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ORIGINAL ARTICLE

Are green bonds priced differently from conventional bonds?

Britta Hachenberg[1] · **Dirk Schiereck**[1]

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Abstract The young growing market for green bonds offers investors the opportunity to take an explicit focus on climate protecting investment projects. However, it is an open question whether this new asset class is also offering attractive risk–return profiles compared to conventional (non-green) bonds. To address this question, we match daily i-spreads of green-labeled and similar non-green-labeled bonds and look at their pricing differentials. We find that rating classes AA–BBB of green bonds as well as the full sample trade marginally tighter for the respective period compared to non-green bonds of the same issuers. Furthermore, financial and corporate green bonds trade tighter than their comparable non-green bonds, and government-related bonds on the other hand trade marginally wider. Issue size, maturity and currency do not have a significant influence on differences in pricing but industry and ESG rating.

Keywords Green bond ESG criteria · Corporate financial performance · Credit rating

Introduction

Sustainable and responsible investments (SRI) are estimated to have reached 22.89 trillion U.S. dollars globally in 2016 (Global Sustainable Investment Alliance 2017). In Canada and Europe,[1] which represent two of the three largest markets, bonds account for 64.4% of SRI. Further indicators show that this large market will grow on an accelerating pace within the next years. A total of 409 investors representing more than 24 trillion U.S. dollars in assets signed a statement that emphasizes the need for climate resilient investments.[2] Likewise, more than 1,500 investors representing around 60 trillion U.S. dollars in assets under management have signed the principles for responsible investment (Principles for Responsible Investment 2016). While the SRI market is globally expanding academic research is following. More than 2000 studies have been published since the 1970s about environmental, social and governance (ESG) criteria (Friede et al. 2015). But contrary to the investment shares, the vast majority of empirical studies has been focused on equity-linked relations, with only a small portion looking into fixed income or real estate.

In line with the overall limited research on fixed-income SRI, there is also hardly empirical evidence for a debt instrument that is attracting a fast growing interest of institutional asset managers while it was only recently developed: the instrument helps to invest according to the principles for responsible investment and is named green

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✉ Dirk Schiereck
schiereck@bwl.tu-darmstadt.de

Britta Hachenberg
britta.hachenberg@stud.tu-darmstadt.de

[1] Technische Universitaet Darmstadt, Darmstadt, Germany

[1] Other regions apart from Canada and Europe did not collect data on asset allocation. Canada and Europe together represent more than 57% of sustainable assets (Global Sustainable Investment Alliance 2017).

[2] http://www.iigcc.org/publications/publication/2014-global-investor-statement-on-climate-change.

bonds. The green bond market has grown significantly during the last couple of years but still represents a niche market. Future success in becoming an important contributor to financial markets and sustainable investments will, among others, depend on pricing and performance of green bonds. Pricing of green bonds versus non-green bonds has so far been touched only in research from investment banks, advisory firms and the like. A few bonds are compared to decide if bonds trade "cheap" or "rich." Trading strategies are outlined (Ridley et al. 2016) or indices compared (Preclaw and Bakshi 2015), but the whole population of green bonds has hardly been analyzed so far and existing studies vary in design and results (Bloomberg 2017; Karpf and Mandel 2017; Zerbib 2017). Within this study we compare green-labeled and non-green-labeled[3] bonds of the same issuers and thereby add to the literature that examines pricing of ESG instruments compared to conventional assets.

The majority of ESG studies report positive influence of ESG criteria on corporate financial performance. Friede et al. (2015) provide evidence that positive findings in bond studies are even higher than in equity studies (63.9% compared to 52.2%). Similar results are explored in loan studies (Goss and Roberts 2011). Positive findings can be defined in multiple ways. Firms facing stronger external monitoring through effective government mechanism are rewarded with lower yields and superior bond ratings (Bhojraj and Sengupta 2003). Firms with superior corporate social responsibility (CSR) scores obtain cheaper equity financing as in El Ghoul et al. (2011). Recent studies about the corporate bond market confirm that bonds with high composite ESG ratings have tighter spreads and tend to outperform their peers with lower ESG ratings (see, e.g., Polbennikov et al. 2016). Likewise, investors demand significantly higher stock returns and lenders demand significantly higher interest rates for loans of companies with environmental concerns (Chava 2014). But research also shows that findings are not always positive. There is evidence as well that socially responsible firms do not have lower cost of public debt (Menz 2010). Renneboog et al. (2008) conclude that the question whether CSR is priced by capital markets is still open. To contribute to this discussion, we analyze the pricing of green bonds in comparison to conventional bonds. Our results indicate that green bonds are indeed priced differently from conventional bonds and ESG ratings can explain some of the divergences.

The rest of the paper is structured as follows. The next section provides a literature review and develops the testable hypotheses. Section "Data and methodology" presents the data and methodology as well as the descriptive statistics. Section "Empirical results" documents the empirical results, and "Conclusion" concludes the paper and outlines possible areas of future research.

Sample literature review and hypotheses development

A green bond is a debt security, whose proceeds are used to support climate-related or environmental projects. The ESG approach usually focuses on analyzing the issuer. But the same issuing institutions (being it agencies, financials, corporates, municipals, sovereigns or special purpose vehicles) can issue green and/or non-green bonds. For the decision, if a bond is considered "green," the use of proceeds for specific projects is crucial.

The green bond market is relatively young, and the first green bond was issued in 2007 as a climate awareness bond from the European Investment Bank (EIB).[4] At the same time, a group of Swedish investors, pension funds and investors focused on SRI, developed together with Skandinaviska Enskilda Banken (SEB) and the World Bank the concept of green bonds. Their first bond was brought to market to a wider range of investors in 2008.[5] During the next couple of years, a number of multilateral development banks and other financial institutions issued green bonds, with the first green bonds brought to market by corporate institutions in 2013. In 2016, 81 billion U.S. dollars of green bonds were issued (Climate Bonds Initiative 2017) with the total volume of outstanding green bonds amounting to 166 billion U.S. dollars (Ridley and Edwards 2017).

To avoid information asymmetry between issuers and investors, green bond issues are not only accompanied by regular reporting about use of proceeds. Around 60% are also certified through an external party in the form of a second-party opinion (Boulle et al. 2016), which could be issued by a profit or non-profit organization. For all market participants, issuers, investors as well as the involved consortium, rating agencies and certifying institutions, it is necessary to define the "green label." Efforts have been made through the "green bond principles" (ICMA International Capital Markets Association 2016), first developed by 13 financial institutions in 2014 and updated yearly

[3] Bloomberg tags bonds with a Green Bond label when the use of proceeds is dedicated to mitigating climate change and advancing environmental sustainability solutions. Within this study, the term green bonds always refers to green labeled bonds as defined by Bloomberg, the term non-green bonds to non-green labeled bonds.

[4] http://www.eib.org/investor_relations/press/2007/2007-042-epos-ii-obligation-sensible-au-climat-la-bei-oeuvre-a-la-protection-du-climat-par-le-biais-de-son-emission-a-l-echelle-de-l-ue.htm?lang=en.

[5] http://treasury.worldbank.org/cmd/htm/GreenBond.html.

thereafter. The green bond principles are voluntary guidelines, and thus market participants also call for binding standards which would help develop the market even further (Krimphoff 2016). A second-party opinion, regular reporting, possibly a sustainability consultant or certification and holding proceeds in separate accounts makes the issuance of green bonds more expensive than issuing conventional, non-green bonds. External costs for the issuer, such as a second-party opinion, are estimated to be between 0.3 and 0.6 bps for a 500 million U.S. dollars issue, depending on the level of work (Ceci 2016). Certification of the issue, e.g., through the non-profit organization Climate Bonds Initiative, costs 0.1 bps.[6] Internal costs for the issuer, like establishing the required internal processes for selecting projects and assets, management of proceeds and regular reporting, are very much dependent on the issuer and frequency of issuing green bonds.

The question arises if green bonds and conventional bonds price equally and the issuer has to bear additional costs for issuing green. Research has been conducted to analyze if increased fixed costs for CSR (called "overinvestment" by Goss and Roberts 2011) harm corporate financial performance and thus increase bondholders default risk. Frooman et al. (2008) investigate bonds and stocks and come to the conclusion that positive corporate social performance reduces risk for long-term bondholders without harming stockholders through the addition of fixed costs. Stellner et al. (2015) measure credit ratings and zero-volatility-spreads of corporate bonds and find only weak statistical support that positive corporate social performance results in reduced credit risk. On the other hand though, they show that superior corporate social performance is rewarded in countries with above average ESG performance. Menz (2010) reveals that the risk premium for bonds of socially responsible firms does not significantly differ from that of less responsible corporations. Derwall and Koedijk (2009) measure the performance of socially responsible bond and balanced funds and their matched conventional fund counterparts. Their results indicate that the average SRI fund performed similar to conventional funds, while SRI balanced funds modestly outperform the respective conventional ones by 1.3%. Oikonomou et al. (2011) investigate the impact of corporate social performance on corporate bond spreads and ratings. In general, they show that good corporate social performance is rewarded with lower spreads and higher ratings. Arguments for or against a positive link between corporate social performance and asset performance usually arise from an issuer level. Goss and Roberts (2011), e.g., state that companies with superior corporate social performance have a more favorable risk profile. Chava (2014) shows that lenders price environmental concerns about issuers such as hazardous waste, toxic emissions and climate change concerns. Oikonomou et al. (2011) not only argue from an issuer level, but also state that research has shown that not all components of a bond spread can be explained; thus, corporate social performance could be one of the missing pieces to the empirical asset pricing puzzle. We hypothesize that the green component of the bond is an additional feature for the investor, which leads to higher demand and thus justifies tighter pricing of a green bond.

Hypothesis 1 Green bonds trade tighter than non-green bonds.

The investor benefits in investing in green bonds in various ways. In contrast to conventional (non-project) bonds, he is able to follow the exact use of his proceeds, choose projects which fulfill his requirements and has a complementary source of analysis in addition to his usual credit analysis. He also benefits from the full faith and credit of the issuer, as in case of default he is in line with other creditors of the same ranking. For sustainable investors, the product range is limited. With green bonds, they receive an additional product to invest into. Thus, it appears reasonable to assume that investors would be willing to accept a tighter spread for green bonds than for conventional, non-green bonds. On the other hand, the investor is exposed to risk of "green-washing," i.e., incorrectly labeled green bonds. Since the issuer still has the power to choose if his bond is labeled green and no sanctions are put in place if this labeling is incorrect, the investor could, in the worst case, be made liable for investing in a non-green product from his investor base. Green bonds are issued from the full range of fixed-income issuers across various currencies, rating classes, maturities and issue sizes. A high percentage of green bonds is issued from government-related institutions which on average trade tighter than lower-rated issuers. This leads to the following hypotheses.

Hypothesis 2 Differences in pricing between green and non-green bonds are larger for lower-rated bonds.

Hypothesis 3 Differences in pricing between green and non-green bonds vary across industries.

Data and methodology

To analyze if green bonds trade tighter than non-green bonds, we use data from Bloomberg. We look at the whole population of August 2016 outstanding, labeled green bonds. We exclude 76 municipal bonds and 39 asset-backed securities as these are unique in nature, issued in various tranches and rarely perfectly comparable to other

[6] See https://www.climatebonds.net/standards/certification/get-certified.

issues. This leaves us with 617 bonds. Since liquidity of the bonds is critical for bond pricing (Amato and Remolona 2003; Bao 2011; Driessen 2003; Zerbib 2017), we only include bonds with a new issue volume of at least 150 million U.S. dollars equivalent. The price of smaller issues might get distorted by a liquidity premium the market charges. We recalculate 22 local currencies with their exchange rate at the respective date of new issue into U.S. dollars. Using 150 million U.S. dollars as a threshold, we obtain 199 bonds to proceed our analysis with.

As a next step, we include "plain vanilla bonds" only, i.e., we drop 36 structured bonds (bonds with call options, caps, floors, multi-coupons, linked to an index, etc.) from our sample. We do not drop bonds with make whole calls and calls at par three months before maturity of the bond, which have become very common, especially for corporate issuers.[7] We adjust for 13 bonds which are set up twice, as RegS and 144A tranches, and include one tranche only, the RegS tranche for European issuers and 144A tranche for US as well as Asian and Australian issuers.

Bonds are mostly traded over-the-counter (OTC) and reliable pricing data are not as easily available as for equities (Duffee 1998; Warga 1991). Since the evolution of TRACE[8] a number of bond studies use TRACE data (Bao 2011; Bessembinder et al. 2006; Edwards et al. 2007) to analyze fixed-income securities. TRACE requires broker-dealers who are member firms of the Financial Industry Regulatory Authority (FINRA) to report trades in eligible securities. Eligible securities as defined by FINRA have to be, among others, denominated in U.S. dollars, and not all bond types are eligible yet. Our green-labeled bonds are a global portfolio of all different types of issuers, supranational organizations, development banks, financials, corporates and real-estate companies, issued in various currencies. Therefore, TRACE has pricing data available for only 21% of our green bonds. Thus, we use Bloomberg data in this study, as Bloomberg prices all apart from one security in question. Bloomberg has various proprietary pricing sources, we consider Bloomberg Valuation Services[9] (BVAL) as the most suitable source to use. BVAL combines data from various pricing sources, TRACE, Municipal Securities Rulemaking Board (MSRB), exchanges and broker quotes.

To decide if a green bond is trading cheap or rich compared to a similar bond (similar in terms of issuer, ranking, currency, maturity and coupon, i.e., fixed or floating) we use Bloomberg's i-spreads[10] for the fixed rated bonds. I-spreads are noted in basis points (bps) above a risk-free benchmark, usually the swap rate. In contrast to yields, they have the advantage to separate interest and credit part of the yield. To decide if a similar non-green bond trades significantly different from a green bond we just look at the credit part of the yield.

The i-spreads we use consist of the difference between the yield in question and the interpolated swap rate at the same maturity. We consider swap rates as the better proxy for the risk-free benchmark in contrast to government securities, in line with previous studies (see, e.g., Hull et al. 2004; Zhu 2006). The use of swap spreads as a benchmark compared to government securities has a number of advantages. Cross-country comparisons are more meaningful, "noise" regarding benchmark government securities is excluded and the curve is fully available with no need for stripping (Mann and Fabozzi 2013). In a number of countries, the swap market is also more liquid than the government bonds market. Bloomberg lists more than 220 swap curves, depending on currency, tenor etc. Our bonds are issued in 23 different currencies and for our data we look at the i-spread above 25 different swap curves. For the floating rate notes, we use the discount margin (i.e., spread above their respective benchmark, Euribor, Libor). We download daily historic spreads since issuance of the green bonds up to October 2016. For all spreads, we use the bid side of the market, and transaction costs are not examined. We also do not separate the new issue premium of bonds, which may "cheapen" bonds by a few bps compared to already outstanding bonds of the same issuers in the first couple of trading days.

To avoid the problem of heterogeneity among bonds (see, e.g., Gordon and Viscione 1984), we decide not to use rating classes or indices to compare our sample but to use matched pairs instead. Matched pairs have been used in previous bond studies. Maul and Schiereck (2017), e.g., provide a comprehensive overview of matched pairs used in bond event studies. We match each green bond with two comparable non-green bonds: one with a shorter maturity, and the other one with a longer maturity. In order to be

[7] There is evidence that make whole calls may influence pricing of bonds (Mann and Powers 2003; Nayar and Stock 2008). Analyzed are groups of bonds only though, a "perfect match" of bonds of the same issuers with identical features has not been conducted yet.

[8] TRACE is FINRA's Corporate and Agency Bond Price Dissemination Service that reports OTC secondary market transactions in eligible fixed income securities.

[9] See e.g. https://www.bloomberg.com/enterprise/content-data/pricing-data/for further explanation. According to Bloomberg BVAL provides transparent and highly defensible prices of fixed income securities across the liquidity spectrum. The methodology combines direct market observations from contributed sources with quantitative pricing models to generate BVAL evaluated prices.

[10] Bloomberg's definition of i-spread: "I-Spread is the interpolated bond spread to a benchmark curve. The I-Spread is calculated by taking the interpolated, maturity matched yield on a benchmark curve, and subtracting that value from the selected bond's yield to worst. This differs from a standard benchmark spread, where the selected bond's yield is compared to the nearest already existing point on a curve, rather than an interpolated point."

considered comparable bonds, the non-green bonds have to fulfill the following criteria: (1) bonds must be from the same issuer as the green bond; (2) bonds must have the same ranking as the green bond; (3) bonds must be denominated in the same currency as the green bond; (4) bonds must not be structured (callable, puttable, convertible, dual currency, dual coupon, step up/down coupon, index linked); (5) bonds must be either fixed or floating, depending on the green bonds; (6) issue size must be at least 150 million U.S. dollars equivalent; (7) bonds must be secured/unsecured, depending on the green bonds. For every green bond, we take the two comparable non-green bonds with the closest maturity to their green counterpart. Seventeen bonds do not have two comparable non-green bonds, so this leaves us with a subsample of 132 green bonds to analyze, issued by 73 different counterparts.

As a next step, we define a historic time frame for our analysis. To avoid including bonds that only have a very short remaining maturity and thus no representative trading, we decide not to use historic prices up to date, but a past period instead. We take the period from October 1, 2015, to March 31, 2016, and download daily i-spreads[11] for the comparable bonds. If the non-green bonds are issued after the green bond or matured before our cutoff date for historic prices, March 31, 2016, we take the next closest bonds for which the full data set is available. If no full data set is available, we take the closest bond to the green bond. Thirty of our green bonds were issued after March 31, 2016, and for 37 green bonds not both comparable non-green bonds are available (18 green bonds do not have a shorter comparable bond, 14 green bonds do not have a longer comparable bond, for 2 green bonds their comparable bonds were only issued after our sample period, and for 3 green bonds their comparable non-green bonds had issue amounts < 150 mm USD equivalent). We also exclude 1 bond which is not rated and 1 bond which was only outstanding a few days during our sample period, so this leaves us with 63 green bonds and 126 non-green bonds to analyze. Exhibit 1 provides an overview of the sample selection procedure.

Exhibit 1

Sample selection procedure

This exhibit shows the sample selection procedure to compare green-labeled and non-green-labeled bonds during the investigation period from October 1, 2015, to March 31, 2016. The final sample is used for the empirical analysis throughout the paper.

	Securities
Initial sample	732
Less municipal bonds	−76
Less asset-backed securities	−39
Less volume < 150 million U.S. dollars equivalent	−418
Less structured bonds	−36
Less bonds set up twice, RegS as well as 144A	−13
Less bond not priced by Bloomberg	−1
Less no comparable bonds available	−17
Less bonds issued after sample period	−30
Less not both comparable bonds available for sample period	−37
Less "other"	−2
Final sample	63

The final sample includes 39 issues from government-related institutions (such as development banks, supranational organizations, cities), 12 issues from financial firms, 8 from corporate issuers and 4 from real-estate companies. The high number of supranational organizations and other government-related institutions is also reflected in the high average rating. According to previous literature (e.g., Friewald et al. 2012; Kiesel and Schiereck 2015; Norden and Weber 2004), we recalculate the ratings of our sample by using a numerical 17 grade scale (AAA/Aaa = 1, AA +/Aa1 = 2, …, CCC/Caa1 and below = 17). The mean rating of green and non-green bonds is 3.05 (Aa2/AA). The average remaining maturity of the sample at the end of our sample period is 5 years. We look at 7,032 daily observations of green bonds. Exhibit 2 provides descriptive statistics of the i-spreads of our sample.

Exhibit 2

Descriptive statistics for daily i-spreads of green bonds

This exhibit shows descriptive statistics of daily i-spreads of our sample of green bonds for the investigation period October 1, 2015, to March 31, 2016. Mean, standard deviation, minimum and maximum i-spread are shown in bps. I-spread is the interpolated spread above the bond's respective swap benchmark for fixed rated bonds and discount margin for floating rate bonds.

[11] For simplicity we use the expression i-spread in this study for both, the i-spread above the swap rate for the fixed rated bonds as well as the discount margin above the reference rate for the floating rate securities.

	Mean	SD	Min	Max	N
AAA	12.913	25.000	−25.734	68.458	3241
AA	40.833	38.148	−14.813	144.792	1445
A	79.618	37.905	19.018	205.967	1691
BBB	150.842	62.586	41.048	260.323	655
Total	47.539	55.679	−25.734	260.323	7032

As a next step, we use linear interpolation to align the i-spreads of the two comparable non-green bonds with the respective green bond. For the linear interpolation, we use Isaac Newton's formula

$$i_{\mathrm{M}} = i_{\mathrm{s}} + \frac{i_{\mathrm{l}} - i_{\mathrm{s}}}{t_{\mathrm{l}} - t_{\mathrm{s}}}\left(t_{\mathrm{g}} - t_{\mathrm{s}}\right) \quad (1)$$

where i_{M} is the model i-spread of the non-green bonds, i_{s} the empirical i-spread of the shorter non-green bond, i_{l} the empirical i-spread of the longer non-green bond, t_{l} the time to maturity in months of the non-green longer bond, t_{s} the time to maturity in months of the shorter non-green bond and t_{g} the time to maturity in months of the green bond. Thereafter we compare the daily difference between the empirical i-spread i_{g} and the theoretical i-spread i_{M}.

$$i_{\mathrm{d,t}} = i_{\mathrm{g,t}} - i_{\mathrm{M,t}} \quad (2)$$

For our sample period, we obtain 7032 daily observations for green bonds and 14,064 daily observations for non-green bonds. We also check for ESG issuer ratings. We take data from Bloomberg and look at ratings from the providers Sustainalytics and RobecoSAM. Eleven of the issuers and 12 of the issues of our sample hold a rating from at least one of the two firms. Exhibit 3 shows descriptive statistics of green and non-green bonds.

Exhibit 3

Descriptive statistics of green and non-green bonds

This exhibit shows descriptive statistics of our sample of green and non-green bonds for the investigation period October 1, 2015, to March 31, 2016. ESG rating is on issuer level, and counted are issuers that have a rating by one of the firms RobecoSAM or Sustainalytics as shown on Bloomberg. The mean remaining maturity is calculated from the last day of the investigation period. Amount issued is shown in U.S. dollars equivalent, recalculated at the exchange rate of the issue date of the respective bond.

	Green	Non-green
Issuer	39	39
Government-related issues	39	78
Financials	12	24
Corporates	8	16
Real estate	4	8
Median rating	3.05 (AA)	3.05 (AA)
ESG rating (issuer)	11	11
Amount issued (mean)	810 million	1.7 billion
Amount issued (mean) AAA	959 million	2.1 billion
Amount issued (mean) AA	689 million	1.8 billion
Amount issued (mean) A	708 million	1.2 billion
Amount issued (mean) BBB	593 million	535 million
Remaining maturity	5 years	5 years
Countries	15	15
Currencies	8	8
Total (issues)	63	126
Total (observations)	7032	14,064

Empirical results

To get a better overview, we group the bonds into rating categories from AAA to BBB. Our group of bonds does not include any non-investment grade bonds. For every split rated bond, we use the highest rating category. The results of our analysis are presented in Exhibit 4. The daily delta between green and non-green bonds $i_{\mathrm{d,t}}$ is across all rating classes more negative than positive. AA-, A- and BBB-rated green bonds trade more days and also on average tighter than their comparable non-green bonds. On the contrary, AAA-rated green bonds trade more days wider than their comparable non-green bonds and their average spread is wider than the average spread of the comparable non-green bonds.

Exhibit 4

I-spreads of green bonds versus non-green bonds

This exhibit shows the daily (t) (October 1, 2015 to March 31, 2016) delta between green and non-green (interpolated) bonds, i_{d}. The sample is sorted by rating classes, spreads green i_{g} and non-green i_{M} are shown in interpolated spread terms (bps) above the bond's respective swap benchmark for fixed rated bonds and discount margin for floating rate bonds. Daily i_{d} (tightest and widest), mean and median are also shown in bps.

Rating	*n* bonds	Tightest daily i_d	Widest daily i_d	Mean i_d	Median i_d	*t* tighter	*t* wider	Mean i_g	Mean i_M
AAA	29	−14.51	8.60	0.45	0.64	1,300	1,941	12.91	12.47
AA	14	−15.90	10.12	−0.99	−0.64	934	511	40.83	41.82
A	15	−48.70	43.60	−3.88	−0.83	883	808	79.62	83.50
BBB	5	−32.15	24.57	−2.69	−1.00	367	288	150.84	153.54
Total	63	−48.70	43.60	−1.18	0.04	3,484	3548	47.54	48.72

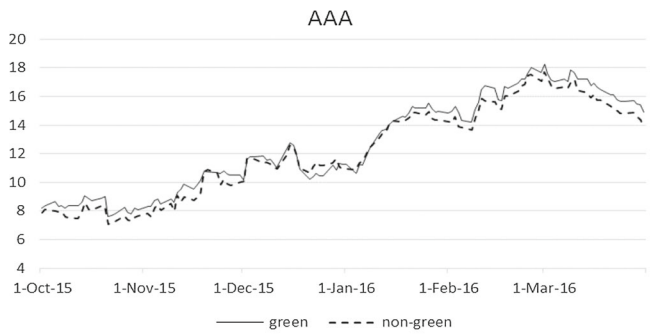
The arithmetic mean of the daily delta between green and non-green comparable bonds shows single A-rated green bond being the richest compared to their non-green counterparts. The delta is relatively small though, green single A bonds trade on average 3.88 bps (4.87%) tighter, AA-rated bonds 0.99 bps (2.42%) tighter and BBB-rated green bonds 2.69 bps (1.78%) tighter than their comparable non-green bonds. Overall, green bonds trade 1.18 bps (2.48%) tighter than their comparable non-green counterparts during our sample period. AAA-rated green bonds on the other hand trade 0.45 bps (3.49%) wider. We will look at the behavior of the AAA-rated bonds more closely while analyzing industry classifications.

Exhibit 5

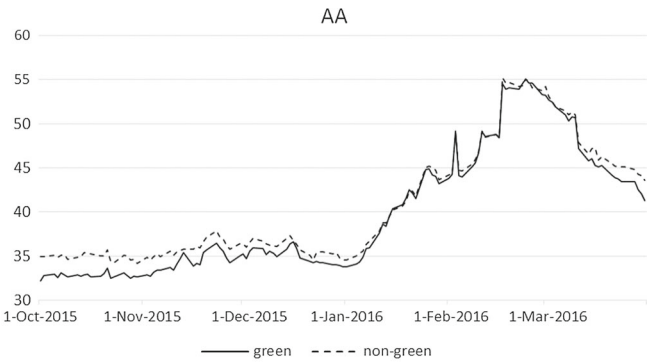
Green bonds versus non-green bonds

This exhibit shows the development of green and non-green daily i-spreads between October 1, 2015, and March 31, 2016, shown in bps. Spreads are calculated in daily means of the sample, and non-green bond spreads are interpolated spreads of comparable bonds.

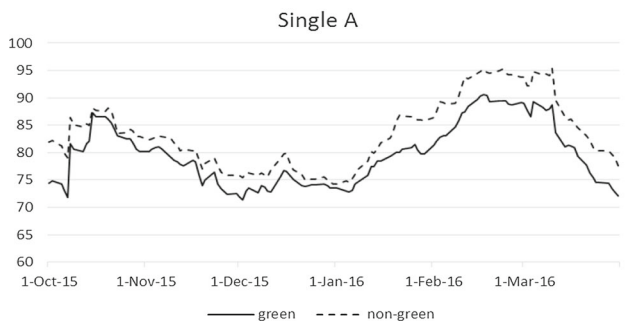
Panel A: AAA rated green bonds vs. AAA rated non-green bonds



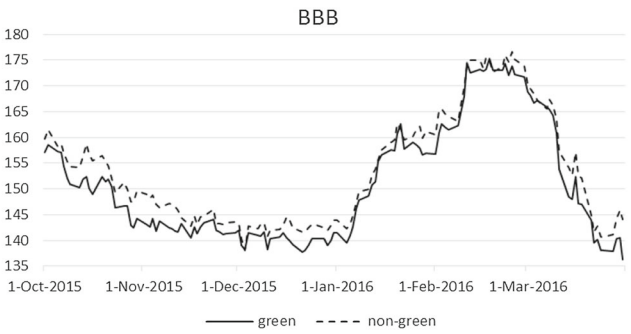
Panel B: AA rated green bonds vs. AA rated non-green bonds



Panel C: A rated green bonds vs. A rated non-green bonds



Panel D: BBB rated green bonds vs. BBB rated non-green bonds



The correlation between green and non-green i-spreads is high, for most rating classes 0.99, for single A-rated bonds 0.94. Exhibit 5 graphically displays average spreads of green bonds and their comparable non-green bonds from October 1, 2015, to March 31, 2016, on a daily basis, grouped by rating classes. Single A-rated green and non-green bonds clearly show the largest pricing differential among ratings examined.

To further investigate if green bonds are priced significantly different from their non-green comparable bonds we use the nonparametric Wilcoxon rank sum as well as the parametric two-sample *t* test. We use the same classification as before, i.e., group our sample by rating classes. We also retain for the green bonds the market observed spread, for their non-green comparable bonds the interpolated spread of the two bonds surrounding the green bond in question. Results of the analysis are presented in Exhibit 6.

Exhibit 6

Results Wilcoxon rank sum and t test for ratings and industries

This exhibit shows the p value results of the Wilcoxon rank sum and *t* test, grouped by ratings and industries. I-spreads between green and non-green bonds are analyzed for investigation period from October 1, 2015 to March 31, 2016. It also shows the correlation r between i-spreads of green and non-green bonds, grouped by ratings and industries for the same sample period.

	Total sample	AAA	AA	A	BBB
N	14,064	6482	2890	3382	1310
p value rank sum	0.107	0.312	0.387	0.000	0.316
p value *t* test	0.209	0.474	0.489	0.002	0.419
$r_{\text{green, non-green}}$	0.989	0.993	0.994	0.936	0.986

	Total sample	Government related	Financials	Corporates	Real estate
N	14,064	9222	1,906	1,888	1048
p value rank sum	0.107	0.753	0.000	0.000	0.126
p value *t* test	0.209	0.732	0.000	0.071	0.566
$r_{\text{green, non-green}}$	0.989	0.995	0.947	0.957	0.995

For the full sample, the statistic results show that green and non-green bonds are not priced significantly different. Thus, despite an economically observed tighter pricing of green bonds, we cannot find statistical significance and need to reject the hypothesis, that overall green bonds trade tighter than non-green bonds. The same results are captured for rating classes AAA, AA and BBB. For single A-rated securities, on the other hand, the Wilcoxon rank sum as well as the *t* test indicates significance, which shows that i-spreads of the two samples green and non-green bonds are different. The results provide support to our second hypothesis, that differences in pricing are larger for lower-rated bonds. With the exception of rating class BBB (the smallest of our sample), the delta between i-spreads of green and non-green bonds gets larger for lower-rated rating classes on an absolute level. Looking at a relative level, this cannot be confirmed though. Thus, our results do not provide full evidence that our second hypothesis can be accepted and therefore needs to be rejected.

To test the results further we separate our sample of bonds by type of industry. We use the group "government related," which includes all supranational organizations, development banks, cities and other government-related issuers. We additionally use the groups "financials," "corporates" and "real estate". This time Wilcoxon rank sum and *t* test show significance for groups financials (both tests) and corporates (Wilcoxon rank sum test). Group financials include ratings AAA, AA and A, and group corporates include ratings AA, A and BBB. The results of the tests indicate already, that we may be able to support our third hypothesis that differences in pricing between green and non-green bonds vary across industries.

Since the issue size of financials and corporates compared to our government-related bonds tends to be smaller and also the issue size of our non-green bonds tends to be larger in most cases than the issue size of the green bonds, we also test the influence of issue size to our sample of bonds. In addition, we want to test for variables which show significance in the Wilcoxon rank sum test, namely industries government related and financials. We also want to investigate features like maturity and currency of the issues. We use a panel regression with the daily delta between green and non-green i-spreads as the dependent variable and the International Securities Identification Number (ISIN) of the bonds as the cluster variable. Our first Model, 1.1, is a random-effects model with the general term

$$Y_{i,t} = \beta_1 \text{Size green}_{it} + \beta_2 \text{Size nongreen}_{it} + \beta_3 \text{Financials}_{it} + \beta_4 \text{Government} + \beta_5 \text{Currency}_{it} + \beta_5 \text{Maturity}_{it} + \alpha + u_{it} + \varepsilon_{it} \quad (3)$$

where $Y_{i,t}$ is the delta of the daily i-spread i_g of the green bonds and the respective model spread of the interpolated non-green bonds i_M at date *t, Size green* is the logarithmized issue size of the green bonds recalculated at new issue date in U.S. dollars, *Size non-green* is the logarithmized issue size of the non-green bonds recalculated at new issue date in U.S. dollars, *Financials* is a dummy variable, which takes value one if the issuer is a financial company and zero otherwise, *Government* is dummy variable, which takes value one if the issuer is a government-related firm and zero otherwise, *Currency* is a dummy variable, which takes value one if the issue is in Euro or U.S. dollars denominated and zero otherwise, *Maturity* is the remaining maturity of the issue, β is the coefficient for the independent variables, α is the intercept, u_{it} is the between-entity error and ε_{it} the within-entity error. We do not account for other firm specific variables, such as leverage, market capitalization, interest rate coverage ratio etc., as conducted in previous literature (Bhojraj and Sengupta 2003; Collin-Dufresne et al. 2001) as the bonds we compare are issued by the same companies. An overview of the dependent and independent variables used throughout this paper is shown in Exhibit 7.

Exhibit 7

Overview of variables

Variable	Description
i_d	Delta of the daily i-spread between green and interpolated, non-green bonds
Size Green	Logarithmized issue amount of green bonds in U.S. dollars
Size non-Green	Logarithmized issue amount of non-green bonds in U.S. dollars
Financials	Dummy variable, which takes value 1 if the issuer of the bond is a financial firm, 0 otherwise
Government	Dummy variable, which takes value 1 if the issuer of the bond is government related, 0 otherwise
Maturity	Maturity of the green bond
Currency	Dummy variable, which takes value 1 if the issue is Euro or U.S. dollars denominated, 0 otherwise
ESG	Dummy variable, which takes value 1 if the issuer is rated by RobecoSAM or Sustainalytics, 0 otherwise
Rating	Highest rating of S&P, Moody's and Fitch, ratings have been coded from 1 (AAA) to 4 (BBB)
AAA	Dummy variable, which takes value 1 if the rating of the bond is AAA, 0 otherwise
AA	Dummy variable, which takes value 1 if the rating of the bond is AA, 0 otherwise
A	Dummy variable, which takes value 1 if the rating of the bond is A, 0 otherwise

We also use a population-averaged model, Model 1.2, which is defined as

$$Y_{i,t} = \beta_1 \text{Size green}_{it} + \beta_2 \text{Size nongreen}_{it} + \beta_3 \text{Financials}_{it} + \beta_4 \text{Government} + \beta_5 \text{Currency}_{it} + \beta_5 \text{Maturity}_{it} + \alpha + r_{it} \quad (4)$$

with the same dependent and independent variables, clustered by ISIN, α as the intercept and r_{it} the error term. Model results are presented in Exhibit 8.

Exhibit 8

Random-effects and population-averaged panel regression (clustered by ISIN)

This exhibit shows coefficients of model results for a random effects (Models 1.1, 2.1, 3.1, 4.1) and a population-averaged panel regression (Models 1.2, 2.2, 3.2, 4.2) testing significance of various independent variables to dependent variable i_d, which is the delta between empirical observed i-spreads of green bonds and interpolated i-spreads of non-green bonds. For a detailed description of panel variables please see Exhibit 6.

	Model 1.1	Model 1.2	Model 2.1	Model 2.2	Model 3.1	Model 3.2	Model 4.1	Model 4.2
Size green	0.295	0.295	0.060	0.061	0.016	0.017	−0.287	−0.288
Size non-green	−0.542	−0.542	−0.571	−0.573	−0.874	−0.876	−0.745	−0.745
Financials	−6.003	−6.003*	−3.713	−3.712				
Government	1.859	1.859	6.646	6.647*	7.930*	7.931*		
Currency	1.063	1.063	1.548	1.549	2.260	2.261	2.029	2.029
Maturity	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
ESG			6.034	6.033*	7.896*	7.895**	4.277	4.278
AAA					4.021	4.021	7.715	7.715
AA					1.661	1.661	4.743	4.743
A					1.505	1.506	−0.138	−0.139
N	7032	7032	7032	7032	7032	7032	7032	7032
Rho	0.740		0.730		0.731		0.746	

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Results of the population-averaged Model 1.2 show that contrary to expectations, neither volume nor currency are significant variables, but the coefficient for the dummy variable financials is significant and negative.

In addition, we test if the existence of an ESG rating has an influence on the delta of our spreads. For the ESG rating we also create a dummy variable, which takes value one if the issuer has at least one ESG rating from Sustainalytics or RobecoSAM and zero otherwise. We use the same panel regression models as before and create our third Model 2.1 for the random-effects panel regression, Model 2.2 for the population-averaged regression, both including the *ESG* dummy variable. This time the population-averaged Model 2.2 indicates that the *ESG* as well as the *Government* dummy variables are significant with a positive coefficient. In a further step we include dummy variables for each rating class apart from BBB, which take value one if the rating is AAA, AA or A and zero otherwise, and leave out the dummy variable *Financials*. We test the same models as before, Model 3.1 with a random-effects panel regression and Model 3.2 with a population-averaged panel regression. This time both models, Model 3.1 as well as Model 3.2 show significance for *ESG* as well as the *Government* dummy. In a last step we leave out the dummy variable *Government* and conduct the same analysis using Model 4.1 for the random-effects regression and Model 4.2 for the population-averaged regression. This time no variables are significant. We use the same regressions with the cluster variable issuer to test our models. Nearly all variables show high levels of significance. Results are presented in Exhibit 9.

Exhibit 9

Random-effects and population-averaged panel regression (clustered by issuer)

This exhibit shows coefficients of model results for a random effects (Models 1.1, 2.1, 3.1, 4.1) and a population-averaged panel regression (Models 1.2, 2.2, 3.2, 4.2) testing significance of various independent variables to dependent variable i_d, which is the delta between empirical observed i-spreads of green bonds and interpolated i-spreads of non-green bonds. For a detailed description of panel variables please see Exhibit 6.

	Model 1.1	Model 1.2	Model 2.1	Model 2.2	Model 3.1	Model 3.2	Model 4.1	Model 4.2
Size green	0.276	0.285	0.274	0.268	.690***	.723**	.687***	.709*
Size non-green	−1.352***	−1.310***	−1.354***	−1.319***	−.630***	−.682**	−.636***	−.706**
Financials	−5.297	−5.209**	−3.395	−3.356				
Government	3.549	3.561*	8.007*	7.991***	23.315***	22.109***		
Currency	2.718***	2.614***	2.726***	2.652***	1.580***	1.495**	1.565***	1.435*
Maturity	−0.000	−0.000	−0.000	−0.000	−.0007***	−.001***	−.001***	−.000**
ESG			5.732	5.697**	10.731**	10.347***	−3.546	−2.941
AAA					−6.098	−5.396	2.062	2.552
AA					−14.530***	−13.291***	−12.824***	−10.940**
A					8.047*	7.352**	9.386*	8.152*
N	7032	7032	7032	7032	7032	7032	7032	7032
Rho	0.740		0.730		0.722		0.734	

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Exhibit 8 documents that only a couple of variables in some of the tested models show significant values. Therefore, we have to be cautious when interpreting the results. However, we interpret specifically the findings for model 1.2 as at least weak evidence in favor of a significant positive effect in direction of tighter spreads for issues by financial institutions. This finding supports hypothesis 3. Neither issue size of the bond nor maturity or currency have significant impact on the pricing differentials, but we see evidence for the industry (notably government related and financials), as well as the existence of an ESG rating. During our sample period, government-related green bonds tend to trade marginally wider than non-green bonds, with a positive coefficient of the dummy variable *Government*. As the same behavior was identified for the AAA-rated bonds, we double-check groups government related and AAA-rated paper and it becomes obvious that all but one of the AAA-rated bonds is issued by a government-related issuer. Financial green bonds tend to trade tighter than their comparable non-green counterparts, with a negative coefficient of the dummy variable *Financials*. One possible explanation for this difference in pricing can be seen from an issuer perspective. Government-related issuers are actively promoting growth of the green bond market and may fear that tight pricing of green bonds compared to non-green bonds might hurt market growth. The EIB, e.g., states on their climate awareness bonds factsheet[12] that "… EIB is committed to provide leadership in climate finance". The same factsheet points out that no premium is charged for their climate awareness bonds, climate awareness bonds are priced like other EIB bonds of comparable size and maturity. Similar statements are made by Kreditanstalt für Wiederaufbau (KfW) in their brochure about green bonds (KfW 2016). Nearly 50% of our government-related bonds are issued by EIB or KfW.

Financial issuers on the other hand might be more pricing sensitive. A different explanation could result from an investor perspective. Dedicated sustainability, green bond and ESG funds are naturally looking for the highest return for their investor base and their demand for single A-rated securities might be larger than for AAA- and AA-rated securities. On the other hand BBB securities might be too close to non-investment grade and investors might fear downgrade rating migration. We have to bear in mind though that our group of BBBs was small, for larger groups results may be different. Looking at our results investors might come to the conclusion that AAA and government-related green bonds offer good value compared to non-green bonds. However, single A-rated and financial non-green bonds might offer better value compared to green bonds if the investor does not need to buy "green." Both industry classifications, government-related issuers and financial issuers, are rather broad; thus, it is only possible to draw preliminary conclusions. Once the universe of green bonds is larger, additional research may be conducted to test the results further. Our dummy variable ESG is significant and, surprisingly, positive. This could mean that if an issuer has an ESG rating, dedicated ESG investors might not be "forced" to buy a (often smaller) green bond issue but can instead also buy the comparable non-green bonds, since the issuer and thus all issues may be considered ESG conform.

Conclusion

The majority of empirical research on ESG so far documents that financial instruments of companies that follow the ESG approach perform better than financial instruments

[12] http://www.eib.org/investor_relations/documents/eib-cab-factsheet.htm.

of companies who do not follow this approach. We look at green and comparable, non-green bonds over a sample period from October 1, 2015, to March 31, 2016. Comparing daily i-spreads of 7032 green bonds and 14,064 non-green bonds, we first provide evidence that green bonds on average do not trade significantly tighter than their counterparts. However, pricing differentials are economically most obvious and show statistical significance for single A-rated bonds, with green bonds trading 3.88 bps (4.87%) tighter than comparable non-green bonds. Green bonds with rating classes AA and BBB trade economically tighter than their non-green comparable bonds, but we could not find any statistical significance. Although issuing green bonds is more expensive than issuing non-green bonds, the difference in pricing between green and non-green bonds for rating classes AA, A and BBB could potentially make up for external costs the issuer has to bear, like a second-party opinion and a possible certification of the transaction.

Analyzing the pricing differentials further, our results indicate that significant are neither maturity, nor volume or currency, but rather industries, namely government-related and financial issuers, as well as the existence of an ESG issuer rating. Government-related green bonds trade marginally wider than comparable non-green bonds, and on the contrary, financial green bonds trade tighter than non-green bonds.

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Britta Hachenberg received her German diploma from the University of Applied Sciences, Cologne, Germany, in 2000. In the same year, she joined the investment bank Goldman Sachs and held various roles in Frankfurt and London as an Executive Director until she left the bank in 2016. Since 2016 she is a doctoral student at the chair of corporate finance at Darmstadt University of Technology and in 2018 she started as an Assistant Professor at TH Koeln, Cologne. Hachenberg is a member of the advisory board of Koelner Boersenverein e.V. and focuses her research on capital markets and banking regulation.

Dirk Schiereck obtained his Master's Degree (German diploma) in Economics from Kiel University and his Ph.D in Business Administration and Banking from Mannheim University, where he also finalized his habilitation in 2000. After 2 years at the Institute for Mergers and Acquisitions of Witten/Herdecke University, he spent 6 years at the European Business School. In 2008 he received an appointment for the Chair of Corporate Finance at Darmstadt University of Technology. Schiereck is a member of the Scientific Advisory Boards of DDV—Deutscher Derivate Verband (the German Derivatives Association) and DKS—Deutsche Kreditmarkt-Standards.