, have higher yield spreads. Next, to maintain the size of our original sample but still address the concern of omitting time-varying issuer characteristics, we include firm-year-fixed effects in our full sample. The estimation results reported in columns (5)-(8) of Table 9 suggest that our conclusions remain the same.

Second, our results of pricing dynamics and investor demand in the primary market are consistent with taste-based asset pricing models. One alternative explanation of our findings is temporary price pressure: temporarily high abnormal investor demand for green bond offerings suppresses their offering yields.[24] The difference between the taste-based asset pricing models and temporary price pressure view is that the former suggests consistently higher investor demand for green bond offerings, in both the primary market and the secondary market, and, thus, causes long-lasting pricing effects, whereas the latter suggests the greater demand for green bonds only exists in the primary market, and, thus, excerts temporary pricing effects. To empirically differentiate between these two competing explanations, we examine whether greenium is reversed in the secondary market by investigating underpricing, measured as the yield change from the offering yield to the secondary market yield. We measure the secondary market yield as the mid quote of yield to maturity on the offering date obtained from Bloomberg. We further adjust the yield change by changes of currency-, rating-, and maturity-matched ICE BofA indexes from the pricing date to the offering date. A more negative yield change means greater underpricing. If greenium is due to temporary price pressure, green bond offerings should experience *smaller* underpricing than conventional offerings to reverse the temporary pricing effects. Taste-based asset pricing models do not have such an implication. Moreover, green bonds could even display greater underpricing if the greater demand for green bonds exhibit substantial uncertainty.

Results presented in Table 10 show that temporary price pressure cannot explain greenium. Underpricing is not economically or statistically different between green and conventional bond offerings in the whole sample and in the corporate subsample (columns (1) and (2)). For the SSA subsample (columns (3)), green bond offerings even exhibit greater underpricing. This result confirms that the large uncertainty of the investor demand for green SSA bond offerings, as evidenced by the high standard error of the coefficient of *Green bond* in column (3) of Table 3, leads to their greater underpricing. The negative coefficient of the offering amount is also consistent with findings of Helwege and Wang (2021) that larger offerings exhibit greater underpricing due to price pressure.

[24]Opposite to the greater investor demand we document for green bond offerings, Helwege and Wang (2021) show that because of their relatively low investor demand, out-sized bond offerings exhibit greater offering yields, but the pricing effects start to dissipate when trading begins in the secondary market

Third, it is plausible that the credit risk of bond issuers becomes lower after they issue green bonds. Choosing to issue green bonds could signal to investors that the issuer has become more aware of climate-related risks and is more committed to reducing such risk (Flammer (2020)). Recent literature also suggests that credit rating agencies consider an issuer's environmental performances when assigning ratings (Seltzer et al. (2020)). Along this line, the credit quality of issuers may be improved when they offer green bonds. The change in credit quality may lead to a lower offering spread of the green and subsequent conventional bonds, compared to the conventional bonds offered before the first green bond. We note that changes in risks is unlikely to explain the observed greater demand for green bonds because the literature suggests that investors chase for riskier rather than safer assets, especially in the IG sector (Becker and Ivashina (2015); Choi and Kronlund (2017)). Nonetheless, to address this concern, we re-estimate our regression models to explain investor demand and offering spread using a subsample composed of green bonds and conventional bonds issued on or after the date when the first green bond is offered. If the risk explanation drives our results, the demand and the offering spread of green bonds should not be different from their conventional counterparts in this subsample. Table A3 reports the estimation results and suggests that our main results are robust to this alternative explanation.

Fourth, to control for time-invariant features associated with bond underwriters, we include underwriter fixed effects in our regressions. Appendix C, Table A4 shows that our main findings are robust to the underwriter fixed effects.

Fifth, we examine if controlling for the restrictiveness of covenants affects our results and find that it does not. To do so, we retrieve from Bloomberg the covenant information pertaining to negative pledge, M&A restriction, restriction, cross default, change of control, fundamental change, coverage ratio, asset sales, debt limit, and restricted payment.We then calculate the restrictiveness of covenants by adding up the number of covenants that take the value of "Y". Appendix C, Table A5 shows that our results are robust.

Lastly, we conduct two more tests to mitigate potential noises in our data. First, the book size information for 297 sample bonds (both green and conventional) is for all bonds issued on the same day (i.e., combined book) rather than a separate book for each bond offering. To address the concern of associated measurement errors, we drop offerings with a combined book and rerun the baseline regressions. Columns (1)-(4) of Table A6 in Appendix C report the estimation results. Our findings are robust to dropping these observations. Second, we exclude the offerings for which the IPT contains ambiguous strings discussed in Section *3.2.2.*. Columns (5)-(8) of Table A6 in Appendix C show that the results are similar to those we report in the main paper.

Overall, our systematic evidence based on investor demand and the pricing dynamics in the primary bond market strongly suggests that greenium exists because of investors' ESG tastes. Our setting of comparing green bonds with their conventional counterparts offered by the same issuer and the various robustness tests address various concerns that the pricing difference might be attributable to differences in firm fundamentals, temporary price pressure, credit risk, underwriters, and covenants. One more potential difference between green and conventional bonds is the plausible ESG-tastes-driven liquidity difference in the secondary market. Conceptually, the greater demand for green bonds can extend to the secondary market, which might lead to better liquidity. However, whether green bonds have greater liquidity than their conventional counterparts and thus enjoy liquidity premium, especially outside the short window after the offering date when trading becomes sparse (Goldstein and Hotchkiss (2020), Goldstein et al. (2019)), is not clear. Higher demand doesn't necessarily translate to greater liquidity (Johnson (2008)). Thus, the potential impact of ESG tastes on liquidity requires rigorous research, which is beyond the scope of our study. Even if ESG tastes in the secondary market increases expected liquidity, it is not clear whether and how it further feeds back to the primary market demand because of bond investors' heterogeneous preference for liquidity. For example, insurance companies may prefer to hold longer maturity and illiquid bonds to earn the illiquidity premium (Chen, Huang, Sun, Yao, and Yu (2020), Murray and Nikolova (2021)), but mutual funds may prefer to hold shorter maturity and liquid bonds (e.g., Bretscher et al. (2020)). Most importantly, our main conclusion that investor demand drives greenium remains regardless of the potential impact of ESG tastes in the secondary market on liquidity.

8. Conclusion

There is a mounting interest in how green assets should be priced. The investor tastes models predict that green assets should offer lower expected returns due to a group of investors' willingness to trade off financial returns for societal benefits. However, the empirical evidence is mixed, largely due to the lack of a clean setting to test this prediction. We tackle this issue by examining investor demand and the pricing dynamics in the primary market for corporate and SSA bonds.

Our findings support the investor tastes models. We find that green bonds exhibit larger oversubscription ratios than their conventional counterparts offered by the same issuer. Anticipating their greater demand, underwriters propose a slightly lower offering spread for green bonds at the beginning of bookbuilding. Upon a positive realization of investor demand, underwriters and issuers further tighten the offering spread of green bond offerings to a greater extent, resulting in significant greenium. These findings coherently suggest that higher investor demand for green bonds leads to their lower expected returns. Furthermore, after controlling for investor demand in the regression to explain the offering spread, the coefficient on the green bond indicator becomes statistically insignificant, implying that the pricing effect of the green label is mostly attributable to investor demand. To the extent that corporate and SSA bond markets are institutional markets, our study not only offers strong empirical support to the tastes-based asset pricing models, but also suggests that ultimate investors' tastes can manifest in asset prices when investment decisions are delegated to institutional managers.

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Table 1: Sample Coverage

This table reports the coverage of green bonds in Bloomberg and in our sample. Panel A displays the comparison by year, and Panel B presents the comparison by currency. Green bonds are government (non-municipal), corporate fixed- or variable-coupon non-perpetual USD or EUR denominated green bonds identified by Bloomberg, with non-missing offering amount and positive coupon rate. The sample period is from January 1, 2013 to May 31, 2021.

Panel A. By year

	All green bonds			Not covered by sample			Covered by sample			% volume
	N	Mean	Sum	N	Mean	Sum	N	Mean	Sum	covered
2013	16	587	9,387	6	321	1,929	10	746	7,458	79%
2014	39	487	18,991	21	131	2,757	18	902	16,234	85%
2015	199	145	28,833	162	40	6,408	37	606	22,425	78%
2016	84	527	44,232	37	316	11,699	47	692	32,533	74%
2017	107	644	68,867	35	341	11,930	72	791	56,937	83%
2018	123	579	71,245	50	231	11,555	73	818	59,690	84%
2019	236	539	127,244	107	310	33,192	129	729	94,052	74%
2020	336	408	137,189	205	206	42,328	131	724	94,860	69%
2021	276	455	125,503	156	199	31,047	120	787	94,455	75%
Total	1,416	446	631,489	779	196	152,845	637	751	478,644	76%

Panel B. By currency

	All green bonds			Not covered by sample			Covered by sample			% volume
	N	Mean	Sum	N	Mean	Sum	N	Mean	Sum	covered
EUR	767	520	398,732	378	194	73,514	389	836	325,217	82%
USD	649	359	232,757	401	198	79,330	248	619	153,427	66%
Total	1,416	446	631,489	779	196	152,845	637	751	478,644	76%

Table 2: Summary Statistics

This table presents summary statistics of bond characteristics. Each sample bond issuer has offered at least one green and one conventional bond during our sample period. All sample bonds have spread compression information available. All variables are defined in Appendix B. The sample period is from January 1, 2013 to May 31, 2021.

Panel A. Full sample

	N	Mean	25th	Median	75th	Std Dev
Green bond	4908	0.130	0.000	0.000	0.000	0.336
Offering yield	4682	214.377	87.200	178.000	303.200	165.495
Offering spread	4672	107.030	47.550	90.800	135.800	80.468
Oversubscription	3767	2.737	1.600	2.200	3.300	1.696
Spread compression	4908	-12.552	-20.000	-10.000	-2.500	11.472
Offering amt (in $mn)	4908	1210.680	577.748	1000.000	1411.170	999.476
Maturity (in years)	4908	8.701	5.022	7.025	10.030	6.579
Listing dummy	4908	0.717	0.000	1.000	1.000	0.451
10-year swap rate	4908	138.821	69.265	141.190	214.825	92.839
Swap rate slope	4908	92.825	46.840	87.810	128.130	64.035
Rating (letter rating)	4866	2.755	2.000	3.000	4.000	1.273

Panel B. Green bonds

	N	Mean	25th	Median	75th	Std Dev
Offering yield	610	182.989	63.900	140.250	253.800	161.347
Offering spread	603	110.762	58.000	96.500	135.000	80.313
Oversubscription	503	3.622	2.000	3.200	4.571	2.000
Spread compression	637	-18.333	-27.000	-17.500	-5.500	13.537
Offering amt (in $mn)	637	738.563	500.000	590.405	840.630	545.951
Maturity (in years)	637	9.002	5.025	7.036	10.030	6.096
Listing dummy	637	0.830	1.000	1.000	1.000	0.376
10-year swap rate	637	92.834	9.880	81.650	160.320	90.883
Swap rate slope	637	71.125	34.910	61.000	105.100	50.030
Rating (letter rating)	630	3.087	2.000	3.000	4.000	1.242

Table 2: Summary Statistics - continued

Panel C. Conventional bonds

	N	Mean	25th	Median	75th	Std Dev
Offering yield	4072	219.079	92.700	184.300	309.450	165.615
Offering spread	4069	106.477	47.000	90.000	136.000	80.486
Oversubscription	3264	2.600	1.533	2.100	3.000	1.601
Spread compression	4271	-11.689	-17.500	-10.000	-2.500	10.873
Offering amt (in $mn)	4271	1281.090	600.000	1000.000	1500.000	1032.170
Maturity (in years)	4271	8.656	5.022	7.022	10.027	6.647
Listing dummy	4271	0.700	0.000	1.000	1.000	0.458
10-year swap rate	4271	145.679	73.620	153.710	220.850	91.171
Swap rate slope	4271	96.062	49.530	90.080	133.280	65.258
Rating (letter rating)	4236	2.705	2.000	3.000	4.000	1.270

Table 3: Demand in the primary market
This table presents estimation results from an analysis of investor demand in the primary market. The dependent variable is *oversubscription*. Columns (1), (2), and (3) present results for the full sample, the corporate subsample, and the SSA subsample, respectively. All variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	All	Corporate	SSA
	(1)	(2)	(3)
Green bond	0.397***	0.538***	0.302
	(0.111)	(0.104)	(0.265)
log(offering amount)	-0.571***	-0.714***	-0.178
	(0.095)	(0.093)	(0.186)
log(maturity)	0.229***	0.233***	0.215**
	(0.052)	(0.063)	(0.106)
Listing dummy	-0.247**	-0.072	-0.037
	(0.122)	(0.112)	(0.156)
10-year swap rate	0.002***	0.002**	0.001
	(0.001)	(0.001)	(0.001)
Swap rate slope	0.000	0.001	-0.001
	(0.001)	(0.001)	(0.001)
Rating FE	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes
Format FE	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	3,769	2,906	863
R-squared	0.474	0.472	0.559

Table 4: Initial offering spread and spread compression

This table presents estimation results from an analysis of initial offering spread and spread compression. The dependent variable is *initial offering spread* in columns (1)-(3) and *spread compression* in columns (4)-(6). Columns (1) and (4) present results for the full sample, columns (2) and (5) present results for the corporate subsample, and columns (3) and (6) present results for the SSA subsample. All variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Initial offering spread			Spread compression		
	All	Corporate	SSA	All	Corporate	SSA
	(1)	(2)	(3)	(4)	(5)	(6)
Green bond	-2.804	-3.807	-2.967	-2.352***	-1.966***	-1.499***
	(1.946)	(2.445)	(2.280)	(0.385)	(0.458)	(0.487)
log(offering amount)	8.088***	12.439***	-0.791	-1.477***	-2.313***	-0.504*
	(1.936)	(2.169)	(2.945)	(0.355)	(0.457)	(0.281)
log(maturity)	22.332***	27.211***	7.426***	0.128	0.521*	-0.695
	(1.903)	(1.913)	(1.631)	(0.246)	(0.293)	(0.446)
Listing dummy	1.785	-0.215	-7.995**	0.680	0.306	-0.897
	(3.095)	(3.865)	(3.901)	(0.541)	(0.703)	(0.815)
10-year swap rate	0.068***	0.091***	-0.021	0.007**	0.009**	0.006
	(0.020)	(0.026)	(0.020)	(0.003)	(0.004)	(0.005)
Swap rate slope	0.061***	0.068***	0.040**	-0.006**	-0.006*	0.003
	(0.014)	(0.018)	(0.016)	(0.003)	(0.004)	(0.002)
Rating FE	Yes	Yes	Yes	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes	Yes	Yes	Yes
Format FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,672	3,556	1,116	4,908	3,749	1,159
R-squared	0.847	0.795	0.931	0.709	0.640	0.883

Table 5: Greenium - Multivariate regression

This table presents estimation results from an analysis of the offering spread. The dependent variable is the *offering spread*. Columns (1), (2), and (3) present results for the full sample, the corporate subsample, and the SSA subsample, respectively. All variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	All	Corporate	SSA
	(1)	(2)	(3)
Green bond	-5.419***	-6.250***	-4.193*
	(1.891)	(2.387)	(2.247)
log(offering amount)	6.616***	10.163***	-1.171
	(1.862)	(2.128)	(2.813)
log(maturity)	22.553***	27.719***	7.087***
	(1.925)	(1.934)	(1.509)
Listing dummy	2.392	0.109	-8.973**
	(2.984)	(3.760)	(3.720)
10-year swap rate	0.073***	0.098***	-0.017
	(0.020)	(0.026)	(0.016)
Swap rate slope	0.055***	0.061***	0.045***
	(0.014)	(0.018)	(0.015)
Rating FE	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes
Format FE	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	4,672	3,556	1,116
R-squared	0.831	0.782	0.919

Table 6: Greenium - Matching sample

This table reports the mean and median of the offering spread for green bonds and matched conventional bonds of the same issuer. To construct the green and conventional bond matched-pairs, we first find for each green bond the conventional bonds from the same issuer with the same rating, currency, seniority, maturity bucket, and offering amount bucket. Bond maturity buckets include <=5, 5-10, 10-30 and >30 years, and offering amount buckets include <=USD 500, USD 500-USD 1,000, USD 1,000-USD 1,500, and >USD 1,500 (in millions). When a green bond is matched to multiple conventional bonds, we keep the conventional bond with the smallest distance to the green bond, calculated based on the offering amount, maturity, and the pricing date. The bottom two rows in each panel report the pairwise differences in mean and median, along with the corresponding p-values. All variables are defined in Appendix B. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Panel A. Full sample

	N	Mean	Median
Green	380	109.370	95.900
Conventional	380	117.463	103.000
Pairwise Difference		-8.093***	-5.050***
P-value		0.004	0.000

Panel B. Corporate

	N	Mean	Median
Green	298	127.694	108.450
Conventional	298	137.329	110.000
Pairwise Difference		-9.636***	-6.450***
P-value		0.007	0.000

Panel C. SSA

	N	Mean	Median
Green	82	42.779	25.000
Conventional	82	45.268	26.900
Pairwise Difference		-2.488	-3.000*
P-value		0.211	0.085

Table 7: Is investor demand the main driver of greenium?
This table shows the impact of the green label on the offering spread, after controlling for investor demand. The dependent variable is *oversubscription* in column (1) and *offering spread* in columns (2)-(4). *Relative initial spread* is the offering's initial yield over the yield of currency- and rating-matched Barclays' index. *Resi demand* is the percentile value of the residual oversubscription ratio estimated from the regression shown in column (1). All other variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	All	All	Corporate	SSA
	(1)	(2)	(3)	(4)
	Oversubscription	Offering spread		
Relative initial spread	0.005***			
	(0.000)			
Green bond		-2.979	-3.001	-2.083
		(2.165)	(2.619)	(2.887)
Resi demand		-0.175***	-0.187***	-0.172***
		(0.037)	(0.044)	(0.063)
log(offering amount)		5.117**	7.227***	-1.413
		(2.425)	(2.464)	(3.876)
log(maturity)		21.868***	26.670***	5.174***
		(1.768)	(1.776)	(1.624)
Listing dummy		3.878	3.168	-10.515*
		(3.329)	(4.165)	(5.677)
10-year swap rate		0.129***	0.179***	-0.010
		(0.022)	(0.027)	(0.018)
Swap rate slope		0.048***	0.035*	0.056***
		(0.016)	(0.019)	(0.017)
Rating FE	No	Yes	Yes	Yes
Currency FE	No	Yes	Yes	Yes
Format FE	No	Yes	Yes	Yes
Seniority FE	No	Yes	Yes	Yes
Firm FE	No	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes
Observations	3,471	3,471	2,682	789
R-squared	0.046	0.841	0.796	0.931

Table 8: Heterogeneous demand for green bonds
This table examines the heterogeneity of investor demand for green bonds using the green bonds subsample. The dependent variable is *oversubscription*. *Relative initial spread* is the offering's initial yield over the yield of currency- and rating-matched Barclays' index. AAA, AA,..., and B are letter rating indicators. *First green* is an indicator variable that equals one if the green bond is the first offered by an issuer, and zero for subsequent green offerings. *Year* refers to the calendar year when a bond is offered. *Greenness indicators* include *Dark green* (the omitted group), which equals one if the ESG project category is renewable energy, and zero otherwise; *Medium green*, which equals one if the ESG project category is green buildings and infrastructure or energy smart technologies and energy efficiency, and zero otherwise; *Light green*, which equals one if the ESG project category is projects other than dark or medium green as defined above, and zero otherwise; and *Unclassified green*, which equals one if the ESG project category has a missing value, and zero otherwise. *Second party opinion* is an indicator variable that equals one if the green bond has an assurance provider, and zero otherwise. All other variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8: Heterogeneous demand for green bonds - continued

	(1)	(2)
Relative initial spread	0.001	0.003
	(0.002)	(0.003)
AA	0.931***	0.682
	(0.353)	(0.927)
A	1.244***	-0.254
	(0.342)	(0.701)
BBB	1.655***	-0.608
	(0.341)	(1.004)
BB	0.826	-0.747
	(0.573)	(1.353)
B	3.809***	
	(0.747)	
First green bond	0.522***	0.811***
	(0.173)	(0.289)
Year	0.180***	0.282***
	(0.048)	(0.088)
Medium green	-0.108	-0.430
	(0.271)	(0.494)
Light green	-0.111	-0.987
	(0.366)	(0.804)
Unclassified green	-0.041	-0.462
	(0.224)	(0.310)
Second party opinion	-0.115	-0.649
	(0.299)	(0.436)
log(offering amount)	-0.534**	-0.376
	(0.208)	(0.378)
log(maturity)	0.009	-0.021
	(0.212)	(0.402)
Listing dummy	1.200***	0.906
	(0.415)	(0.737)
Denominated in USD	-0.218	0.456
	(0.358)	(0.696)
SSA	0.095	
	(0.301)	
Format FE	Yes	Yes
Firm FE	No	Yes
Observations	475	475
R-squared	0.249	0.742

Table 9: Robustness: Control for firm characteristics and firm-year-fixed effects

This table shows the robustness of our main results after controlling for firm characteristics for corporate bond offerings in columns (1)-(4), and controlling for the firm-year-fixed effects for all sample bond offerings in columns (5)-(8). The dependent variables are in table header. *Log(Asset)* is the natural logarithm of the total asset of the issuer, *ROA* is the issuer's net income over total assets, and *Leverage* is the issuer's total debt over total assets. Other controls include *log(Offering amount), log(Maturity), Listing dummy, 10-year swap rate*, and *Swap rate slope*, and are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Corporate bond subsample				Full sample			
	Over-subscription	Initial offering spread	Spread compression	Offering spread	Over-subscription	Initial offering spread	Spread compression	Offering spread
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Green bond	0.620***	-5.363	-2.280***	-8.023**	0.593***	-4.106	-1.426***	-6.010**
	(0.139)	(3.614)	(0.610)	(3.562)	(0.181)	(2.955)	(0.499)	(2.827)
log (Assets)	0.039	-8.647	-3.821*	-10.675				
	(0.471)	(13.633)	(2.024)	(13.957)				
Return on assets	9.147**	-138.283	-38.780	-175.611				
	(3.988)	(130.864)	(27.277)	(141.205)				
Leverage	0.320	128.448***	1.079	125.392***				
	(0.984)	(41.536)	(8.072)	(42.961)				
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Format FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	No	No	No	No
Firm-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Observations	1,715	2,105	2,192	2,105	3,767	4,672	4,908	4,672
R-squared	0.448	0.767	0.610	0.757	0.759	0.930	0.870	0.923

Table 10: Underpricing

This table shows the relation between underpricing and the green bond label. The dependent variable is the yield change from the offering yield to the secondary market yield, adjusted for changes of currency-, rating-, and maturity- matched ICE BofA indexes. Secondary market yield is the mid quote of yield to maturity on the offering date obtained from Bloomberg. All other variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	All	Corporate	SSA
	(1)	(2)	(3)
Green bond	-0.044	0.671	-2.273**
	(0.786)	(1.004)	(0.939)
log(offering amount)	-1.196*	-1.671*	-0.972
	(0.677)	(0.963)	(0.707)
log(maturity)	0.979*	1.915**	-0.121
	(0.567)	(0.782)	(0.460)
Listing dummy	1.365	1.432	0.864
	(1.013)	(1.544)	(1.462)
10-year swap rate	-0.063***	-0.075***	-0.045***
	(0.009)	(0.013)	(0.010)
Swap rate slope	-0.015**	-0.007	-0.036***
	(0.007)	(0.009)	(0.008)
Rating FE	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes
Format FE	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	4,203	3,092	1,111
R-squared	0.292	0.316	0.208

Appendix

Appendix A. An example of green bond offerings

This appendix shows the excerpts of the data vendor's news related to Apple Inc's $1 billion 10-year green bond announced and priced on June 13, 2017. This bond is an SEC-registered senior unsecured offering via BAML/GS/JPM. The use of proceeds is as follows, "An amount equal to such net proceeds will be allocated to one or more Eligible Projects (as defined below). Eligible Projects may include projects of our subsidiaries that meet the Eligibility Criteria (as defined below) set forth below. We plan to identify Eligible Projects that fall within three environmental priorities where we believe we can make the most environmentally positive impact: 1. Reduce our impact on climate change by using renewable energy sources and driving energy efficiency in our facilities, products and supply chain. 2. Pioneer the use of greener materials in our products and processes. 3. Conserve resources."

4:46 am - The bond offering is announced, with the details about the offering amount, tenor, credit rating, format, callable features, bookrunners, and use of proceeds. The IPT is T+95-100 bps.

7:23 am - The data vendor provides an update on the offering with the following information, "The nearest comparable for the new bonds is an outstanding Apple 3.2% May 2027 that were trading at a G spread of 83bp. Compared to those bonds, the IPT levels imply 12bp-17bp in new issue concessions. These levels are very likely to be tightened during bookbuilding so bankers expect the bonds to end up pricing with little to no new issue concessions, as has become the norm in the hot high-grade primary market."

8:51 am - Guidance is announced, with the price range updated to T+85 area.

9:43 am - Launch is announced, with the offering spread set at T+82 bps.

12:09 pm - The bond is announced to be priced, with the coupon and bond price set that the offering spread is 82 bps over the benchmark Treasuries.

15:52 pm - The data vendor provides another update on the offering with the following information, "Tech giant Apple notched up a US$3.5bn book for its new US$1bn 10-year Green bond on Tuesday which priced with no new issue premium."

Appendix B. Variable definitions

Green bond is a indicator of whether a bond is labeled as a green instrument by Bloomberg.

Offering yield is the yield at issue.

Offering spread is the spread over the government benchmark security at issue.

Oversubscription is the the order book size scaled by the proposed offering amount.

Spread compression is the spread change from the midpoint of the initial spread/yield range to the offering spread/yield.

Initial offering spread is the offering spread subtracts the spread compression.

Initial offering yield is the offering yield subtracts the spread compression.

Offering amount is the USD-equivalent offering amount in millions.

Maturity is the maturity at issue in years.

Listing dummy is an indicator of whether an offering is listed.

10 year swap rate is the 10-year interest rate swap rate of the currency of the bond issued.

Swap rate slope is the difference between the 10- and 1-year interest rate swap rates of the currency of the bond issued.

Rating is the numerical value for letter ratings, where 1 indicates AAA, 2 indicates AA, and so on.

Format includes SEC registered, Reg S only, Rule 144A/Reg S and Rule 144A, and others.

Currency includes USD and EUR.

Relative initial spread is the offering's initial offering yield over the yield of currency- and rating-matched Barclays' index.

Resi demand percentile is the percentile value of the residual oversubscription ratio estimated from regressing the oversubscription ratio on the relative initial yield spread.

Appendix C. Additional tests

Table A1: Robustness: Excluding upsized offerings

This table reports robustness tests of our main results excluding offerings that are upsized. The dependent variables include *oversubscription* in column (1), *initial offering spread* in column (2), *spread compression* in column (3), and *offering spread* in column (4). All variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Over-subscription	Initial offering spread	Spread compression	Offering spread
	(1)	(2)	(3)	(4)
Green bond	0.397***	-2.804	-2.352***	-5.419***
	(0.115)	(2.010)	(0.398)	(1.953)
log(offering amount)	-0.571***	8.088***	-1.477***	6.616***
	(0.099)	(2.000)	(0.366)	(1.923)
log(maturity)	0.229***	22.332***	0.128	22.553***
	(0.054)	(1.966)	(0.254)	(1.989)
Listing dummy	-0.247*	1.785	0.680	2.392
	(0.127)	(3.197)	(0.558)	(3.083)
10-year swap rate	0.002***	0.068***	0.007**	0.073***
	(0.001)	(0.021)	(0.003)	(0.021)
Swap rate slope	0.000	0.061***	-0.006**	0.055***
	(0.001)	(0.015)	(0.003)	(0.015)
Rating FE	Yes	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes	Yes
Format FE	Yes	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3,767	4,672	4,908	4,672
R-squared	0.479	0.847	0.709	0.831

Table A2: Offering yield

This table reports robustness tests of our main results. Columns (1)-(3) are the same as Table 5, columns (1)-(3), except that the left-hand side variable is the offering yield. Columns (4)-(6) are the same as Table 7, columns (2)-(4), except that the left-hand side variable is the offering yield. All variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	All	Corporate	SSA	All	Corporate	SSA
	(1)	(2)	(3)	(4)	(5)	(6)
Green bond	-7.486***	-9.820***	-2.478	-3.714	-4.938	0.268
	(2.429)	(3.079)	(3.154)	(2.883)	(3.658)	(3.455)
Resi demand percentile				-0.309***	-0.303***	-0.390***
				(0.054)	(0.072)	(0.079)
log(offering amount)	10.151***	10.062***	10.277**	8.862***	7.277*	12.046**
	(2.402)	(2.795)	(4.536)	(2.913)	(3.886)	(5.104)
log(maturity)	86.615***	89.039***	83.027***	83.531***	87.032***	77.050***
	(2.547)	(3.235)	(3.959)	(2.983)	(3.430)	(5.592)
Listing dummy	-1.992	-2.361	-10.350	-1.089	1.777	-19.161
	(4.584)	(6.675)	(10.503)	(6.327)	(9.657)	(17.666)
10-year swap rate	1.176***	1.174***	1.148***	1.223***	1.261***	1.114***
	(0.031)	(0.039)	(0.053)	(0.036)	(0.045)	(0.056)
Swap rate slope	-0.376***	-0.310***	-0.497***	-0.385***	-0.357***	-0.437***
	(0.027)	(0.036)	(0.037)	(0.029)	(0.040)	(0.035)
Rating FE	Yes	Yes	Yes	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes	Yes	Yes	Yes
Format FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,245	3,130	1,115	3,127	2,333	794
R-squared	0.916	0.914	0.926	0.917	0.913	0.939

Table A3: Robustness: Comparing to post-green conventional bonds
This table shows the robustness of our results only using the green bonds and the conventional bonds offered on or after the date when the first green bond is offered. The dependent variable is *oversubscription* in columns (1)-(3) and *offering spread* in columns (4)-(6). All variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Oversubscription			Offering spread		
	All	Corporate	SSA	All	Corporate	SSA
	(1)	(2)	(3)	(4)	(5)	(6)
Green bond	0.572***	0.703***	0.193	-5.509***	-6.080**	-3.205
	(0.118)	(0.125)	(0.235)	(2.044)	(2.703)	(2.052)
log(offering amount)	-0.449***	-0.731***	-0.161	3.680*	5.170*	-0.302
	(0.118)	(0.116)	(0.199)	(1.876)	(2.949)	(1.524)
log(maturity)	0.260***	0.269***	0.162	22.056***	30.046***	7.171***
	(0.064)	(0.086)	(0.120)	(2.585)	(2.388)	(2.568)
Listing dummy	-0.212	0.154	0.219	3.374	0.020	0.363
	(0.186)	(0.155)	(0.174)	(4.173)	(5.134)	(3.437)
10-year swap rate	0.002**	0.003*	0.000	0.053**	0.087**	-0.011
	(0.001)	(0.002)	(0.001)	(0.026)	(0.040)	(0.017)
Swap rate slope	-0.001	0.001	-0.004*	0.057***	0.065**	0.067***
	(0.001)	(0.002)	(0.002)	(0.019)	(0.027)	(0.016)
Rating FE	Yes	Yes	Yes	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes	Yes	Yes	Yes
Format FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,093	1,448	645	2,534	1,732	802
R-squared	0.550	0.556	0.607	0.833	0.760	0.894

Table A4: Robustness: Control for underwriter fixed effects
This table reports robustness tests of our main results, controlling for underwriter fixed effects. The dependent variables include *oversubscription* in column (1), *initial offering spread* in column (2), *spread compression* in column (3), and *offering spread* in column (4). All variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Over-subscription (1)	Initial offering spread (2)	Spread compression (3)	Offering spread (4)
Green bond	0.392***	-1.983	-2.374***	-4.487*
	(0.133)	(2.507)	(0.411)	(2.425)
log(offering amount)	-0.572***	6.065***	-1.530***	4.479**
	(0.095)	(2.010)	(0.330)	(1.927)
log(maturity)	0.229***	22.105***	0.216	22.429***
	(0.056)	(2.007)	(0.237)	(2.021)
Listing dummy	-0.257*	1.788	0.659	2.567
	(0.136)	(3.187)	(0.570)	(3.093)
10-year swap rate	0.002***	0.078***	0.004	0.080***
	(0.001)	(0.020)	(0.003)	(0.020)
Swap rate slope	0.001	0.050***	-0.007**	0.045***
	(0.001)	(0.015)	(0.003)	(0.015)
UW FE	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes	Yes
Format FE	Yes	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3,761	4,901	4,901	4,675
R-squared	0.525	0.739	0.741	0.915

Table A5: Robustness: Control for Covenants

This table reports robustness tests of our main results, controlling for the number of covenants. Covenants in this table include negative pledge, M&A restriction, restriction, cross default, change of control, fundamental change, coverage ratio, asset sales, debt limit, and restricted payment. We calculate the number of covenants by counting the number of covenants that take the value of "Y". All other variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	(1) Over-subscription	(2) Initial offering spread	(3) Spread compression	(4) Offering spread
Green bond	0.363**	-2.917	-2.474***	-5.713**
	(0.148)	(2.469)	(0.477)	(2.408)
log(offering amount)	-0.582***	8.810***	-1.448***	7.442***
	(0.110)	(1.671)	(0.395)	(1.654)
log(maturity)	0.227***	24.867***	-0.064	24.917***
	(0.063)	(2.149)	(0.278)	(2.165)
Listing dummy	-0.232	-1.376	1.007	-0.281
	(0.145)	(3.294)	(0.645)	(3.209)
10-year swap rate	0.002*	0.056**	0.007**	0.062**
	(0.001)	(0.024)	(0.004)	(0.024)
Swap rate slope	0.000	0.074***	-0.008**	0.065***
	(0.001)	(0.017)	(0.004)	(0.016)
Number of covenants	0.031	-0.593	0.131	-0.466
	(0.041)	(0.798)	(0.171)	(0.793)
Rating FE	Yes	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes	Yes
Format FE	Yes	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm-year FE	No	No	No	No
Observations	2,776	3,558	3,761	3,558
R-squared	0.505	0.862	0.708	0.848

Table A6: Robustness - subsamples

This table reports robustness tests of our main results using subsamples. Columns (1)-(4) use the subsample that excludes offerings whose order book is a combined book for all bonds by an issuer on an offering day. Columns (5)-(8) use the subsample that excludes offerings whose initial offering pricing includes ambiguous words such as "high", "medium", and "low". Dependent variables are in table header. All variables are defined in Appendix B. Robust standard errors clustered at the issuer level are in parentheses. The sample period is from January 1, 2013 to May 31, 2021. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Drop offerings with combined book				Drop offerings with ambiguous initial spread			
	Over-subscription	Initial offering spread	Spread compression	Offering spread	Over-subscription	Initial offering spread	Spread compression	Offering spread
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Green bond	0.403***	-3.291*	-2.256***	-5.975***	0.387***	-3.748*	-2.310***	-6.351***
	(0.113)	(1.964)	(0.389)	(1.907)	(0.115)	(2.071)	(0.393)	(2.013)
log(offering amount)	-0.584***	7.789***	-1.457***	6.375***	-0.590***	6.912***	-1.094***	5.999***
	(0.095)	(1.796)	(0.354)	(1.716)	(0.104)	(1.979)	(0.323)	(1.934)
log(maturity)	0.215***	21.740***	0.270	22.236***	0.217***	22.362***	0.124	22.585***
	(0.058)	(2.002)	(0.262)	(2.027)	(0.055)	(1.959)	(0.244)	(1.970)
Listing dummy	-0.277**	0.003	0.911*	0.980	-0.267**	1.868	0.363	2.023
	(0.126)	(3.102)	(0.476)	(2.971)	(0.135)	(3.414)	(0.553)	(3.272)
10-year swap rate	0.002***	0.069***	0.008***	0.076***	0.002***	0.090***	0.006*	0.094***
	(0.001)	(0.022)	(0.003)	(0.022)	(0.001)	(0.024)	(0.003)	(0.024)
Swap rate slope	0.000	0.059***	-0.006*	0.055***	0.001	0.065***	-0.010***	0.054***
	(0.001)	(0.016)	(0.003)	(0.016)	(0.001)	(0.016)	(0.003)	(0.016)
Rating FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Seniority FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Format FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,478	4,380	4,612	4,380	3,371	4,171	4,384	4,171
R-squared	0.487	0.846	0.713	0.830	0.487	0.846	0.734	0.829