Environmental value in corporate bond prices: Evidence from the green bond market

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Abstract

I examine whether there is a green premium in the US and Euro corporate bond prices in the secondary markets indicating that investors would pay a premium for holding green bonds. The premium is estimated as the yield spread between green and conventional bonds of similar characteristics. I find a significant premium of 28 basis points for investment grade bonds, while the premium does not persist for high yield and unrated bonds. This suggests that investors accept a lower yield on investment grade green bonds in order to pursue their social responsibility agenda.

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1 Introduction

In recent years, investors have become increasingly aware of the risks and opportunities that climate change poses to businesses. As a result, many investors have taken measures to address these concerns by integrating environmental, social and corporate governance (ESG) criteria into their investment decision making. The increased ability to measure the exposure to climate change risks has in turn resulted in increased management of these risks and divestment in fossil fuel assets. However, finding viable investment alternatives can be challenging as equity markets play only a limited role in financing climate change solutions.

Green bonds represent a growing segment of the fixed-income market that allocates funds for environmentally sustainable projects without exposing investors to the risks of the projects. The first green bond was issued in 2008 by the World Bank, and since then, the market has grown rapidly to $118 billion in 2016 (Climate Bonds Initiative, 2016a), attracting corporate, governmental and supranational issuers to tap into the capital of sustainability-conscious investors. In contrast to conventional bonds, the proceeds of green bonds are used exclusively to finance new or existing projects with clear environmental benefits. Another important feature of green bonds is that they are subject to increased reporting requirements. The issuer is committed to provide detailed information on the allocation of the funds and their environmental impacts, which increases investor confidence in these securities.

Even though socially responsible investing has been subject to extensive research in recent years, the pricing of green bonds remains largely unexplored in the literature. However, few studies investigate the relation between corporate environmental performance and debt financing. Bauer and Hann (2010) find that environmentally responsible firms have a higher credit rating and a lower credit spread explained by lower credit risk. Schneider (2011) reports similar results for the most polluting US industries. Chava (2014) provides evidence on bank loans and further finds that fewer banks are willing to participate in loan syndicates of environmentally irresponsible firms.

Due to the demand by socially responsible investors, green bonds are likely to attract a wider range of investors than conventional bonds, which may affect the pricing of these bonds. In this study, I examine whether there is a green premium in the US and Euro corporate bond prices in the secondary markets indicating that investors would be willing to pay a premium for holding green bonds. The premium is estimated by comparing green bond prices to the prices of conventional bonds with similar characteristics. The sample consists of monthly observations of yields for 92 green and 258

conventional bonds for the time period from November 2013 to October 2016. Moreover, I investigate the premium using a subsample consisting of bonds only from green bond issuers in order to control for firm-specific variation.

The remainder of the paper is organized as follows. Section 2 gives an overview of the key features of green bonds and the related literature. In Section 3, I present main hypotheses, data and research methods used to examine the hypotheses. Section 4 introduces the main results and robustness checks. Finally, Section 5 concludes.

2 Conceptual framework and literature review

2.1 Key features of green bonds

The bond market provides a wide variety of debt securities with environmental attachments, such as climate-themed bonds and environmental impact bonds. Although green bonds are not the first debt securities to target environmentally conscious investors, their similarity to conventional bonds in terms of structure, risk and initial return makes them appeal to investors with limited due diligence. However, the current green bond market is based on self-regulation, which can raise investors' concerns over the environmental integrity of green bonds. To overcome these concerns, several market-driven frameworks have been proposed to create common principles of credible green bond issues and to foster greater transparency between issuers and investors. To date, most of the green bonds have been issued under the Green Bond Principles framework which was established by a coalition of investment banks in 2014 (Shishlov et al., 2016). The main purpose of this framework is to provide guidelines on the use of proceeds and reporting procedures.

Green bonds can take several different forms which vary in terms of covenant, guarantee and payback structure. The most common type of these securities is the Green Use of Proceeds Bond which is similar to a straight bond in structure, risk and initial return (OECD, 2015). The distinctive feature of green bonds is that the proceeds are used exclusively to fund new or existing environmentally sound projects which are aligned with the Green Bond Principles. Typically, this means that the funds are allocated to large-scale, capital-intensive infrastructure projects in renewable energy, energy efficiency and low-carbon transportation (Climate Bonds Initiative, 2016a).

To be recognized as a credible green bond, the issuer discloses a mandatory prospectus at the issuance to demonstrate compliance with the common principles concerning project evaluation and selection as well as the management of the proceeds and reporting. In practice, this means that the issuer provides information on the allocation of the funds on a regular basis and ensures segregation of the funds. Furthermore, the reporting should provide sufficient insights into the funded projects and their environmental impact to keep investors informed about the environmental performance of their investments (Green Bond Principles, 2016).

To enhance investor confidence, many issuers also disclose external reviews as an additional verification on the environmental credentials of the bond. The purpose of the external review depends on whether it is being disclosed before or after the issuance. Before the issuance, the external review provides information on the projects to be funded and the management of the funds, whereas after the issuance the external review is used to assure investors that the proceeds have been allocated as promised and to provide more information on the environmental impacts of the funded projects (Climate Bonds Initiative, 2016b).

2.2 Determinants of corporate credit spread

The value of corporate debt depends mainly on three factors: 1) the required return on riskless debt, 2) certain provisions and restrictions of the debt security (e.g. maturity, coupon rate, callability, seniority, etc.) and 3) the probability that the firm will be unable to meet its debt obligations, i.e., the probability of default (Merton, 1974). In the literature, the pricing of corporate bonds is often studied using the yield spread between a corporate bond and a Treasury security of comparable maturity. The yield spread is often referred to as the credit spread since part of the yield spread is due to the credit risk of corporate bonds (Huang and Huang, 2012).

Most studies on corporate bond pricing investigate the determinants of credit risk using structural models, first introduced by Black and Scholes (1973) and Merton (1974). In structural models, a firm is assumed to default when the value of its assets falls below the value of its liabilities. In these models, credit spread changes are often explained by the value and the volatility of a firm's assets, spot rates, the slope of the yield curve and business climate. Longstaff and Schwartz (1995), for example, show that credit spread decreases with the level of interest rates because of the correlation between a firm's assets and the level of interest rates. Collin-Dufresn et al. (2001) conclude that changes in

credit spreads are driven by interest rates, business climate and market volatility, instead of factors associated with equity or Treasury markets. They also find that credit spreads are positively correlated with leverage and the effect tends to increase with leverage.

By contrast, reduced form models are used to investigate the non-credit-related determinants of the credit spread, such as liquidity and tax factors. Longstaff et al. (2005) measure the default component in corporate credit spreads using credit default swaps and find that the unexplained nondefault component of the credit spread is strongly associated with bond liquidity. Chen et al. (2007) provide similar results using different liquidity measures and a comprehensive sample of 4,000 corporate bonds. The authors find that half of the cross-sectional variation in credit spread levels is explained by liquidity. Elton et al. (2001) argue that if corporate bond returns are sensitive to movements in other assets, whereas government bond returns are not, then investor would require a risk premium to compensate for the nondiversifiable risk. They find that 85 percent of the credit spread not accounted for by taxes and the expected default can be explained by a systematic risk factor.

2.3 Corporate environmental responsibility and credit spread

In the literature, corporate environmental responsibility is usually studied as a part of corporate social responsibility (CSR) along with social responsibility and corporate governance. Most studies on CSR explore its effect on firm performance and the cost of equity (see e.g. Fatemi et al., 2015, Ghoul et al., 2011, McGuire et al., 1988, Pava and Krausz, 1996). The findings suggest that socially responsible firms are generally considered to be less risky and that shareholders regard investing in CSR as enhancing the firm value regardless of the costs associated with it.

By contrast, few studies examine the effect of CSR on debt financing and conclude that debt holders are concerned about CSR only when it is likely to increase the credit risk of the firm. For instance, Goss and Roberts (2011) investigate the relation between CSR performance and the cost of private bank loans. Their findings suggest that firms with CSR issues are charged with a risk premium ranging from 7 to 18 basis points. However, they find that banks do not reward firms for superior CSR performance. Menz (2010) provides similar results for the European corporate bond market. He finds that the risk premium on bonds of socially responsible firms does not differ significantly from those of less responsible firms. However, Ge and Liu (2015) provide contradicting evidence on the relation of CSR and credit spread using new bond issues. They find that a higher level of CSR is associated

with better credit rating. In addition, they show that better CSR performance leads to a lower credit spread implying that only a part of CSR is captured by credit ratings.

A few studies focus on the environmental dimension of CSR and suggest that the relation between corporate bond prices and environmental responsility may be stronger than the relation between corporate bond prices and CSR. Schneider (2011) explores the effect of toxic emissions on bond prices in the most polluting US industries, i.e., chemical, pulp and paper industries. He finds that toxic emissions increase the risk of bankruptcy, which leads to a higher risk premium for polluting firms. Similarly, Bauer and Hann (2010) argue that environmental practices determine a firm's exposure to legal, reputational and regulatory risks, and thus, influence the solvency of the firm. They conclude that corporate environmental responsibility is associated with lower credit spreads and higher credit ratings. Moreover, Chava (2014) provides evidence that environmentally irresponsible firms are charged with a higher risk premium on bank loans.

3 Data and methodology

3.1 Main hypotheses

The main objective of this study is to test whether there is the green premium in corporate bonds prices indicating that, other things equal, investors are willing to pay a premium for green bonds relative to conventional bonds. Prior research suggest that socially responsible investors have both financial and social objectives, and thus they may be willing to accept lower financial returns in order to pursue a social or ethical agenda (see e.g. Bauer et al., 2005, Galema et al., 2008, Renneboog et al., 2008). Similarly, as green bonds attract more socially responsible investors than conventional bonds, investors may accept a lower yield on green bonds in exchange for environmental impact.

Moreover, I examine whether the magnitude of the premium decreases with credit risk. Given that the corporate bond market is dominated by institutional investors with restrictions on holding non-investment grade and unrated bonds, the demand for investment grade green bonds is likely to be higher than that of high yield and unrated green bonds. Therefore, I hypothesize that the magnitude of the premium depends on the bond's rating and that the premium is significantly higher for investment grade bonds than for high yield and unrated bonds.

3.2 Description of data

For the estimation of the premium, I construct a sample by combining a set of green bonds and a control group consisting of conventional bonds with similar characteristics. Using a broader control group will produce results that will be less sensitive to the particular choice of bonds than using matched pairs of bonds (Davies and Kim, 2009). Therefore, given that the size of the green bond sample is relatively small and the bonds in the sample are quite dissimilar, I test the hypotheses using a broad control group that may produce more reliable results.

The green bond sample used in this study consists of 92 green bonds issued by 46 firms during the time period from November 2013 to October 2016. To construct the sample, I use a data set of green bonds provided by the Climate Bonds Initiative. The bonds are classified as green bonds in the Reuters Eikon database and further screened by the Climate Bonds Initiative to ensure alignment with the Green Bond Principles. From the selected bonds, 41 bonds have external reviews attached. I restrict the sample to US and Euro corporate bonds because US and Euro corporate bond markets are comparable in liquidity.

The group of control bonds is constructed using several criteria in order to match the green bonds with conventional bonds of similar characteristics. Focusing on credit risk, I select the control bonds by issuer, industry, credit rating and time-to-maturity. First, the bond is matched with three conventional bonds from the same issuer when possible. If there are no bonds available from the same issuer, then the bond is matched with three control bonds using only the latter three of the previously presented criteria. As a result, 48 green bonds are matched with at least one bond from the same issuer leaving 44 green bonds to be matched with other issuers' bonds. The resulting set of control bonds consists of 258 conventional bonds from 86 firms.

The final sample consists of 7,422 monthly observations of yields for a total of 350 corporate bonds during the time period from November 2013 to October 2016. The bond data, market-level control variables and risk-free rates are collected from Datastream. The bonds in the sample are issued by financial and non-financial corporations denominated in US Dollars and euros with a minimum issue size of 5 million dollars. All bonds have a fixed rate coupon and remaining time-to-maturity of at least one year and maximum 15 years. Corporate bonds with a put option, a sinking fund or other option features except a call option are excluded. In addition, securitized corporate bonds, such as asset-backed and covered bonds, are excluded.

Table 1: Description of the full sample

The sample consists of 92 green and 258 conventional bonds during the time period from November 2013 to October 2016. The table describes the green bond and control bond sets by currency and industry.

	Financials	Utilities	Other	Full sample
Green bonds				
US dollar	20	38	1	59
Euro	21	9	3	33
Green bonds subtotal	41	47	4	92
Control bonds				
US dollar	60	107	3	170
Euro	58	23	7	88
Control bonds subtotal	118	130	10	258
Total	159	177	14	350

Table 1 describes the characteristics of green and control bonds in the sample. The green bond sample consists of 59 USD-denominated and 33 euro-denominated bonds and the proportion of the bonds is similar in the control group. The euro-denominated bonds are mainly issued by financials, whereas over half of the USD-denominated bonds are issued by utilities. In the whole sample, the portion of financial and utility bonds is more balanced because the sample consists of 159 financial and 177 utility bonds.

Table 2 summarizes bond characteristics for the two sets of bonds. Several observations can be made from the data. First, there is a great amount of variation in issue size in both sets of bonds. The issue size tends to be higher for control bonds with a median issue size of $500 million compared to that of $326.6 million for green bonds. The median rating for both sets is close to 7, which corresponds to Moody's A3. Although not shown here, the sample also includes unrated bonds, of which 36 are green bonds and 9 conventional bonds. The average maturity in both sets is around 6 years, while the average age is 1 year for green bonds and 2.2 years for control bonds. This can be explained by the fact that all green bonds are issued during the sample period and a higher share of them are issued in the second half of the time period, whereas the control bonds are selected based on time-to-maturity.

In the whole sample, credit spread ranges from 21 to 1941 basis points, which can be attributed to credit rating differences in the sample. Moreover, this can be a result of including callable bonds in the sample as the credit spread tends to be higher for those bonds. Based on the bid-ask spread, the bonds are similar in terms of liquidity with an average bid-ask spread of 50 basis points. However, the highest value of bid-ask spread in the sample suggests that the control group might have less liquid bonds which may be outliers affecting the results.

Table 2: Characteristics of the green and control bond sets

The sample consists of 92 green bonds and 258 conventional bonds denominated in US dollars and euros during the time period from November 2013 to October 2016. The table describes the characteristics of the green and control bond sets. Credit spread is the yield spread between a bond and an equivalent Treasury bond. Bid-ask spread is the difference between the ask and the bid price divided by the mid price. Bond age is the time since the issuance in years. Amount is the bond's outstanding amount. Maturity is the bond's time-to-maturity in years. Coupon is the coupon rate of the bond. Rating is the bond's average rating from Moody's, S&P and Fitch converted into a numerical value.

Green bonds	Mean	St. Dev.	Min	Median	Max
Credit Spread (bp)	260.3	197.3	41.9	199.6	1,578.1
Bid−Ask Spread (bp)	52.2	39.3	9.4	40.0	206.0
Bond Age	1.0	0.6	0	0.9	2.9
Amount (in USD)	356.8	386.3	5.0	326.6	1,596.4
Maturity	6.6	3.5	1.1	6.0	14.8
Coupon (%)	3.2	1.7	0.4	2.8	9.8
Rating	7.8	2.9	2.0	7.0	16.5
Control bonds	**Mean**	**St. Dev.**	**Min**	**Median**	**Max**
Credit Spread (bp)	180.6	187.5	21.0	113.2	1,941.4
Bid−Ask Spread (bp)	49.2	41.5	0.6	36.8	486.0
Bond Age	2.2	2.2	0	1.7	13.9
Amount (in USD)	647.6	643.8	5.3	500.0	5,500.0
Maturity	6.2	2.5	1.0	6.2	12.0
Coupon (%)	3.7	1.6	0.5	3.5	9.8
Rating	7.8	2.9	2.0	7.3	19.0

3.3 Methodology

For the estimation of the premium, I employ the multiple regression model of Chen et al. (2007) with few modifications. First, industry and year fixed effects are included to the regression to account for industry-specific and macroeconomic effects that are not captured by the other variables. As in Güntay and Hackbarth (2010) and Bao et al. (2011), the model is estimated by ordinary least squares (OLS) method using the Newey-West robust standard errors to correct for heteroskedasticity and autocorrelation. The premium is estimated using the following model with credit spread as the dependent variable:

$$\begin{aligned} \textit{Credit Spread}_{it} = {} & \alpha_0 + \beta_1 \textit{Green\_IG}_i + \beta_2 \textit{Green\_HY\&UR}_i + \beta_3 \textit{Bid-Ask Spread}_{it} \\ & + \beta_4 \textit{Bond Age}_{it} + \beta_5 \textit{Ln(Amount)}_{it} + \beta_6 \textit{Maturity}_{it} + \\ & + \beta_7 \textit{Rating}_i + \beta_8 \textit{Unrated}_i + \beta_9 \textit{Callable}_i + \beta_{10} \textit{EUR}_i \\ & + \beta_{11} \textit{Volatility}_t + \beta_{12} \textit{1y Treasury Rate}_t + \beta_{13} \textit{10y-2y Treasury Rate}_t + \varepsilon_{it}, \end{aligned} \tag{1}$$

where the subscript *it* refers to bond i and month t. *Credit Spread* is calculated as the yield

spread between a bond and a Treasury bond of comparable maturity. The Treasury yield curves are interpolated using the yields of US Treasury and German government bonds. The premium for green bonds is estimated by including two dummy variables to the model. The first dummy variable *Green_IG* equals to one, when the bond is an investment grade green bond, whereas the second dummy variable *Green_HY&UR* equals to one when the bond is a high yield or unrated green bond and zero otherwise. The coefficients of variables *Green_IG* and *Green_HY&UR* estimate the premium for investment grade green bonds and high yield and unrated green bonds, respectively.

The other variables included to the model control for bond liquidity, bond-specific and market-specific effects on credit spread. To control for liquidity, three different liquidity measures are employed. The first liquidity measure *Bid-Ask Spread* is the difference between the ask and the bid price divided by the mid price. Bid-ask spread is expected to capture liquidity differences as less traded bonds tend to have wider bid-ask spreads. The second liquidity measure *Bond Age* indicates how long the bond has been trading. Sarig and Warga (1989) note that when the bond gets older, the bond tends to get locked in investors' buy-and-hold portfolios decreasing the total amount of trading. In addition, Fisher (1959) points out that smaller issues are likely to trade less frequently increasing the uncertainty of future market prices. Thus, the natural logarithm of the bond's outstanding amount *Ln*(*Amount*) is included to the model. For euro-denominated bonds, the outstanding amount is converted to US dollars using end-of-month exchange rates from European Central Bank.

To control for bond characteristics, I include bond's maturity, rating and several dummies to the model. *Maturity* is defined as the remaining time to bond's maturity date. Credit spreads tend to increase with bond's maturity reflecting the increased uncertainty on future interest rates. The second bond-specific factor *Rating* controls the effect of the issuer's credit risk. Bond's rating is the average of Moody's, Standard & Poor's and Fitch's rating that is converted to a numerical value using the scale from 1 to 19, corresponding to Moody's Aaa and Caa3. Following Chen et al. (2003), I include a dummy variable *Unrated* for unrated bonds. Although unrated bonds can have different risk profiles, it is important to control for the variation on credit spread caused by the lack of rating. In addition, I include a dummy variable *Callable* for callable bonds since they tend to have higher credit spreads. Finally, I include a dummy variable *EUR* for euro-denominated bonds.

Next, three market-level variables are included to control for market-level and macroeconomic conditions. As in Güntay and Hackbarth (2010), equity volatility index *Volatility* is included in order to capture changes in market sentiment. I use VIX and VSTOXX as volatility index for USD- and

euro-denominated bonds, respectively. As the current level of interest rates is likely to affect credit spread in the short-run, I include 1-year risk-free rate, $1y\ Treasury\ Rate$, to reflect the current level of interest rates. In addition, I include $10y\text{-}2y\ Treasury\ Rate$ defined as the yield spread between 10-year and 2-year Treasury rates to control for the steepness of the risk-free yield curve. As in calculating the credit spread, I use the yields of US Treasury and German government bonds as risk-free rates.

4 Results

4.1 Full sample analysis

Table 3 presents the results from four separate regressions of credit spread determinants on credit spread. The regressions are performed using the full sample covering 7,422 monthly observations of 350 corporate bonds. The first column represents the regression results without controlling for industry and year effects. The second column represents the results with industry fixed effects, while the third column presents results with year fixed effects. Finally, the fourth column represents the results with both industry and year fixed effects.

The main finding in Table 3 is that the sign of the premium is different for investment grade green bonds compared to high yield and unrated green bonds. The coefficient for investment grade bonds, $Green\_IG$, is negative across the regressions, which implies that there is a premium in the prices of investment grade green bonds. On the contrary, the coefficient for high yield and unrated bonds, $Green\_HY\&UR$, is positive suggesting that instead of paying a premium investors demand a discount on these bonds. Both premium measures are economically and statistically significant at the 1% level with and without industry and year effects.

The coefficient of investment grade green bonds suggests that investors pay a premium of 19 to 28 basis points relative to non-green investment grade bonds, other things equal. An explanation for the premium could be that investors value the environmental attributes of the green bonds over financial performance and thus, they are willing to accept a lower yield on the bonds to pursue their social responsibility agenda. The lower risk premium could also indicate that investors perceive green bond issuers less risky than comparable non-green firms due to their environmentally-friendly business.

However, the coefficient for high yield and unrated green bonds suggests that investors perceive these bonds more risky and demand a discount from 100 to 110 basis points. Given that the credit

Table 3: Credit Spread Determinants of the Full Sample

This table reports regressions results with credit spread as the dependent variable. Newey-West robust t-statistics are reported in parentheses. Credit spread is the yield spread between a bond and an equivalent Treasury bond. Green_IG is the dummy variable for investment grade green bonds. Green_HY&UR is the dummy variable for high yield and unrated green bonds. Bid-ask spread is the difference between the ask and the bid price divided by the mid price in basis points. Bond Age is the time since issuance in years. Ln(Amount) is the natural logarithm of the bond's amount outstanding in millions of US dollars. Maturity is the bond's time-to-maturity in years. Rating is the bond's average rating from Moody's, S&P and Fitch converted into a numerical value. Unrated is the dummy variable for unrated bonds. Callable is the dummy variable for bonds with a call option. EUR is the dummy variable for euro-denominated bonds. Volatility is the equity volatility index in percent. 1y Treasury Rate is the 1-year risk free Treasury rate in basis points. 10y-2y Treasury Rate is the difference between 10-year and 2-year Treasury rates in basis points. The data are at monthly frequency and cover the time period from November 2013 to October 2016.

	Credit Spread			
	Full sample			
	(1)	(2)	(3)	(4)
Constant	-224.477^{***}	-187.048^{***}	-243.287^{***}	-207.580^{***}
	(-10.25)	(-8.90)	(-8.31)	(-7.27)
Green_IG	-19.219^{***}	-25.315^{***}	-22.483^{***}	-28.503^{***}
	(-3.37)	(-4.55)	(-3.86)	(-5.00)
Green_HY&UR	110.601^{***}	102.691^{***}	107.598^{***}	99.728^{***}
	(3.99)	(3.77)	(3.90)	(3.67)
Bid-Ask Spread	1.055^{***}	1.065^{***}	1.048^{***}	1.059^{***}
	(16.48)	(15.94)	(16.42)	(15.87)
Bond Age	-0.092	1.481^{**}	-0.250	1.322^{**}
	(-0.15)	(2.24)	(-0.41)	(2.00)
Ln(Amount)	-1.344	-3.164^{*}	-1.408	-3.224^{*}
	(-0.75)	(-1.79)	(-0.79)	(-1.83)
Maturity	-0.780	1.355^{**}	-0.626	1.510^{**}
	(-1.16)	(2.02)	(-0.93)	(2.25)
Rating	45.173^{***}	43.515^{***}	45.260^{***}	43.595^{***}
	(33.37)	(33.73)	(33.50)	(33.87)
Unrated	401.597^{***}	409.905^{***}	402.156^{***}	410.542^{***}
	(25.63)	(26.55)	(25.72)	(26.64)
Callable	-10.482^{***}	-3.544	-10.929^{***}	-3.962
	(-3.00)	(-1.02)	(-3.14)	(-1.15)
EUR	-32.981^{***}	-55.912^{***}	-17.519^{**}	-39.773^{***}
	(-6.19)	(-10.55)	(-2.23)	(-5.15)
Volatility	2.562^{***}	2.600^{***}	2.307^{***}	2.316^{***}
	(6.84)	(7.20)	(5.66)	(5.91)
1y *Treasury Rate*	0.359^{***}	0.337^{***}	0.419^{***}	0.400^{***}
	(5.45)	(5.36)	(5.88)	(5.79)
10y-2y *Treasury Rate*	-0.194^{***}	-0.190^{***}	-0.030	-0.020
	(-5.21)	(-5.08)	(-0.43)	(-0.30)
Industry Fixed Effects	No	Yes	No	Yes
Year Fixed Effects	No	No	Yes	Yes
Observations	7,422	7,422	7,422	7,422
Adjusted R^2	67.68	69.24	67.77	69.32

*** significant at 1 %

** significant at 5 %

* significant at 10 %

risk is not measured for unrated bonds and that the relationship between rating and credit spread is unlikely to be linear and fully captured by the rating variable, the premium can be a result of uncontrolled credit risk. Moreover, it is possible that the high yield and unrated green bonds suffer from greater illiquidity due to investor preferences, and thus, the premium may capture liquidity effects not explained by the liquidity measures.

In overall, the estimated model explains an unexpectedly high portion of the variation on credit spread. Most of the coefficients for control variables appear highly significant despite that the sample is relatively hetegeneous and includes bonds from several industries and two different markets, which might be a result of omitted variable bias. One potential source for omitted variable bias could be the inclusion of firm-specific factors in the model and, in particular, accounting variables that were excluded due to a lack of data. In the existence of omitted variables, the regression model may over- or underestimate the effect of the included varibles to compensate for the missing factor.

4.2 Subsample analysis

The results in Section 4.1 provided evidence that investors pay a premium for investment grade green bonds. To study whether the results are driven by firm-specific factors, the premium is estimated using a subsample that consists of bonds only from green bond issuers. By doing this, green bonds are compared to conventional bonds of the same issuer which have identical credit rating and similar issue size. This approach is likely to address the concerns for firm-specific effects and to produce more reliable results.

The subsample covers 3,413 monthly observations of 174 corporate bonds for a total of 35 firms. The subsample includes 48 green and 126 conventional bonds. To analyse the effect of different control variables on the premium, I perform four separate regression where the liquidity, bond-specific and market-level variables are included to the model sequentially. Table 4 reports the regression results with industry and year fixed effects.

The main finding in Table 4 is that the premium for investment grade bonds remains fairly unchanged after controlling for bond-specific effects, but the premium for high yield and unrated bonds is insignificant in all four regressions. In addition, the premium for high yield and unrated bonds has high variance as it ranges between 375 and 175 basis points. These results provide evidence that the premium for investment grade bonds persists even using a smaller sample and that the premium is

Table 4: Credit Spread Determinants of the Issuer-Matched Subsample

This table reports regressions results with credit spread as the dependent variable. Newey-West robust t-statistics are reported in parentheses. Credit spread is the yield spread between a bond and an equivalent Treasury bond. Green_IG is the dummy variable for investment grade green bonds. Green_HY&UR is the dummy variable for high yield and unrated green bonds. Bid-ask spread is the difference between the ask and the bid price divided by the mid price in basis points. Bond Age is the time since issuance in years. Ln(Amount) is the natural logarithm of the bond's amount outstanding in millions of US dollars. Maturity is the bond's time-to-maturity in years. Rating is the bond's average rating from Moody's, S&P and Fitch converted into a numerical value. Unrated is the dummy variable for unrated bonds. Callable is the dummy variable for bonds with a call option. EUR is the dummy variable for euro-denominated bonds. Volatility is the equity volatility index in percent. 1y Treasury Rate is the 1-year risk free Treasury rate in basis points. 10y-2y Treasury Rate is the difference between 10-year and 2-year Treasury rates in basis points. The data are at monthly frequency and cover the time period from November 2013 to October 2016.

	Credit Spread			
	Issuer-matched subsample			
	(1)	(2)	(3)	(4)
Constant	141.895***	200.577***	−134.216***	−225.433***
	(21.93)	(12.46)	(−3.91)	(−4.75)
Green_IG	−19.408***	−41.169***	−29.777***	−28.180***
	(−4.06)	(−6.73)	(−5.54)	(−5.45)
Green_HY&UR	375.095	342.144	180.680	175.717
	(1.48)	(1.43)	(1.11)	(1.12)
Bid-Ask Spread		0.684***	0.287***	0.306***
		(5.45)	(4.01)	(4.30)
Bond Age		−6.178***	0.284	0.723
		(−12.21)	(0.60)	(1.50)
Ln(Amount)		−12.878***	−2.227	−2.077
		(−5.90)	(−1.38)	(−1.30)
Maturity			8.600***	8.546***
			(9.85)	(9.80)
Rating			34.689***	34.850***
			(10.08)	(10.30)
Unrated			335.411***	337.954***
			(14.00)	(14.23)
Callable			12.235	14.409
			(1.21)	(1.41)
EUR			−35.887***	−3.231
			(−6.16)	(−0.26)
Volatility				1.772***
				(4.45)
1y *Treasury Rate*				0.490***
				(4.90)
10y-2y *Treasury Rate*				0.166***
				(2.73)
Industry Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	3,413	3,413	3,413	3,413
Adjusted R^2	14.77	21.60	57.86	58.75

*** significant at 1 %

** significant at 5 %

* significant at 10 %

is likely to be of the same magnitude for investment grade bonds, around 28 basis points.

From the liquidity measures, only bid-ask spread remains statistically significant after including bond-specific variables to the model. Bid-ask spread is positively correlated with credit spread, in line with the previous results. Even though the coefficients for bond age and issue size are not statistically significant, their signs show that credit spread increases with bond age and decreases with bond's outstanding amount.

The inclusion of bond-specific variables improves the model's fit significantly. Of these variables, maturity, rating and the dummy for unrated bonds are statistically significant at the 1 % level after controlling for macroeconomic effects. Similar to the full sample, the coefficient for rating is also economically significant, which implies that the bond's rating explains a great deal of variation in credit spread.

Finally, the fourth column presents the results after controlling for equity market volatility, the interest rate level and the slope of the yield curve. Based on the model's adjusted R squared, adding market-level variables seems to improve the model's fit only marginally. Although the statistical significance of many variables remains unchanged, the economical and statistical significance of the dummy variable for euro-denominated bonds declines notably when these variables are included.

4.3 Robustness checks

To further investigate the robustness of the results, I perform additional regressions using swap rates as the risk-free rates. Feldhütter and Lando (2008) argue that the swap rate is a better proxy for the risk-free rate than Treasury rate for all maturities. Therefore, I calculate the credit spreads using US Libor and Euribor swap rates and replace 1-, 2- and 10-year Treasury rates in the model with the corrresponding swap rates. The Table 5 presents the regression results using the full sample and the issuer-matched subsample.

The regression results show only a small change in premia if swap rates are used as risk-free rates, which means that the findings are consistent with the previous results. The premium for investment grade bonds is highly significant at the 1 % level and its magnitude remains fairly unchanged in both regressions. Again, the premium for high yield and unrated bonds has a negative sign and appears highly significant using the full sample. In addition, the significance of the premium does not persist with the issuer-matched sample, consistent with previous results.

Table 5: Credit Spread Determinants: Robustness Check

This table reports regressions results with credit spread as the dependent variable. Newey-West robust t-statistics are reported in parentheses. Credit spread is the difference between the yield of a bond and a swap rate. Green_IG is the dummy variable for investment grade green bonds. Green_HY&UR is the dummy variable for high yield and unrated green bonds. Bid-ask spread is the difference between the ask and the bid price divided by the mid price in basis points. Bond Age is the time since issuance in years. Ln(Amount) is the natural logarithm of the bond's amount outstanding in millions of US dollars. Maturity is the bond's time-to-maturity in years. Rating is the bond's average rating from Moody's, S&P and Fitch converted into a numerical value. Unrated is the dummy variable for unrated bonds. Callable is the dummy variable for bonds with a call option. EUR is the dummy variable for euro-denominated bonds. Volatility is the equity volatility index in percent. 1y Swap Rate is the 1-year swap rate in basis points. 10y-2y Swap Rate is the difference between 10-year and 2-year swap rates in basis points. The data are at monthly frequency and cover the time period from November 2013 to October 2016.

	Credit Spread	
	Full sample	Issuer-matched subsample
	(1)	(2)
Constant	-254.198^{***}	-256.684^{***}
	(-8.42)	(-5.28)
Green_IG	-30.908^{***}	-29.516^{***}
	(-5.29)	(-5.38)
Green_HY&UR	97.550^{***}	175.293
	(3.55)	(1.08)
Bid-Ask Spread	1.067^{***}	0.315^{***}
	(15.95)	(4.37)
Bond Age	1.683^{**}	0.784
	(2.51)	(1.56)
Ln(Amount)	-2.951	-1.983
	(-1.63)	(-1.23)
Maturity	3.563^{***}	9.947^{***}
	(5.28)	(10.99)
Rating	43.747^{***}	34.901^{***}
	(33.76)	(10.08)
Unrated	413.108^{***}	339.715^{***}
	(26.71)	(14.14)
Callable	-4.128	15.723
	(-1.17)	(1.52)
EUR	-47.274^{***}	-14.826
	(-5.75)	(-1.25)
Volatility	2.664^{***}	1.947^{***}
	(6.67)	(4.79)
1*y Swap Rate*	0.609^{***}	0.670^{***}
	(7.05)	(6.74)
10*y*-2*y Swap Rate*	-0.010	0.161^{**}
	(-0.15)	(2.55)
Industry Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	7,422	3,413
Adjusted R^2	69.97	60.24

*** significant at 1 %
** significant at 5 %
* significant at 10 %

However, there is an econometric issue in the used methodology. The OLS regression assigns an equal weight to each bond observation, regardless of the number of observations per bond, which gives more weight on bonds that have been trading for a longer period during the sample period. In order to correct for such a bias, I perform the regressions using the weighted least squares (WLS) method, in which each observation is assigned a weight based on the total number of observations for a given bond. The conclusion from the WLS regressions is that the results are robust with respect to the regression method.

5 Conclusions

In this study, I have examined whether there is a green premium in the US and Euro corporate bonds prices in the secondary markets, i.e., whether investors are willing to pay a premium for holding green bonds. The premium is estimated by comparing the prices of green bonds with those of conventional bonds with similar characteristics. My data consists of monthly observations of yields for 92 green and 258 conventional bonds between the time period from November 2013 to October 2016. The premium is estimated using the full sample and a subsample including bonds only from the green bond issuers.

I find a statistically and economically significant premium in prices of investment grade bonds, whereas the premium does not persist for high yield and unrated bonds. The findings suggest that investors pay a premium of 28 basis points for holding investment grade green bonds relative to non-green bonds. The magnitude of the premium remains unchanged when using the subsample, which confirms that the premium is not driven by firm-specific factors. In addition, the results are robust to the choice of risk-free rate and regression method.

The results provide further evidence on the relationship between corporate environmental responsibility and corporate bond pricing. The findings support the view that corporate environmental responsibility is not fully captured by credit rating and suggest that investment grade bonds with environmental features have lower credit spreads. In addition, the results provide evidence on the behaviour of socially responsible investors, suggesting that investors accept a lower yield on investment grade green bonds in order to pursue their social and ethical objectives. This is consistent with prior research on socially responsible investing (see e.g. Bauer et al., 2005, Galema et al., 2008, Renneboog et al., 2008).

On the other hand, there are some drawbacks in the properties of the regression model. First, the relationship between the credit spread and the control variables is likely to be nonlinear, which causes errors in the estimated coefficients. Second, estimating a common model for bonds in several industries does not consider factors specific to each industry. For example, the effect of interest rate changes on credit spread is likely to be different for highly rated electric utility bonds than for high-risk renewable energy bonds.

For future research, the premium could be estimated using more complex pricing models, such as nonlinear regression models or by including more explanatory variables to the linear regression model. For example, it would be interesting to investigate whether external review disclosures affect the magnitude of the premium and whether firm-specific characteristics, such as CSR performance, can further explain the premium. In addition, a natural extension to this study would be to investigate the premium using the initial prices of green bonds. When more data becomes available, it would be of interest to examine the premium in different bond markets, such as in municipal bond markets.

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