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Borsa İstanbul Review

Borsa İstanbul Review 22-6 (2022) 1182–1194
http://www.elsevier.com/journals/borsa-istanbul-review/2214-8450

Full Length Article

The grass is greener on the other side: Comparison of green versus brown corporate bonds

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Received 15 March 2022; revised 12 August 2022; accepted 12 August 2022
Available online 23 August 2022

Abstract

This study compares the yield-to-maturities on green versus brown corporate bonds on their issue dates, after controlling for the market, firm, bond, and currency characteristics of the bonds. Our analyses show that if these characteristics are not addressed, it is possible to find support for the existence of a "greenium" at a magnitude of about 25 basis points. However, when all yield factors are included in the models, the results change and indicate that issuers do not necessarily enjoy any cost advantage when they issue green bonds, instead of brown bonds. Failure to consider these interactions might lead to biased findings.

JEL classification: G11; G12; G41

Keywords: Blended-value investing; Green bonds; Greenium; Impact investing

1. Introduction

The global, multi-stakeholder Fourth Sector Mapping Initiative[1] states that social impact investment contracts are designed to pursue a blended-value objective, and nonmonetary (social) returns are thus integrated into investment decisions (Daggers & Nicholls, 2016). Riedl and Smeets (2017) argue that the financial return required from a social impact investment may be lower than that from an investment of similar risk that has no nonfinancial return. A review of the existing literature reveals relatively few academic studies directly compare the returns on for-profit (financial) versus blended-value investment. This study contributes to this strand of literature by comparing the risk and return performance of brown (for-profit) versus green (blended-value) bonds. Green bonds, first issued in 2007 by the European Investment Bank (Rosembuj & Bottio, 2016), are debt securities issued by corporations, governments, and supranational institutions and their proceeds are earmarked for supporting sustainable investments. Green bonds are viewed as a bottom-up initiative by private investors and a financial innovation for funding current environmental mitigation policies for which the financing cost will be repaid by the next generation, which is also going to reap the benefits of such policies (Flaherty et al., 2017; Glomsrød & Wei, 2018; Monk & Perkins, 2020). As such, green bonds allow investors to incorporate an ethical criterion into their investment choices and create sustainable, as well as financial, value as a result (Paranque & Revelli, 2019). The market for green bonds expanded rapidly with the cumulative issuance volume reaching $1 trillion in 2020 compared with a volume of merely $500 million in 2012.[2] Whereas the early market was

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Peer review under responsibility of Borsa İstanbul Anonim Şirketi.

[1] https://www.mapping.fourthsector.org/about-fsmi/.

[2] Climate Bonds Initiative, Green Bond Market Summary Q3 2020 (https://www.climatebonds.net/resources/reports/green-bonds-market-summary-q3-2020/).

https://doi.org/10.1016/j.bir.2022.08.006

dominated by supranational institutions, at present financial and nonfinancial corporations are the major issuers (Kapraun et al., 2021). One of the main factors that helped the development of the green bond market is increased certification of these bonds by third parties, providing assurance that the bond proceeds will be used in line with the goals in the Paris Agreement (Beschloss & Mashayekhi, 2019; Ehlers & Packer, 2017). According to the Climate Bonds Initiative, the leading certification institution in the market, certified green bonds comprise about 10 percent of the cumulative bond volume of $1 trillion at the end of 2020.[2]

Because of the increased popularity of green bonds in financial markets, literature on this new debt instrument also developed. Many studies compare the yields on green bonds with those on conventional (brown) bonds and find that green bonds sell at a premium from the issuer's point of view (offer a greenium) at the time of their issuance (Baker et al., 2018; Fatica et al., 2021; Gianfrate & Peri, 2019; Kapraun et al., 2021; MacAskill et al., 2021) or when traded on the secondary market (Gianfrate & Peri, 2019; Kapraun et al., 2021; Karpf & Mandel, 2018; MacAskill et al., 2021; Partridge & Medda, 2020; Zerbib, 2019). Interestingly, no consensus has been reached on the size of the greenium, with the results ranging widely, between 2 basis points (bps) (Zerbib, 2019) and 100 bps (Fatica et al., 2021). In addition, the size of the greenium increases when the green bond is certified by a third party, such as the Climate Bonds Initiative (Bachelet et al., 2019; Fatica et al., 2021; Hyun et al., 2020; Kapraun et al., 2021). A smaller number of studies find that the yields on green bonds do not differ from those on brown bonds (Hachenberg & Schiereck, 2018; Kanamura, 2020; Partridge & Medda, 2020). Finally, although green bonds seem to offer a cost of borrowing advantage, they are highly correlated with the corporate and Treasury bond markets as well as the movements in clean energy markets and, therefore, do not offer any special diversification benefits for bond portfolios (Liu et al., 2021; Reboredo, 2018; Reboredo & Ugolini, 2020).

This study compares green versus brown corporate bond yields at the time of their issuance. As shown in Table 1,[3] previous studies that focus on the primary market yields of corporate green bonds find that the greenium is either positive (Ehlers & Packer, 2017; Hyun et al., 2020) or zero (Flammer, 2021). All three studies and many others that analyze the greenium for mixed issuers as well as in secondary markets use a matching methodology in order to provide a direct yield comparison between green and brown bonds. One of the potential problems with matching green and brown bonds is the difficulty in finding bonds that are issued under the same macroeconomics conditions, with the same bond features, such as size, maturity, coupon type, and rating, and with the same issuer characteristics. For example, Zerbib (2019) claims it is possible to match a green bond with a brown counterpart that may have been issued six years earlier or later, with an issue size up to four times larger, or as small as one-fourth that of the green bond and with a maturity that is two years longer or shorter. In fact, even if the quantitative characteristics are similar, two bonds from the same issuer still may not be perfect matches for each other as their bond indentures might have different clauses (Karpf & Mandel, 2018). Instead of using an imperfectly matched sample of green and brown bonds, this study compares the primary market yields on these two types of bonds within a cross-sectional regression framework, taking into account the market, firm, bond, and currency characteristics as well as the green status of the bond. The empirical findings suggest that if these characteristics are not taken into consideration, it is possible to find support for the existence of a greenium at a magnitude of about 25 bps. However, when the models account for all factors that affect bond yields, the results completely change and indicate that green bond issuers do not necessarily enjoy a cost advantage when they issue green instead of brown bonds. Bond yields are determined by a complex set of interactions among the market, firm, bond, and currency factors. Failure to consider these interactions might lead to biased findings regarding the existence of a greenium.

The rest of the study is organized as follows. Section 2 describes the data sources and the construction of the matched sample for building efficient frontiers based on secondary market returns. Section 3 presents the methodology and estimation results for the efficient frontiers, yield curves, and the univariate as well as multivariate return analyses. Section 4 concludes the study.

2. Data

2.1. Data sources and sample description

We collect information on all corporate bonds that are flagged as “green” in the Thomson Reuters database between 2013 and August 2019.[4] This initial sample includes 1038 bonds issued by 480 different companies.[5] Among the 1038 bonds, 93.3 percent consist of those that are denominated in the US dollar, euro, Swedish krona, Chinese renminbi (RMB), and Japanese yen whereas those denominated in other currencies make up a negligible proportion. The currency filter decreases the sample size to 878 green bonds. The remaining bonds in the sample have different coupon structures. In order to calculate comparable yields, only plain vanilla fixed-coupon bonds are retained. Furthermore, dual-currency bonds and bonds whose issue-date information has apparent input errors are eliminated. The resulting sample includes 643 green bonds issued by 325 different companies and are denominated in these five currencies.

Because the main objective of the study is to perform different comparisons between green and brown bonds, the next step in data collection is to obtain information on the brown bonds issued by the same companies that issued the

[3] This table is similar in format to Table 1 in Agliardi and Agliardi (2021).

[4] The number of green bonds in the database is negligible before 2013, with an average of 0.9 bonds per year between 1982 and 2012.

[5] The database has 36 green-flagged bills with maturities shorter than one year. These bills are excluded from the sample because the effect of time to maturity may be very different for bills versus bonds.

Table 1
Literature review.

Study	Dataset	Market	Sample size	Sample period	Method	Issuer/currency control	Greenium ($yield_G - yield_B$)
Ehlers and Packer (2017)	Corporate	Primary	21 green and conventional bonds of the same issuer	2014–2017	Nearest neighbor	Yes/yes	Negative
Baker et al. (2018)	US munis	Primary	2083 green and 643,229 conventional bonds of the same issuers	2010–2016	Ordinary least squares (OLS) with fixed effects and controls	Yes/no	Negative
Hachenberg and Schiereck (2018)	Mixed issuers	Secondary	63 green and 126 conventional bonds of the same issuers	Oct. 2015–March 2016	Nearest neighbor/panel with controls	Yes/yes	0
Karpf and Mandel (2018)	US munis	Secondary	1880 green and 36,000 conventional bonds of the same issuers	2010–2016	Yield curve/regressions with Oaxaca–Blinder twofold decomposition	Yes/yes	Positive overall but negative in recent years
Bachelet et al. (2019)	Mixed issuers	Secondary	89 green and conventional bonds of the same issuers	2013–2017	Nearest neighbor/OLS and panel with controls	Yes/no	Negative for institutional
Gianfrate and Peri (2019)	Mixed issuers	Primary/secondary	121 green and 2934 conventional euro bonds of the same issuers	2007–2017	Matching (propensity score)/ OLS with primary market data	Yes/yes	Negative
Zerbib (2019)	Mixed issuers	Secondary	110 green and matching synthetic conventional bonds	July 2013–December 2017	Nearest neighbor/regressions with controls	Yes/yes	Negative
Hyun et al. (2020)	Corporate	Primary	60 green and matching synthetic conventional bonds of the same issuers	2010–2017	Nearest neighbor/OLS with fixed effects and controls	Yes/yes	Negative for certified
Larcker and Watts (2020)	Munis	Primary	640 green and conventional bonds of the same issuers	June 2013–July 2018	Nearest neighbor/OLS with fixed effects	yes/yes	0
Fatica et al. (2021)	Mixed issuers	Primary	1397 green and 269,915 conventional bonds of the same issuers	2007–2018	OLS with controls	Yes/yes	Negative for supranational, certified, and nonfinancial
Flammer (2021)	Corporate	Primary	152 green and conventional bonds of the same issuer	2013–2018	Nearest neighbor/univariate comparison	Yes/not known	0
Kapraun et al. (2021)	Mixed issuers	Primary/secondary	2099 green and 202,394 conventional bonds of the same issuer	2009–Feb. 2021	Regressions with controls	Yes/yes	Negative for government, supranational, and large issue size and certified corporate (primary only)

Note: This table presents the sample, methodology, and main findings of the studies that compare green versus brown bond yields.

green bonds in the sample. The reason for selecting green and brown bonds issued by the same companies is to control for company-specific factors that might affect bond yields. If an issuer does not have any brown bonds and issues only green bonds, then it is excluded from the sample because a comparison of the two bond classes is not possible. The final sample includes 563 green bonds and 12,197 brown bonds issued by 265 companies between 2013 and August 2019. Table 2 provides information on some of the characteristics of the final sample.

2.2. Matched samples

In order to draw pseudo efficient frontiers, green and brown bonds need to be matched with each other based on several criteria. The procedure employed for this purpose generates pairs of green and brown bonds issued by the same company, in which the match is performed in the following order of priority:

$$\text{Absolute match}\begin{cases}\text{Coupon type}\\ \text{Principal currency}\\ \text{Country (Market) of issue}\end{cases}$$

$$\text{Nearest match}\begin{cases}\text{Absolute difference in issue dates}\\ \text{or}\\ \text{Absolute difference in original maturities}\end{cases}$$

Table 2
Sample description.

	Green		Brown	
	Frequency	Percent	Frequency	Percent
Panel A: currency of denomination				
US dollar	223	39.61	3581	29.85
Euro	146	25.93	5447	45.40
Chinese RMB	116	20.60	660	5.50
Japanese yen	51	9.06	1986	16.55
Swedish krona	27	4.80	324	2.70
Panel B: Issuer's industry				
Financial	302	53.64	11,288	94.08
Utility	170	30.20	160	1.33
Others	91	16.16	550	4.59
Panel C: issue year				
2013	6	1.07	1327	11.06
2014	18	3.20	1330	11.09
2015	140	24.87	1802	15.02
2016	58	10.30	1861	15.51
2017	98	17.41	1893	15.78
2018	132	23.45	2263	18.86
January–August 2019	111	19.72	1522	12.69
Panel D: issue characteristics				
Investment grade	220	39.08	3287	27.40
Secured	43	7.64	801	6.68
Public	407	72.29	6638	55.33
Underwritten	366	65.01	9080	75.68
Callable	98	17.41	1307	10.89

Notes: This table presents information on the characteristics of the green and brown corporate bonds in the final sample. The sample includes all green and brown bonds issued by a given corporation between 2013 and August 2019. The final sample consists of 563 green bonds and 12,197 brown bonds issued by 265 corporations between 2013 and August 2019.

Using this algorithm, each green bond is matched with its best brown counterpart. The matched sample has 538 pairs of bonds (a total of 1076 green and brown bonds).[6] Of the 538 pairs, 136 are denominated in euros, 101 in US dollars, 99 in Chinese RMB, 60 in Swedish krona, and 45 in Japanese yen.

3. Analyses and results

3.1. Efficient frontiers

As preliminary evidence, our first research interest is to compare green and brown bonds based on their risk/return tradeoff in the secondary market. Flammer (2021) shows that proceeds from green bond issuance are used for projects that improve the issuer's environmental footprint and help attract investors with environmental sensitivities. Furthermore, Agliardi and Agliardi (2019) show that an improvement in the issuer's credit quality induced by the green label of the project leads to a lower cost of capital for green bond issuers. If investors, indeed, take into account the social impact of their investment decisions then it is plausible to expect that, for the same risk, an investor with a sensitivity to environmental issues might be willing to accept a lower rate of return from a green bond compared to a brown bond.[7] One way to determine whether such a difference in returns exists is to compare the green and brown bond yields in a Markowitz mean-variance framework by constructing efficient frontiers for the two bond classes.

For the matched sample, daily total bond returns are collected from the Thomson Reuters database for the period January 1, 2013, to October 30, 2020.[8] If either of the bonds in the matched pairs lacks the return data, then both bonds in that pair are excluded from the sample. The final sample used for constructing the efficient frontiers has 381 pairs of green and brown bonds. Fig. 1 displays the number of bond pairs available for efficient frontier construction in each year.

In Fig. 1, the sample is divided into two subperiods: 2013–2016 and 2017–2020. Efficient frontiers are constructed separately for each subperiod and each currency.[9]

Fig. 2 presents the efficient frontiers for the two subperiods. A greenium is clearly observed in the 2013–2016 period, because at each risk level, green yields are lower than brown yields. The greenium detected in earlier years is in contrast to

[6] When the original maturity is required to have the nearest match, the issue dates for the resulting pairs differ by between 0 and 6.52 years whereas the original maturities differ by between 0 and 21.02 years. If the issue date is required to have the nearest match, the issue dates for the resulting pairs differ by between 0 and 6.03 years whereas the original maturities differ by between 0 and 25.36 years. Efficient frontiers based on original maturity matches are used in this study.

[7] In the case of green bonds, the "social impact" is manifested as the impact of the bond investment on the environment.

[8] Daily total returns are winsorized at 1% and 99%.

[9] The number of remaining matched bond pairs that are denominated in Japanese yen is not sufficient to construct an efficient frontier. Therefore, Japanese yen bonds are excluded from this step of the analyses. The Stata command efrontier is used for constructing the efficient frontiers.

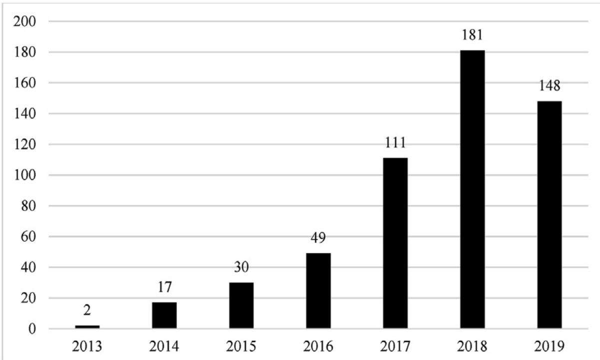

Fig. 1. Number of matched bond pairs. Note: this figure shows the number of matched pairs of green and brown bonds for each year in the sample period.

the findings by Karpf and Mandel (2018) for municipal bonds. However, in the 2017–2020 period the picture changes: although green yields are lower in the low-risk categories, investors seem to ask for higher yields from green bonds than brown bonds as the risk of the bond portfolio increases. The number of green bonds issued is considerably higher in the second period than in the first period.

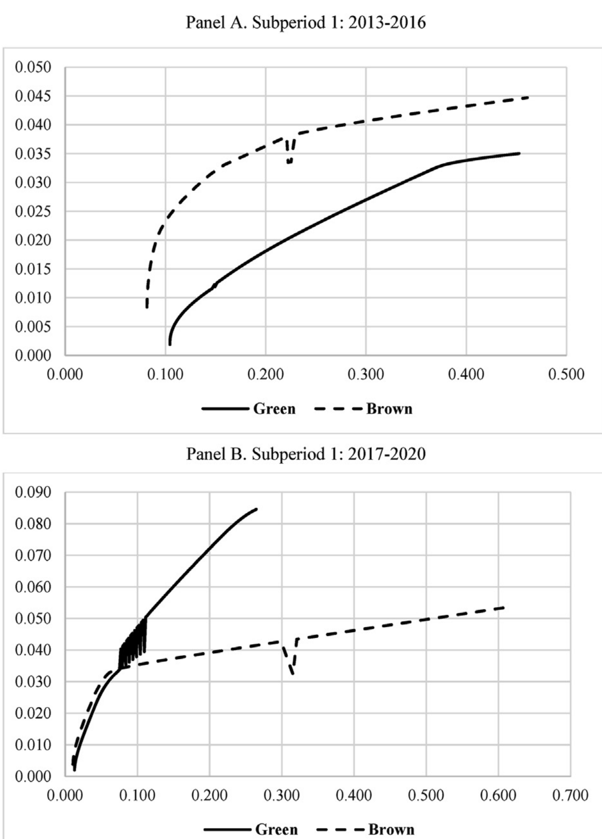

Fig. 2. Efficient frontiers by subperiod. Notes: this figure shows the efficient frontiers constructed for different subperiods in the sample. Panel A plots the efficient frontier for all matched green and brown bond pairs traded between 2013 and 2016. Panel B plots the efficient frontier for all matched green and brown bond pairs traded between 2017 and 2020. The x-axis shows the standard deviation of returns, and the y-axis shows the daily total returns. Daily total return is the secondary market return based on accrued interest and capital gains. The standard deviation of returns is the standard deviation based on the relevant subperiod.

Fig. 3 shows the efficient frontiers that are constructed for the different currencies over the full sample period. When currency denominations are taken into consideration, a greenium is not necessarily available to all green bond issuers, especially if the bond is denominated in euros or the Swedish krona. In all currencies, as expected, the difference between green and brown yields is wider as the bond risk increases. Previous studies that do not distinguish the currency denominations of bonds might have somewhat biased results because the efficient frontiers in Figs. 2 and 3 clearly show that, for corporate green bonds, a greenium might not exist in more recent years and for bonds denominated in euros and the Swedish krona. Table 3 also supports the need to account for currency denomination. Although US dollar–denominated green bonds with an apparent greenium dominate the sample in the first subperiod, euro-denominated green bonds with no observed greenium are the most frequent type issued during the second subperiod.

3.2. Univariate yield analysis

The next step is to compare the green and brown bonds in terms of their yield to maturity (*YTM*) levels at the time of their issuance. The efficient frontiers presented in Figs. 2 and 3 are constructed based on the secondary market yields of the bonds. As summarized above, several studies also argue that green bonds might prove to be an attractive borrowing vehicle for companies because these bonds are issued at a premium compared to their brown counterparts. For this step of the analysis, issue-date YTMs are calculated for the green and brown bonds in the sample. Table 4 presents the results of a univariate comparison.

The average issue-date YTM on the green and brown corporate bonds in the sample is 2.93 percent and 2.75 percent, respectively. The *t*-test shows that these average yields are not equal and indicates a higher yield on green bonds. Our results showing higher issue-date YTM on corporate green bonds compared to their brown counterparts are not consistent with the results in the existing literature. As mentioned earlier, the comparisons in Table 4 do not take into account other bond characteristics, such as seniority, collateralization, call features, and bond rating, which are all likely to affect the issue-date yield on bonds. Although the two bond types have a similar time to maturity, green bonds, in both measurement terms, have a larger average issue size than brown bonds. A larger issue size might indicate higher risk and, therefore, could be one of the reasons for the higher average YTM for green bonds.

3.3. Pseudo yield curve analysis

Another way to compare issue-date YTMs is to plot yield curves, thereby controlling for the maturity effect. Fig. 4 presents the pseudo yield curves constructed by fitting logarithmic trend lines to the distribution of yields on investment-grade green and brown corporate bonds. These curves compare the

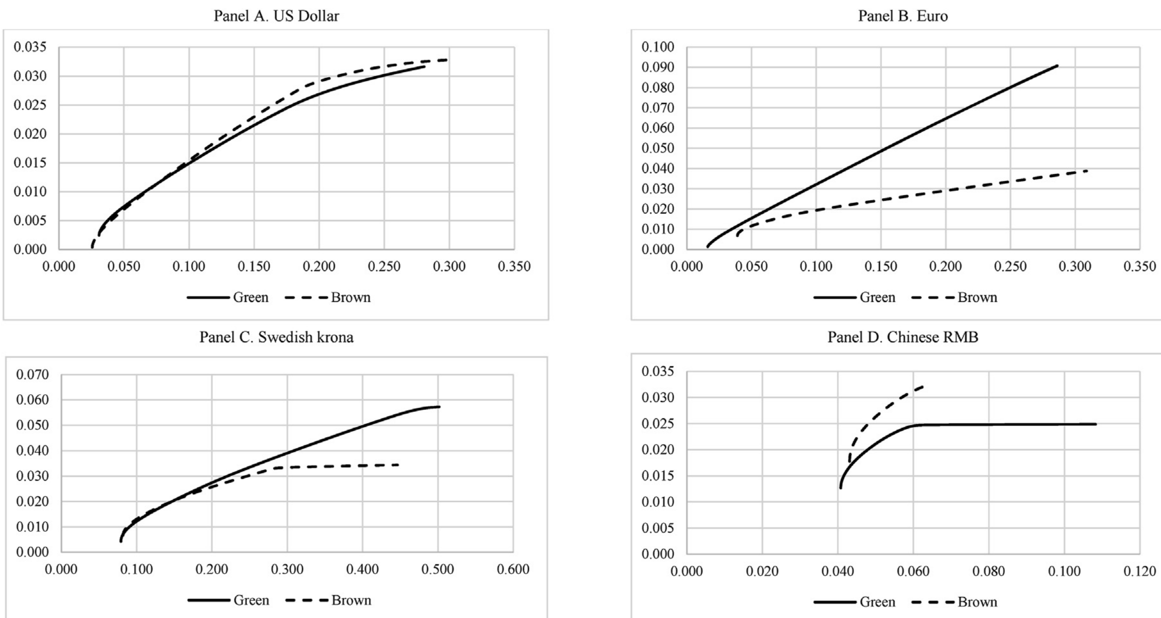

Fig. 3. Efficient frontiers by currency. Notes: this figure shows the efficient frontiers constructed for different currencies. Panel A plots the efficient frontier for all matched green and brown bond pairs that are denominated in US dollars. Panel B plots the efficient frontier for all matched green and brown bond pairs that are denominated in euros. Panel C plots the efficient frontier for all matched green and brown bond pairs that are denominated in the Swedish krona. Panel D plots the efficient frontier for all matched green and brown bond pairs that are denominated in Chinese RMB. The x-axis shows the standard deviation of returns, and the y-axis shows the daily total returns. Daily total return is the bond's secondary market return based on accrued interest and capital gains. Standard deviation of returns is the standard deviation based on the full sample period.

green and brown primary market YTMs for different maturity classes.[10]

The curve in Panel A is plotted using the YTMs calculated for all investment-grade green and brown bonds in the sample. This figure shows that green bonds have higher yields than brown bonds at maturities up to five years, but the relationship is reversed for maturities longer than five years. This is the first evidence that partially supports the main premise of this study, which states that investors of green bonds might be willing to sacrifice some financial return in order to create social value. As in Karpf and Mandel (2018), we also find that, for longer maturities, a green bond might provide a cost of debt advantage, a greenium, for the issuer although this advantage disappears at shorter maturities.

As in the results for efficient frontiers, the relationship between green and brown yield curves might change when the currency denomination of the bonds is taken into account. Panels B–E show the pseudo yield curves for bonds denominated in different currencies. For all currencies but the Japanese yen, green yields are higher for shorter maturities and lower for longer maturities. These observations imply that companies need to issue longer-maturity green bonds in order to take advantage of a lower cost of borrowing.

[10] Once again, because bond characteristics other than maturity are not taken into consideration, these curves do not represent, by any means, a statistical test of the relationship between time to maturity and YTM on green versus brown bonds.

3.4. Multivariate analysis

Efficient frontier and yield curve results clearly show the importance of accounting for differences in bond characteristics when comparing green and brown yields. Performing this comprehensive comparison is quite difficult when green and brown bonds are matched with each other because it is likely to find zero matched pairs if the many bond characteristics are inserted into the matching algorithm. That is why a multiple

Table 3
Currency denomination of bonds in the subperiods.

	Green		Brown	
	Frequency	Percent	Frequency	Percent
Panel A: 2013–2016				
US dollar	151	68.02	1896	30.00
Euro	41	18.47	2907	46.00
Chinese RMB	19	8.56	293	4.64
Japanese yen	6	2.70	1030	16.30
Swedish krona	5	2.25	194	3.07
Panel B: 2017–2019				
US dollar	72	21.11	1685	29.68
Euro	105	30.79	2540	44.73
Chinese RMB	97	28.45	367	6.46
Japanese yen	45	13.20	956	16.84
Swedish krona	22	6.45	130	2.29

Notes: This table presents information on the currency denomination of bonds that are issued during the subperiods. The sample includes all green and brown bonds that are issued by a given corporation between 2013 and August 2019. The final sample has 563 green bonds and 12,197 brown bonds that are issued by 265 corporations between 2013 and August 2019.

Table 4
Univariate yield to maturity comparisons.

	All bonds		Green		Brown		p-value
	Mean	Std dev	Mean	Std dev	Mean	Std dev	Test of $\mu_G = \mu_B$
Yield to maturity	2.756	2.665	2.925	1.859	2.748	2.697	0.0318
Time to maturity	7.333	5.165	7.250	4.982	7.337	5.174	0.6940
Log issue size	17.075	2.348	18.639	2.202	17.001	2.329	<0.0001
Issue size (in billions of USD)	0.233	0.544	0.429	0.560	0.224	0.541	<0.0001
N	12,561		563		11,998		

Notes: This table presents the univariate mean test results. Yield to maturity is calculated on the issue date of the bonds and is presented in percentage. Time to maturity is the original maturity in years. Issue size is presented in both natural log and billions of USD. *N* is the number of bonds used to calculate the mean and standard deviation. Mean and standard deviation are calculated for the stated bond sample over the full sample period.

regression framework is more appropriate for accounting for the differences in market, firm, and other bond characteristics when green and brown yields are compared.

Two separate regression equations are estimated. The first model, given in Equation (1), controls for only market, firm, and bond characteristics, along with the green status of the bond:

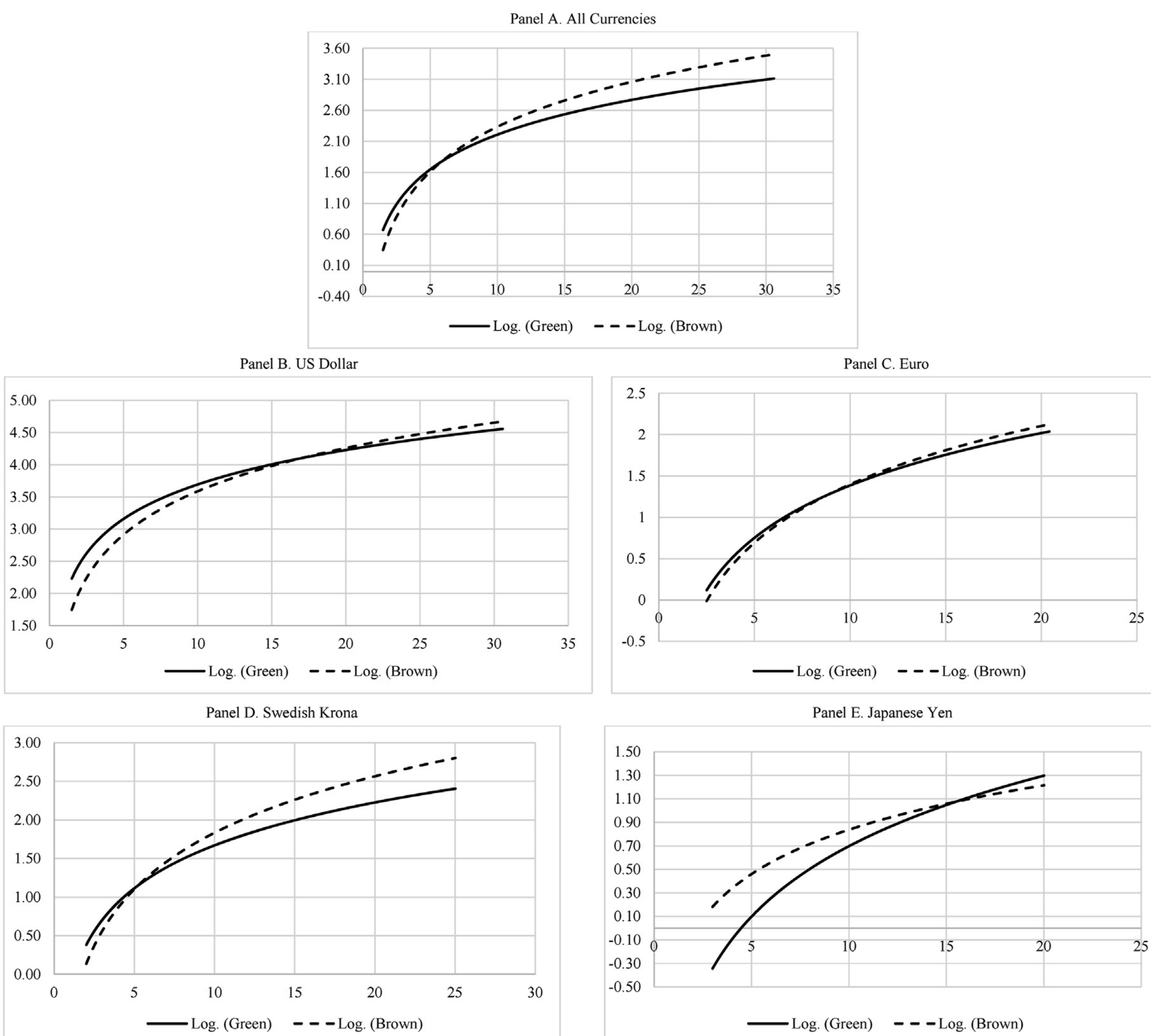

Fig. 4. Pseudo Yield Curves. Notes: This figure presents the pseudo yield curves constructed by fitting logarithmic trend lines to the distribution of yields on investment-grade green and brown corporate bonds. Panel A plots the yield curves for all matched green and brown bond pairs in the sample. Panel B plots the yield curves for all matched green and brown bond pairs that are denominated in US dollars. Panel C plots the efficient frontier for all matched green and brown bond pairs that are denominated in euros. Panel C plots the efficient frontier for all matched green and brown bond pairs that are denominated in the Swedish krona. Panel E plots the efficient frontier for all matched green and brown bond pairs that are denominated in Japanese yen. The *x*-axis shows the original time to maturity in years, and the *y*-axis shows the log yield to maturity on the issue date.

Table 5
Variable definitions.

Variable	Definition
Panel A. Dependent variable	
YTM	Yield to maturity in percentages at the time of issue
Panel B. Explanatory variables	
Green	Dummy variable that equals 1 for bonds with a "Thomson Reuters Green Flag"; 0 otherwise
Panel C. Control variables	
Market variables	
RF (risk-free rate)	2-year yield on government securities denominated in the same currency as the bond whose yield is on the left-hand-side of the regression equation
Issue year	Last two digits of the calendar year in which the bond is issued
Bond Characteristics	
Time to maturity in years	Time to maturity of a bond at the time of issue in years
Log time to maturity in days	Natural logarithm of the time to maturity in days at the time of issue
Short term	Dummy variable that equals 1 if the bond's original time to maturity is less than 5 years; 0 otherwise
Medium term	Dummy variable that equals 1 if the bond's original time to maturity is 5–10 years; 0 otherwise
long term	Dummy variable that equals 1 if the bond's original time to maturity is more than 10 years; 0 otherwise
Issue size	Amount issued in billions of US dollars
Investment grade	Dummy variable that equals 1 if the bond's rating is "Investment Grade", 0 otherwise
Secured	Dummy variable that equals 1 if the bond is "Secured, Senior Secured, Senior Secured—First Mortgage, Senior Secured—First Lien, Senior Secured—First and Refunding Mortgage, Senior Secured—General and Refunding or Senior Secured—Mortgage"; 0 otherwise
Underwritten	Dummy variable that equals 1 if the issue is underwritten; 0 otherwise
Public	Dummy variable that equals 1 if the issued bond is traded on an exchange; 0 otherwise
Callable	Dummy variable that equals 1 if the bond is callable; 0 otherwise
Currency of denomination	
Euro—base currency	Dummy variable that equals 1 if the bond's cash flows are denominated in euros; 0 otherwise
USD	Dummy variable that equals 1 if the bond's cash flows are denominated in US dollars; 0 otherwise
RMB	Dummy variable that equals 1 if the bond's cash flows are denominated in Chinese RMB; 0 otherwise
Yen	Dummy variable that equals 1 if the bond's cash flows are denominated in Japanese yen; 0 otherwise
Krona	Dummy variable that equals 1 if the bond's cash flows are denominated in Swedish kronas; 0 otherwise
Firm control variables	
Financial	Dummy variable that equals 1 if the issuer is operating in "Banking, Financial—Other, Mortgage Banking, Real Estate Investment Trust or Property and Casualty Insurance"; 0 otherwise
Utility	Dummy variable that equals 1 if the issuer is operating in "Utility—Other, Railroads, or Gas Utility—Local Distribution"; 0 otherwise
Others	Dummy variable that equals 1 if the issuer is operating in a sector that is not identified as financial or utility above; 0 otherwise
Additional control variables	
Green interaction terms	Interaction of all the explanatory variables listed above with the *Green* indicator variable

$$\begin{aligned} YTM_i = {} & \alpha_0 + \beta_0 \mathrm{Green}_i + \alpha_1 \mathrm{RF}_i + \alpha_2 \mathrm{Issueyear}_i + \alpha_3 \mathrm{TTM}_i \\ & + \alpha_4 \mathrm{Issuesize}_i + \alpha_5 \mathrm{Investmentgrade}_i + \alpha_6 \mathrm{Secured}_i \\ & + \alpha_7 \mathrm{Underwritten} + \alpha_8 \mathrm{Public} + \alpha_9 \mathrm{Callable} + \alpha_{10} \mathrm{USD}_i \\ & + \alpha_{11} \mathrm{RMB}_i + \alpha_{12} \mathrm{Yen}_i + \alpha_{13} \mathrm{Krona}_i + \alpha_{14} \mathrm{Financial}_i \\ & + \alpha_{15} \mathrm{Utility}_i + u_i \end{aligned} \tag{1}$$

This model allows for a different intercept for green and brown bonds but forces the independent variables to have the same slope coefficients. This is a more restrictive model. The second model, in Equation (2), allows for not only a separate intercept for green and brown bonds but also separate slope coefficients for the explanatory variables:

$$\begin{aligned} YTM_i = {} & \alpha_0 + + \beta_0 \mathrm{Green}_i + \alpha_1 \mathrm{RF}_i + \alpha_2 \mathrm{Issueyear}_i + \alpha_3 \mathrm{TTM}_i \\ & + \alpha_4 \mathrm{Issuesize}_i + \alpha_5 \mathrm{Investmentgrade}_i + \alpha_6 \mathrm{Secured}_i \\ & + \alpha_7 \mathrm{Underwritten} + \alpha_8 \mathrm{Public} + \alpha_9 \mathrm{Callable} + \alpha_{10} \mathrm{USD}_i \\ & + \alpha_{11} \mathrm{RMB}_i + \alpha_{12} \mathrm{Yen}_i + \alpha_{13} \mathrm{Krona}_i + \alpha_{14} \mathrm{Financial}_i \\ & + \alpha_{15} \mathrm{Utility}_i + \beta_1 \mathrm{Green}_i \times \mathrm{RF}_i + \beta_2 \mathrm{Green}_i \times \mathrm{Issueyear}_i \\ & + \beta_3 \mathrm{Green}_i \times \mathrm{TTM}_i + \beta_4 \mathrm{Green}_i \times \mathrm{Issuesize}_i + \beta_5 \mathrm{Green}_i \\ & \times \mathrm{Investmentgrade}_i + \beta_6 \mathrm{Green}_i \times \mathrm{Secured}_i + \beta_7 \mathrm{Green}_i \\ & \times \mathrm{Underwritten}_i + \beta_8 \mathrm{Green}_i \times \mathrm{Public}_i + \beta_9 \mathrm{Green}_i \times \mathrm{Callable}_i \\ & + \beta_{10} \mathrm{Green}_i \times \mathrm{USD}_i + \beta_{11} \mathrm{Green}_i \times \mathrm{RMB}_\mathrm{i} + \beta_{12} \mathrm{Green}_i \\ & \times \mathrm{Yen}_i + \beta_{13} \mathrm{Green}_i \times \mathrm{Krona}_i + \beta_{14} \mathrm{Green}_i \times \mathrm{Financial}_i \\ & + \beta_{15} \mathrm{Green}_i \times \mathrm{Utility}_i + u_i \end{aligned} \tag{2}$$

These two models are estimated by ordinary least squares (OLS) with heteroskedasticity-consistent standard errors.[11] Variable definitions are presented in Table 5.

[11] As a robustness check, the models are also estimated using Generalized Method of Moments (GMM). The results are qualitatively the same. In the interest of saving space, GMM results are not reported, but they are available from the authors upon request.

Table 6 presents the estimation results for Model 1. When only the market, firm, bond, and currency characteristics as well as the green versus brown status are included, the model explains around 35 percent of the variation in bond yields, regardless of how the time to maturity of a bond is measured. The coefficient of the main variable of interest, the green bond indicator, is negative and statistically significant in all panels, implying that green bonds are issued at yields that are 23–26 bps lower than those of comparable brown bonds. Almost all the market, firm, and bond control variables have coefficients that are statistically significant at the 5 percent level. The exceptions are the log maturity in Panel B and Medium-Term indicator variable in Panel C. The insignificant coefficient of the Medium-Term indicator variable is consistent with a relatively flat yield curve at the shorter end of the term structure.

As the market interest rate (*RF*) increases, as expected, the *YTM* on all bonds increases in tandem. The coefficient on this variable is approximately 1 (0.994, 0.982, and 0.989 in Panels A, B, and C, respectively), indicating almost a one-to-one relationship between the market interest rate and the *YTM* on bonds. This result is consistent with a priori expectations and the term structure of interest rate theories. Also, bonds issued during the later years in the sample have yields about 3 bps higher than those issued at the beginning of the sample in Panel A. This is an indication of a general increase in market interest rates during the sample period.

One of the main determinants of the *YTM* at the time of issuance is a bond's original maturity. The results in Table 6 show that, as the time to maturity (*TTM*) of a bond increases, its *YTM* increases as well. For a one-year increase in the time to maturity of a bond, its yield increases by merely 1.3 bps in Panel A. This finding is consistent with a priori expectations and shows a positive albeit small maturity premium. This positive maturity premium supports the liquidity preference theory. However, the relationship between log maturity in days and *YTM* is not significant in Panel B. Similarly, in Panel C, the coefficient of Medium Term is not statistically significant, but the coefficient of Long Term is positive and significant. The *YTM* is 13 bps higher on a bond with more than 10 years to maturity than on a bond with a maturity of less than five years. These findings are all consistent with a relatively flat term structure of interest rates.

In the univariate analysis in Table 4, one other difference between green and brown bonds is the issue size. The estimation results in Table 6 show that, as the issue size increases, the *YTM* on all bonds decreases significantly. This finding can be explained by the increased liquidity of the bond. Because

Table 6
OLS results: model 1.

	Panel A		Panel B		Panel C	
	Coefficient estimate	p-value	Coefficient estimate	p-value	Coefficient estimate	p-value
Variable of interest						
Green status	**−0.231**	<0.0001	**−0.261**	<0.0001	**−0.242**	<0.0001
Market conditions						
Risk-free rate	**0.994**	<0.0001	**0.982**	<0.0001	**0.989**	<0.0001
Year of issue	**0.030**	0.0016	**0.031**	0.0016	**0.031**	0.0015
Bond characteristics						
Time to maturity in years	**0.013**	0.0002				
Log time to maturity in days			−0.040	0.3166		
Medium term					−0.051	0.3576
Long term					**0.130**	0.0225
Issue size	**−0.092**	0.0222	**−0.104**	0.0135	**−0.098**	0.0163
Investment grade	**−0.812**	<0.0001	**−0.754**	<0.0001	**−0.805**	<0.0001
Secured	**−0.448**	<0.0001	**−0.432**	<0.0001	**−0.440**	<0.0001
Underwritten	**−0.132**	0.0043	**−0.127**	0.0064	**−0.124**	0.0073
Publicly traded	**−0.620**	<0.0001	**−0.595**	<0.0001	**−0.602**	<0.0001
Callable	**0.524**	<0.0001	**0.577**	<0.0001	**0.524**	<0.0001
Currency of denomination						
USD	**0.857**	<0.0001	**0.862**	<0.0001	**0.845**	<0.0001
RMB	**−0.640**	<0.0001	**−0.639**	<0.0001	**−0.660**	<0.0001
Yen	**−1.184**	<0.0001	**−1.117**	<0.0001	**−1.181**	<0.0001
Krona	**1.162**	<0.0001	**1.121**	<0.0001	**1.141**	<0.0001
Issuer characteristics						
Financial firm	**0.579**	<0.0001	**0.524**	<0.0001	**0.547**	<0.0001
Utility firm	**0.552**	<0.0001	**0.579**	<0.0001	**0.546**	<0.0001
Intercept	**1.873**	<0.0001	**2.285**	<0.0001	**1.976**	<0.0001
Adj. R-square	0.352		0.351		0.352	
F stat.	426.73	<0.0001	425.88	<0.0001	401.84	<0.0001
Number of observations	12,561		12,561		12,561	

Notes: This table presents the estimation results for Model 1. Variable definitions are in Table 4. In Panel A, time to maturity is measured in years. In Panel B, time to maturity is measured as log maturity in days. In Panel C, time to maturity is measured with dummy variables representing maturities between 5 and 10 years (Medium) and more than 10 years (Long). p-values for the coefficient estimates are shown next to the estimates and estimates in boldface indicate significance at an alpha level of 0.05 or smaller. The model is estimated with heteroskedasticity-consistent errors.

investors have a smaller liquidity risk, they require a smaller risk premium for bearing that risk. An increase in the issue size of a bond of $1 billion results in a decrease in its yield of 9.2 (9.8) bps, holding everything else constant in Panel A (Panel C). All the other control variables in the model have coefficients that are in line with a priori expectations.

The base currency for the estimation results presented in Table 6 is the euro. The currency of denomination indicator variables all have statistically significant coefficients, indicating that bonds denominated in the US dollar, Swedish krona, Chinese RMB, and Japanese yen have yields that are significantly different from those denominated in euros. Bonds denominated in the krona (1.162%) and US dollar (0.857%) have higher yields and bonds denominated in Chinese RMB (0.64%) and Japanese yen (1.184%) have lower yields than euro-denominated bonds. These differences in yields on bonds denominated in different currencies is a reflection of the macroeconomic conditions in the respective countries and is an indication of the need to account for currency differences in the analyses.

The results in Table 6 show that when the market, firm, bond, and currency characteristics are controlled for, the yield to maturity is lower on green bonds than brown bonds. The next relevant question to ask is whether the market, firm, bond, and currency characteristics affect green and brown bond yields differently. In order to answer this question, we interact all market, firm, bond, and currency variables with the green indicator variable in Model 2. Tables 7–9 present the estimation results for Model 2, along with tests for whether the coefficients on green and brown bonds differ significantly.

When interaction terms with the *Green* variable are added, the adjusted R^2 of the model increases slightly. Considering the fact that the sample consists of only 563 green bonds, this change in adjusted R^2 can be considered a material increase in the explanatory power of the regression. Moreover, a joint significance test of the coefficients of the interaction terms rejects the null hypothesis that coefficients of these variables are jointly equal to zero. This finding indicates that interaction terms are also important in explaining yields on green versus brown bonds. With the addition of the interaction variables, the coefficient estimates for explanatory variables and their statistical significances remain qualitatively the same as in Model 1, except for the *Green* variable. In this new model, which allows for different slope coefficients, the *Green* variable has a positive and statistically significant coefficient, indicating that the yield on a green bond denominated in euros and issued by a firm operating in neither the financial nor the utility sector is 1.984 percent higher than that of a comparable brown bond. This is an economically significant increase in the borrowing cost of a firm. The positive and statistically significant coefficient of the *Green* variable is inconsistent with the existing greenium arguments in the literature.

Tables 7–9 have some other noteworthy findings. The coefficient of $Green \times RF$ is negative and statistically significant. The relationship between the market interest rate (RF) and YTM does not seem to be one-to-one for green bonds. As RF

Table 7
Model 2 estimation results and coefficient difference tests (maturity measured in years).

	Brown bonds		Green bonds		Green minus brown	
	Coefficient estimate	p-value	Coefficient estimate	p-value	Coefficient estimate	p-value
Market conditions						
Risk-free rate	**1.001**	<0.0001	**0.670**	<0.0001	**−0.331**	0.0012
Year of issue	**0.033**	0.0009	**−0.085**	0.0045	**−0.118**	0.0002
Bond characteristics						
Maturity in years	**0.010**	0.0063	**0.104**	<0.0001	**0.094**	<0.0001
Issue size	**−0.093**	0.0308	**−0.239**	0.0002	**−0.146**	0.0593
Investment grade	**−0.790**	<0.0001	**−1.132**	<0.0001	**−0.343**	0.0503
Secured	**−0.458**	<0.0001	0.063	0.6758	**0.521**	0.0011
Underwritten	**−0.111**	0.0218	**−0.553**	<0.0001	**−0.442**	0.0001
Publicly traded	**−0.629**	<0.0001	−0.143	0.3345	**0.486**	0.0026
Callable	**0.514**	<0.0001	**0.298**	0.0275	−0.217	0.1593
Currency of denomination						
USD	**0.865**	<0.0001	**0.621**	0.0105	−0.244	0.3472
RMB	**−0.715**	<0.0001	0.605	0.1795	**1.320**	0.0055
Yen	**−1.156**	<0.0001	**−1.752**	<0.0001	**−0.595**	0.0057
Krona	**1.253**	<0.0001	**−0.525**	0.0051	**−1.779**	<0.0001
Issuer characteristics						
Financial firm	**0.615**	<0.0001	−0.039	0.7258	**−0.654**	<0.0001
Utility firm	**0.639**	<0.0001	0.039	0.7722	**−0.599**	0.001
Intercept	**1.804**	<0.0001	3.788	<0.0001	**1.984**	0.0016
Adj. R-square	0.345		0.8045			
F stat.	421.64	<0.0001	155.16	<0.0001		
Number of observations	11,998		563			

Notes: This table presents the estimation results for Model 2 and tests whether the estimated coefficients for the green versus brown subsamples are significantly different from each other. Variable definitions are provided in Table 4. In this table, time to maturity is measured in years. p-values for the coefficient estimates are shown next to the estimates and estimates in boldface indicate significance at an alpha level of 0.05 or less. The model is estimated with heteroskedasticity-consistent errors.

Table 8
Model 2 estimation results and coefficient difference tests (maturity measured as log of maturity in days).

	Brown BONDS		Green bonds		Green minus brown	
	Coefficient estimate	p-value	Coefficient estimate	p-value	coefficient estimate	p-value
Market conditions						
Risk-free rate	**0.987**	<0.0001	**0.691**	<0.0001	**−0.297**	0.0038
Year of issue	**0.033**	0.0009	**−0.077**	0.0075	**−0.110**	0.0003
Bond characteristics						
Log maturity in days	−0.074	0.0742	**1.117**	<0.0001	**1.191**	<0.0001
Issue size	**−0.104**	0.0197	**−0.222**	0.0009	−0.118	0.1424
Investment grade	**−0.727**	<0.0001	**−1.183**	<0.0001	**−0.456**	0.0096
Secured	**−0.445**	<0.0001	0.116	0.4142	**0.562**	0.0002
Underwritten	**−0.106**	0.0293	**−0.524**	<0.0001	**−0.418**	0.0002
Publicly traded	**−0.600**	<0.0001	−0.095	0.4731	**0.505**	0.0006
Callable	**0.568**	<0.0001	0.233	0.0746	**−0.335**	0.0253
Currency of denomination						
USD	**0.863**	<0.0001	**0.712**	0.0023	−0.150	0.5485
RMB	**−0.717**	<0.0001	0.803	0.0813	**1.520**	0.0017
Yen	**−1.087**	<0.0001	**−1.690**	<0.0001	**−0.604**	0.004
Krona	**1.208**	<0.0001	−0.279	0.1313	**−1.487**	<0.0001
Issuer characteristics						
Financial firm	**0.558**	<0.0001	0.036	0.7654	**−0.523**	0.0002
Utility firm	**0.665**	<0.0001	0.067	0.6237	**−0.598**	0.0012
Intercept	**2.450**	<0.0001	**−4.387**	<0.0001	**−6.838**	<0.0001
Adj. R-square	0.345		0.824			
F stat.	421.52	<0.0001	176.06	<0.0001		
Number of observations	11,998		563			

Notes: This table presents the estimation results for Model 1 and tests whether the estimated coefficients for the green versus brown subsamples are significantly different from each other. Variable definitions are in Table 4. In this table, time to maturity is measured as log of maturity in days. p-values for the coefficient estimates are shown next to the estimates and estimates in boldface indicate significance at an alpha level of 0.05 or less. The model is estimated with heteroscedasticity-consistent errors.

Table 9
Model 2 estimation results and coefficient difference tests (maturity measured with dummy variables).

	Brown bonds		Green bonds		Green minus brown	
	Coefficient estimate	p-value	Coefficient estimate	p-value	Coefficient estimate	p-value
Market conditions						
Risk-free rate	**0.996**	<0.0001	**0.729**	<0.0001	**−0.266**	0.0102
Year of issue	**0.033**	0.001	**−0.081**	0.0065	**−0.113**	0.0003
Bond characteristics						
Medium	−0.071	0.2163	**0.622**	<0.0001	**0.694**	<0.0001
Long	0.084	0.1543	**1.519**	<0.0001	**1.435**	<0.0001
Issue size	**−0.097**	0.0247	**−0.201**	0.0038	−0.104	0.2045
Investment grade	**−0.783**	<0.0001	**−1.202**	<0.0001	**−0.419**	0.018
Secured	**−0.454**	<0.0001	0.240	0.0968	**0.695**	<0.0001
Underwritten	**−0.103**	0.0339	**−0.550**	<0.0001	**−0.446**	<0.0001
Publicly traded	**−0.611**	<0.0001	−0.111	0.4283	**0.500**	0.0011
Callable	**0.512**	<0.0001	**0.332**	0.0218	−0.180	0.2682
Currency of denomination						
USD	**0.851**	<0.0001	**0.576**	0.0187	−0.274	0.2951
RMB	**−0.734**	<0.0001	0.555	0.2416	**1.289**	0.0096
Yen	**−1.155**	<0.0001	**−1.779**	<0.0001	**−0.625**	0.0051
Krona	**1.231**	<0.0001	**−0.431**	0.0296	**−1.662**	<0.0001
Issuer characteristics						
Financial firm	**0.588**	<0.0001	−0.002	0.9864	**−0.590**	<0.0001
Utility firm	**0.652**	<0.0001	0.033	0.8205	**−0.620**	0.001
Intercept	**1.905**	<0.0001	**3.667**	<0.0001	**1.762**	0.0033
Adj. R-square	0.345		0.812			
F stat.	395.60	<0.0001	152.70	<0.0001		
Number of observations	11,998		563			

Notes: This table presents the estimation results for Model 1 and tests whether the estimated coefficients for the green versus brown subsamples are significantly different from each other. Variable definitions are in Table 4. In this table, time to maturity is measured with dummy variables representing maturities of 5–10 years (Medium) and more than 10 years (Long). p-values for the coefficient estimates are shown next to the estimates and estimates in boldface indicate significance at an alpha level of 0.05 or less. The model is estimated with heteroskedasticity-consistent errors.

increases, the *YTM* on green bonds increases by only 67 bps, less than that for brown bonds (100 bps). In addition, the coefficient on *Green* × *IssueYear* is negative and statistically significant. The yield is 8.5 bps lower for green bonds issued in later years in the sample than for those issued at the beginning of the sample. This might imply an increase in the greenium over time but would be inconsistent with studies that claim a decrease in the greenium over time (Fatica et al., 2021; Kanamura, 2020). It might also be the result of an increase in the credit quality of green bonds over time, as Karpf and Mandel (2018) argue.

In Tables 7–9, the observed effect of time to maturity is also different from Table 6. The coefficient on *Green* × *TTM* is positive and statistically significant. This indicates a significantly different impact of time to maturity on yields of green and brown bonds. Based on these results, for an increase in time to maturity of one year, the yield on a brown bond increases by 1 bp, whereas the yield on a green bond increases by 10.4 bps. This is an indication that green bonds are susceptible to a somewhat higher maturity risk. This might be due to the specialized use of proceeds for green bonds and investors' decreasing confidence if they perceive ambiguity regarding the channeling of green bond funds as the time to maturity increases.

The effect of issue size on green bond yields is negative and statistically significant. This indicates that, as the issue size increases, yields decrease more for green bonds than for brown bonds. This combined effect signifies the higher importance of liquidity for green bonds. As Febi et al. (2018) argue, however, because of the rapid growth of the market, liquidity concerns in the green bond market might dissipate over time.

When currency effects are examined in Tables 7–9, it is seen that green bonds denominated in euros have yields that are significantly higher than those denominated in Japanese yen (1.752%) and lower than those denominated in the US dollar (62.1 bps). No significant differences in yields on green bonds are found between those denominated in euros and those in Swedish krona and Chinese RMB.

Finally, our estimation results suggest that although secured brown bonds have significantly lower primary market returns, the same is not observed for green bonds. Because the proceeds from a green bond issue must be earmarked for sustainable investment, the additional security provided by collateral does not seem to be interpreted as a significant factor by green bond investors.

4. Conclusion

Social impact investment contracts, such as green bonds, are designed to pursue a blended-value objective, implying that investors integrate the nonmonetary (social) outcomes of these contracts into their investment decisions. Riedl and Smeets (2017) argue that the financial return required on such an investment might be lower than the return required on an investment with similar risk and no social return. This study contributes to the literature by comparing the return and risk performance of green and brown corporate debt securities.

We offer preliminary evidence of a possible difference between green and brown bonds based on their secondary market yields, in which the efficient frontiers constructed suggest that green bonds trade at lower returns, especially during the first half of the sample period. However, when the analyses focus on primary market yields, a different picture emerges. Controlling for market, firm, bond, and currency characteristics, we initially find that, at the time of their issuance, green bonds offer a greenium of about 25 bps over their brown counterparts. When the control variables are allowed to affect green and brown bonds differently, green bonds offer higher yields to maturity than the brown bonds in the sample. Because bond yields are determined by a complex set of interactions among the market, firm, bond, and currency factors, ignoring these interactions can lead to biased findings regarding the existence of a greenium.

Declaration of competing interest

There is no conflict of interest associated with this research.

References

Agliardi, E., & Agliardi, R. (2019). Financing environmentally-sustainable projects with green bonds. *Environment and Development Economics, 24*(6), 608–623. https://doi.org/10.1017/S1355770X19000020

Agliardi, E., & Agliardi, R. (2021). Corporate green bonds: Understanding the greenium in a two-factor structural model. *Environmental and Resource Economics, 80*(2), 257–278. https://doi.org/10.1007/s10640-021-00585-7

Bachelet, M. J., Becchetti, L., & Manfredonia, S. (2019). The green bonds premium puzzle: The role of issuer characteristics and third-party verification. *Sustainability, 11*(4), 1–22. https://doi.org/10.3390/su11041098

Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). *Financing the response to climate change: The pricing and ownership of US green bonds (No. w25194)*. National Bureau of Economic Research.

Beschloss, A., & Mashayekhi, M. (2019). *A greener future for finance* (Vol. 56, pp. 60–61). Finance & Development.

Daggers, J., & Nicholls, A. (2016). *The landscape of social impact investment research: Trends and opportunities* (pp. 1–44). University of Oxford, Said Business School. Report.

Ehlers, T., & Packer, F. (2017). Green bond finance and certification. *BIS Quarterly Review*, 1–16.

Fatica, S., Panzica, R., & Rancan, M. (2021). The pricing of green bonds: Are financial institutions special? *Journal of Financial Stability, 54*, Article 100873.

Febi, W., Schafer, D., Stephan, A., & Sun, C. (2018). The impact of liquidity risk on the yield spread of green bonds. *Finance Research Letters, 27*, 53–59.

Flaherty, M., Gevorkyan, A., Radpour, S., & Semmler, W. (2017). Financing climate policies through climate bonds: A three-stage model and empirics. *Research in International Business and Finance, 42*, 468–479.

Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics, 142*(2), 499–516. https://doi.org/10.1016/j.jfineco.2021.01.010

Gianfrate, G., & Peri, M. (2019). The green advantage: Exploring the convenience of issuing green bonds. *Journal of Cleaner Production, 219*, 127–135.

Glomsrød, S., & Wei, T. (2018). Business as unusual: The implications of fossil divestment and green bonds for financial flows, economic growth and energy market. *Energy for Sustainable Development, 44*, 1–10.

Hachenberg, B., & Schiereck, D. (2018). Are green bonds priced differently from conventional bonds? *Journal of Asset Management, 19*, 371–383.

Hyun, S., Park, D., & Tian, S. (2020). The price of going green: The role of greenness in green bond markets. *Accounting and Finance, 60*, 73–95.

Kanamura, T. (2020). Are green bonds environmentally friendly and good performing assets? *Energy Economics, 88*, Article 104767.

Kapraun, J., Latino, C., Scheins, C., & Schlag, C. (2021). (In)-credibly green: Which bonds trade at a green bond premium?. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3347337.

Karpf, A., & Mandel, A. (2018). The changing value of the "green" label on the US municipal bond market. *Nature Climate Change, 8*, 161–165.

Larcker, D. F., & Watts, E. M. (2020). Where's the greenium? *Journal of Accounting and Economics, 69*, Article 101312. https://doi.org/10.1016/j.jacceco.2020.101312

Liu, N., Liu, C., Da, B., Zhang, T., & Guan, F. (2021). Dependence and risk spillovers between green bonds and clean energy markets. *Journal of Cleaner Production, 279*, Article 123595. https://doi.org/10.1016/j.jclepro.2020.123595

MacAskill, S., Roca, E., Liu, B., Stewart, R. A., & Sahin, O. (2021). Is there a green premium in the green bond market? Systematic literature review revealing premium determinants. *Journal of Cleaner Production, 280*, Article 124491. https://doi.org/10.1016/j.jclepro.2020.124491

Monk, A., & Perkins, R. (2020). What explains the emergence and diffusion of green bonds? *Energy Policy, 145*, Article 111641.

Paranque, B., & Revelli, C. (2019). Ethico-economic analysis of impact finance: The case of green bonds. *Research in International Business and Finance, 47*, 57–66.

Partridge, C., & Medda, F. R. (2020). The evolution of pricing performance of green municipal bonds. *Journal of Sustainable Finance & Investment, 10*(1), 44–64.

Reboredo, J. C. (2018). Green bond and financial markets: Co-movement, diversification and price spillover effects. *Energy Economics, 74*, 38–50.

Reboredo, J. C., & Ugolini, A. (2020). Price connectedness between green bond and financial markets. *Economic Modelling, 88*, 25–38. https://doi.org/10.1016/j.econmod.2019.09.004

Riedl, A., & Smeets, P. (2017). Why do investors hold socially responsible mutual funds? *The Journal of Finance, 72*(6), 2505–2550.

Rosembuj, F., & Bottio, S. (2016). *Mobilizing private climate finance-green bonds and beyond* (pp. 1–16). International Finance Corporation EMCompass Note.

Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance, 98*, 39–60.