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The Green Bonds Premium Puzzle: The Role of Issuer Characteristics and Third-Party Verification

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Abstract: If we examine the characteristics of a sample of green bonds matched with their closest brown bond neighbors, we encounter a challenge. Green bonds have higher yields, lower variance, and are more liquid. The institutional/private issuer and the green third-party verification/non-verification breakdowns help explain this puzzle. Green bonds from institutional issuers have higher liquidity with respect to their brown bond correspondents and negative premia before correcting for their lower volatility. Green bonds from private issuers have much less favorable characteristics in terms of liquidity and volatility but have positive premia with respect to their brown correspondents, unless the private issuer commits to certify the "greenness" of the bond. An implication of our findings is that the issuer's reputation or green third-party verifications are essential to reduce informational asymmetries, avoid suspicion of green (bond)-washing, and produce relatively more convenient financing conditions.

Keywords: green bonds; environmental sustainability; bond yields; liquidity

JEL Classification: Q01 Sustainable Development Asset; G10 General Financial Markets; G12 Asset Pricing • Trading Volume • Bond Interest Rates

1. Introduction

Sustainable development is one of the most important goals that humankind must attain in the coming years. The achievement of sustainable development includes the reduction of the carbon footprint, which is crucial for keeping the growth of the world temperature within reasonable limits, such as limits that prevent climate disasters such as small island and coastal area disappearance due to the rise of ocean levels. In order to reach the target, changes in production and CONSUMPTION patterns through what is called "green investment"—investment that modifies the current production standards fostering the adoption of technologies that support the circular economy and reduce the carbon footprint of production and consumption—is of utmost importance. These are the reasons why understanding the mechanisms of green investment financing is of particular interest for scholars and for policymakers.

Our paper contributes to this field by identifying the specificities of green bond characteristics with respect to their closest "brown" counterparts in terms of yields, liquidity, and volatility, and by considering the role of only partially explored factors such as the institutional and private characteristics of the issuer and the presence or absence of green third-party verifications.

Our contribution is original in a new field of literature that has mainly concentrated on the identification of the green bond premium and on co-movements of green bond prices with other relevant financial assets with mixed findings. Zerbib [1] showed that there is a mostly negative green bond premium, which is especially high in some market segments, claiming that the rating and the amount issued are the main drivers of the premium. Wulandari et al. [2] analyzed how liquidity

risk affects the yield spread between a couple of matched green and brown bonds, arguing that liquidity risk is negligible for green bonds. Reboredo [3] found that green bond returns are strictly correlated with corporate and treasury bond returns, whereas they weakly co-move with stocks and energy commodities. Karpf and Mandel [4], analysing a sample of bonds issued by the US municipal bond market, showed that the green bond premium has been positive in the last years. Hachenberg and Schiereck [5] reported that green bonds rated AA-BBB trade tighter with respect to their similar non-labelled bond as well as financial and corporate green bonds, whereas government green bonds trade marginally wider. Glavas and Bancel [6] studied the determinants of green bond issuance and showed that agency motive and state-driven stakeholder motive are their key determinants.

The originality of our paper within this body of literature is in examining three bond characteristics (i.e., yields, volatility, and liquidity) and focusing on the role of the private and institutional issuer and the green (third-party) verification/non-verification breakdowns as key factors to explain the mixed findings reported in the literature. We provide an interpretation of the observed aggregate puzzle of green bonds, i.e., their higher yields in the presence of higher liquidity and lower volatility with respect to their brown bond counterparts. More specifically, we document a considerable difference between private and institutional green bond issuers. In the case of private issuers, we found significant positive premia for private green versus brown bond issuers in the presence of relatively lower liquidity and slightly lower volatility. On the contrary, institutional issuers have negative premia, before correcting for their lower volatility, and much higher liquidity and lower volatility. We also found that private issuers of green bonds without third-party verification have significantly higher premia and lower liquidity than their private verified counterparts. A likely interpretation of our findings is that institutional issuers (e.g., World Bank) have attracted large institutional investors allocating significant resources to fixed income and having a strategic interest in investing in climate-change-related projects. In addition, institutional issuers have transparency and information rules that increase their effectiveness in reducing informational asymmetries and overcoming investors' doubts on the effective greenness of their products. Our findings show that a similar reputational result can be obtained by private issuers through external green verification. Hence, the higher on average premia of green bonds mainly reflect exposure to greenwashing risk of green bonds of private issuers non-verified by third parties.

Note that the term "greenwashing" includes companies that declare a commitment to environmental responsibility that is greater than in reality. The benefit of greenwashing (temptation function) is the advantage gained in terms of reputation and the willingness to pay of environmentally-sensitive consumers. The cost of greenwashing (punishment function) is the "sanction" arising when the public becomes aware of the gap between declarations and facts. As an example of these costs, consider the case of Volkswagen whose stock recorded a 20% loss on 21 September 2015 after the Environmental Protection Agency's notice of violation became public. The price remained 30% lower at a one-year distance.

2. The Development of the Green Bond Market

A green bond is defined as a "plain-vanilla" fixed income product that offers investors the opportunity to participate in financing green projects, helping to mitigate climate change and supporting countries in their climate change adaptation plans. A key feature of green bonds is the due diligence process that the issuer is expected to conduct to identify and monitor the projects [7]. As clarified by the United Nation Development Program (UNDP) green bonds have no other differences from conventional bonds; their only unique characteristic is the specification that the proceeds from bond sales have to be invested in projects generating environmental benefits.

A substantial boost to the green bond market was provided by the Copenhagen Accord in 2009, establishing that financial markets have to play a central role in the fight against climate change through the mobilization of private investments for mitigation and adaptation projects. Several major economies agreed that the best strategy to boost investment needed to prevent air pollution, and the

consequent enhancement of the global temperature, was to create and promote financial products that appeal to investors with a substantial asset base. Green bonds were therefore considered the main example of an innovative fixed-income investment product that could activate a significant amount of capital to finance the fight against climate change. Green bonds are extremely effective in this regard due to their standard financial characteristics bundled with the dedication to environmental issues. This feature makes them desirable for a wide range of investors, from retail and high-net-worth to institutional investors who have a separate asset class for climate-oriented investments, or to socially conscious investors who have specific environmental strategies. From the issuer's point of view, green bonds have been proven to produce several benefits: diversification of the investor base, providing the potential to enjoy long-term pricing advantages; pro-active messages to stakeholders on environmental sustainability; and appealing to millennials as employees and customers. In this respect, developments in the financial markets have clearly confirmed that an issuer can broaden its investor base by providing green products and that investors are focusing on climate-related investment opportunities as part of their fixed income allocation [7] (the World Bank green bonds, for example, appealed to large institutional investors who had both significant allocations to fixed income and a strategic interest in investing in climate-change related projects, and reached investors who would not otherwise have purchased World Bank bonds [8]). From this perspective, corporations are increasingly starting to realize that managing environmental exposure may be more than just risk management and it may actually improve their economic performance. With the potential for progressively tighter ecological requirements for national and multi-national companies, environmental sustainability and profit maximization may actually work cooperatively.

2.1. The Growth in Green Bond Emissions

The first green bond was issued in June 2007 by the European Investment Bank. The Paris Climate Agreement of 2015 later pushed for renewable energy investments and other initiatives to reduce global warming, when 195 countries adopted the first-ever legally binding global climate deal. The deal includes an action plan to avoid dangerous climate change and limit global warming below the threshold of 2 °C. After being flat for three consecutive years, CO_2 emissions grew by 1.4% in 2017, reaching a historic high of 32.5 gigatons due to higher energy demand and the slowing of energy efficiency improvements. [9] The increase in CO_2 emissions, however, was not across all countries. While most major economies saw a rise, some others experienced declines, including the United States, the United Kingdom, Mexico, and Japan. The biggest drop occurred in the United States mainly because of the higher deployment of renewables. This means the current climate action effort is too weak to meet the target of staying 2 °C below the global energy-related CO_2 emissions limit. According to the Climate Bond Initiative estimates, although 2017 was an encouraging year, the green bond market should reach 1 trillion USD by 2020 in order to produce a concrete impact on climate targets [10].

The progressive development of the green bond market is trying to support this difficult and ambitious task by providing financial resources for the required investments. After the issuance of the first AAA-rated green bond in 2007 by European Investment Bank (EIB), the wider green bond market expanded in March 2013 after the first USD $1 billion green bond was sold within an hour by the IFC. The yearly issuance of labelled green bonds in 2014 reached USD $37 billion, which is over three times the 2013 issuance, and it grew further the following year to USD $40 billion issued by 2015. In the meantime, the broader unlabeled "climate-aligned" bond market was valued at USD $600 billion in June 2015 [11]. In 2017, green bond issuance was almost USD $157 billion, reaching a new record [10]. The volume of issuances is practically doubling year after year, whereas the portion of corporate green bonds (both financial and non-financial) is constantly growing, with 146 new private issuers entering the green bond market in 2017. Large corporate issuers today include SNCF, Berlin Hyp, Apple, Engie, ICBC, and Credit Agricole.

2.2. Standards and Regulation

To keep pace with the progressively growing green finance market, domestic and transnational institutions are promoting guidelines, regulations, and incentives. A number of initiatives are underway to harmonize differences between regional standards and definitions. The European Commission, for instance, introduced a High-Level Expert Group on Sustainable Finance (HLEG) in late 2016 that has been working toward defining clear recommendations to support the development of green finance and establish common European green bond standards. The recommendations of the HLEG and the new "European taxonomy for sustainable finance" formed the basis for the action plan on sustainable finance adopted by the Commission in March 2018. Other national financial institutions, standard setters, and regulatory bodies are cooperating around the world to re-assess and unify green bonds principles and criteria. The EIB and China's Green Finance Committee have recently published a white paper identifying differences between the European and Chinese green bond standards to work on convergence in the future. The ASEAN Capital Markets Forum launched the ASEAN Green Bond Standards in November 2017, which will improve transparency and unification of the market and ensuring investors have access to sufficient information. To date, the most important and widely accepted initiative at the international level is the "Green Bond Principles" (GBP) [12]. The GBP are voluntary guidelines that encourage transparency and disclosure and promote integrity in the development of the Green Bond market by clarifying the procedure for issuance of a green bond. In particular, the GBP recommends that issuers use an external review to certify green definitions and criteria and the processes and systems applied.

The European Commission Technical Expert Group (TEG) report on Sustainable Finance [13] suggests a refinement of indicators for green bond issuers, arguing that companies should consider disclosing their green bond ratio (the proportion of the total green bond outstanding amount over the total bond outstanding amount) or their green debt ratio (total amount of green bond or green debt instruments over the total debt amount) in order to transparently communicate the intensity of their overall low carbon transition plan beyond the individual green bond issue.

If governments and financial institutions are working to harmonize standards, they are providing incentives to promote the issuance of green financial instruments. Several national and international initiatives have been launched to diversify portfolios away from carbon-based investments and redirect assets toward more environmentally-friendly projects. For example, in December 2017, the European Commission announced willingness to lower capital requirements for lending against energy efficient buildings and electric cars.

The crux of the matter remains how to determine whether the bond may be classified as green or as conventional. Demand for accessible information on the use of proceeds has grown in parallel with the expansion of the green bond market, as investors require knowing exactly where their money is going. Thus, in addition to evaluating the standard characteristics of the security (such as maturity, coupon, price, and credit quality of the issuer), financial market players want to be able to assess the specific environmental impact of the projects that green bonds intend to support. An objective evaluation of the environmental benefits has been a key question since the market started to grow. The reputational risk for green bonds issuers, i.e., when bonds labelled as green are found not to be green, is high and can have an impact on investor trust. For these reasons, rating agencies recently started to include evaluation on the greenness of financial products in order to help investors when choosing their portfolio allocations. In addition, a broad network exists of non-financial rating agencies, of "second" and "third opinion", and auditing agencies. However, labelling and the use of external reviews are not yet mandatory, and according to the CBI Report [10], only 60% of green bonds are externally reviewed.

To summarize, green bond authenticity is based on invisible characteristics subject to asymmetric information. In this paper, we analyzed the consequences of greenness on bond performance and how asymmetric information about genuine green characteristics affects issuers with different reputation and issues with and without green verification.

3. Research Hypothesis

Based on the above considerations, our research questions include:

1. The green adjective defining the bond issue may create, per se, a difference in terms of bond pricing, liquidity, and volatility on secondary markets;
2. The effects of the issuer's characteristics on asymmetric information and greenwashing risk perceived by investors, and, therefore, on the green bond premium.

For point (1), several theoretical reasons support why this may be the case. First, in the presence of the same characteristics and financial conditions, environmentally concerned investors may be willing to receive a lower yield for environmental responsibility, and as a consequence, the yield difference between the green bond and its brown correspondent should be negative. Roe et al. [14] found that investors are willing to receive a lower yield when emission reductions stem from the increased reliance upon renewable fuels, suggesting that several product features could help explain real price premiums. Kaenzig et al. [15] showed that consumers are willing to receive a lower yield of about 16% for an upgrade from the current average German default electricity mix to a more environmentally-friendly default electricity mix. Rommel et al. [16] found that, compared to investor-owned firms, willingness to receive a lower yield for renewable energy doubles when offered by cooperatives or municipally-owned electricity utilities, claiming that public policy may reduce information asymmetries and foster labeling of green energy products.

With respect to point (1) (related to volatility), green bonds should be (coeteris paribus) relatively less exposed to the specific source of stakeholder risk related to environmental lack of responsibility. As a consequence, they may attract relatively higher demand from risk averse investors. Amiraslani et al. [17] showed that firms with high corporate social responsibility (CSR) better resist financial crisis probably because they are trusted more by financial investors. Bauer et al. [18] observed that environmental concerns are positively correlated with a higher cost of debt and lower credit ratings. Graham et al. [19] reported that environmental information has a significant impact on bond rating. Oikonomou et al. [20] analyzed the impact of CSR on bond pricing and claimed that corporate social transgressions are penalized through higher corporate bond yield spreads. Becchetti et al. [21] documented that CSR risk is an additional orthogonal risk factor to which stocks are exposed in Fama–French multi-factor capital asset pricing models. Becchetti et al. [22] found that stocks with higher environmental reputational risk have, coeteris paribus, lower price-earnings ratios. Sharfman and Fernando [23] showed that lower environmental risk is associated with a lower cost of capital.

Based on the above considerations, we tested the following null hypotheses:

Hypothesis 0 (H0). *No green bond premium.*

Under our null hypothesis, there should be no difference between green and brown bonds once we consider yield differentials between green and brown "twins" that have the same characteristics. Rejection of the null may be related to one of the above described rationales proposed in the literature for the difference between green and brown investments. A negative premium is expected if, coeteris paribus, investors are willing to pay for the environmental features of green bonds or they address relatively higher demand to a class of bonds that is relatively less exposed to a source of risk orthogonal to those traditionally considered (i.e., idiosyncratic non-diversifiable risk, bankruptcy risk, small size risk, etc.), such as stakeholder risk.

We also consider that the premium may be affected by informational asymmetry in point (2). If bonds are not green certificated, the risk of greenwashing is higher, and investors may require a premium. The private or institutional characteristics of the issuer may also affect the premium in a framework of asymmetric information since an institutional issuer has a higher reputation and is more likely to be believed as effectively using financial resources for green investment.

Hypothesis 1 (H1). *No difference in liquidity in the secondary market.*

Under the null hypothesis, there should be no difference in liquidity between green and brown bonds.

Rejection of the null may be interpreted on several grounds. By assuming that the market microstructure for green and brown bonds is the same (i.e., same market makers with the same characteristics), bonds that are traded with a higher frequency tend to have more potential buyers and greater liquidity than bonds traded at a lower frequency. For this reason, if green bonds are able to attract a higher (lower) number of investors and transactions they may end up being more (less) liquid with respect to their brown twins.

Hypothesis 2 (H2). *No difference in yield (price) volatility in the secondary market.*

The null hypothesis here states that there is no difference in risk exposure between green and brown bonds that have the same characteristics. Rationales for the rejection of the null may be found in the literature, arguing that green bonds are exposed to an additional source of (greenwashing) risk. Conversely, we have already provided ample theoretical and empirical evidence on the relatively lower exposure of green bonds to stakeholder risk. The two opposite effects may or may not offset each other.

3.1. Matching Method and Dataset

As is usually the case, the best methodological approach for testing this research question is unusable since the counterfactual information (what would have happened if the same bond would not be "green"?) is not available. The second best to a full-fledged randomized experiment is also impossible since it requires that both treatment and control, respectively green and brown bonds, are issued after the experiment starts and with ad-hoc procedures that satisfy randomness. Hence, randomized experiments cannot be used to evaluate the impact of already existing or existed bonds. We were therefore obliged to use the third best approach that uses econometric specifications to compare bonds that are as similar as possible to each other, except for the greenness.

Based on these considerations, to analyze the yield spreads between green bonds and their closest "brown" (non-green) neighbors, we adopted an exact matching method. Matching methods have been widely used in the financial literature to compare responsible versus conventional funds [24–26] and to measure bond credit risk and the effect of volatility on returns. Other studies [27–29] used pairs of matched bonds to control for credit risk. Helwege et al. [30] and Dick-Nielsen et al. [31] used this approach to evaluate liquidity premia.

More specifically, bonds defined as "green" in our sample were those defined as such by the issuer itself and listed in the Climate Bonds Initiative website. Within the green bond group, we defined a subgroup of the green bonds as "certified" if they meet one of the following two criteria: (1) they meet the CBI-defined requirements; (2) they have been externally certificated by a third party (Figure 1). The role of an external review mainly involves avoiding adverse selection and green washing through third-party verification of green value creation, showing the issuer's capability to implement the program, and the likely realization of the output promised. Green bond assessment is based on the verification of the corporate use of proceeds (renewable energy, clean water, etc.), the management of proceeds (tracking of proceeds and audit), and ongoing reporting (monitoring and environmental impact).

For each green bond in the dataset, we searched for a brown bond that was the nearest neighbor in terms of selected crucial characteristics (Table 1). In particular, we required that the two bonds: (1) were issued by the same organization (including supranational, municipal, and corporate institutions), (2) had the same currency, (3) had the same rating (Moody's rating or, when not available, S&P

rating), (4) had the same bond structure, and (5) had the same coupon type (we only considered fixed rate bonds).

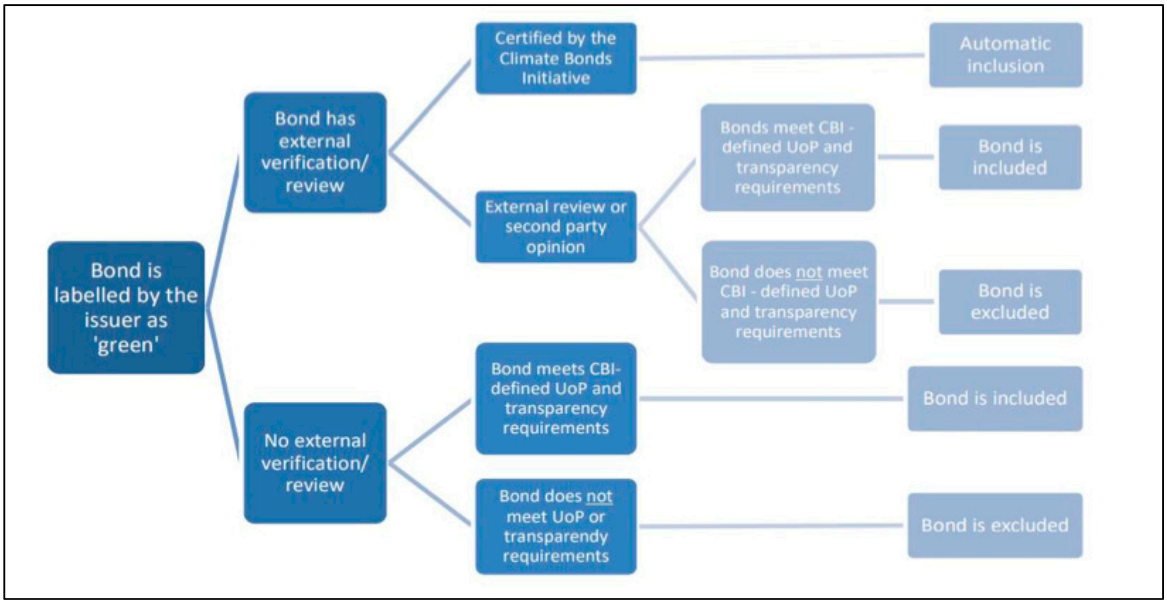

Figure 1. Green bond database inclusion assessment explained. Source: Green Bond Market Summary [32] Q1 2018.

For the maturity date, the coupon rate, and the amount issued, given the impossibility of finding two bonds with exactly the same characteristics, we based the matching method on specific thresholds in order to find a brown bond that was as similar as possible to its closest green bond correspondent. For the maturity date, we allowed for a maximum two-year lead/lag. For the amount issued, we considered amounts up to four times larger or smaller. Finally, for the coupon rate, we accepted values at most 0.25 higher or lower than the green bond rate (when defining matching criteria, we faced a trade-off between the number of matched bonds and accuracy of the matching. For the coupon rate, we chose a threshold that was slightly larger with respect to Helwage et al. [30] that, in order to study the effect on liquidity on the yield spread, fixed 1.5% as the maximum difference in coupon rate. For other criteria, we followed Zerbib [1]). In order to control for a possible bias arising from the mismatch, we controlled for these variables in our econometric analysis. All criteria used for the matching are summarized in Table 1.

Table 1. Matching method between green and brown bond.

Bond Characteristic	Matching Criterion
Amount issued	±400%
Coupon rate	±0.25%
Maturity date	±2 years
Currency	Same
Issuer	Same
Rating	Same
Coupon type	Same (fixed rate)

In addition to the above described one-to-one matching, when deemed necessary, we created a synthetic bond through a linear combination of two otherwise unmatched bonds in order to meet our matching conditions. We did so when we found two brown bonds with a slightly higher coupon rate (max. 0.5% over the threshold) or slightly lower (max. 0.04% under the threshold) with respect to the

matching condition. In these cases, a linear combination allowed us to create a synthetic matched bond. In our dataset, three green bonds were matched with a synthetic bond using this approach.

Based on these principles we identified 89 bond couples (corresponding to 179 different bonds, more than twice the 89 couples due to the synthetic bond cases) (details of each bond are provided in the Appendix A). For these bonds, we included in the dataset daily observations of ask price, bid price, and redemption yield in the period spanning from 1 January 2013 to 31 December 2017. By doing so, we could compare green and brown bonds with similar characteristics that were traded in the same day. These bonds had the same credit risk, bond characteristics, and were exposed to the same market shocks. Thus, their yields do not differ because of credit risk, taxes, or market risk. Ask and bid official prices, returns and issuer, and bond characteristics were downloaded from Datastream (see Table 2 for variable legend). Yields were computed as net present value (NPV) considering the amount of money paid for the bond and relating this to the future dividend and capital payments. The issued amount was converted to dollars considering the exchange rate on the issuing date. Liquidity was computed using the bid-ask spread (price bid–price ask); hence, by construction, a higher value is associated with higher liquidity. Zero trading day (ZTD) was a dummy variable that took a value of 1 if there had not been any trade during the whole day. Finally, delta liquidity, delta yield, and delta ZTD were computed using the difference in daily returns, daily liquidity, and the daily ZTD dummy variable, respectively.

Table 2. Variables legend.

Variable Name	Variable Description
Agency	Rating agency
Amount	Amount issued (national currency)
amount dollar	Amount issued (USD)
Bond type	Bond type
Borrower	Name of the issuer of the bond
C_type	Coupon type (fixed or floating)
Country	Country of risk
Coupon	Coupon rate
Currency	Currency of amount issued
Date	Date
Green	Dummy variable equal to 1 if the bond is green and 0 otherwise
I_year	Issue year
Id_pair	Number identifying the green-brown pair
Isin	International Securities Identification Number for the bond
Issue Date	Issue date of the bond
Verified	Dummy variable equal to 1 if the green bond is third-party verified and 0 otherwise
Pask	Ask price (Datastream)
Pbid	Bid price (Datastream)
Institutional	Dummy variable equal to 1 if the bond is issued by national governments, municipalities or supranational institutions such as World Bank and 0 if private institution
Rating	Rating of the bond by Moody's (from C to AAA)
Sector	Industry sub-sector description
Time	Number that identifies the trading day
Time to Maturity	Number of days to reach maturity date
Zero Trading Day (ZTD)	Dummy variable equal to 1 if the bond has not been traded during the whole day and 0 otherwise
Liquidity	Difference between the bid and the ask price
Yield Standard Deviation (SD)	Bond yield standard deviation computed ex post

The summary statistics for the abovementioned variables are reported in Table 3. The average green bond yield was positive and around 200 bps. Non-trading days were around 5.5% of the overall sample trading days for both the green and brown bonds. The bid-ask spread of green and brown was close from a descriptive point of view (27 against 22 bps, respectively). The green bond yield was slightly higher (2.03 against 2.01) and brown bonds appear to have been more volatile. Time to maturity of brown bonds was on average one month higher. The distribution of coupon and amount

was almost the same in the two groups. These descriptive statistics across green and brown groups were independent from the matching between green and brown bonds with the closest characteristics.

Around 34% of the green bonds had an institutional issuer (national government, municipality, or supranational institution, such as the World Bank), whereas 22% were bank issuers. The majority were American (22.15%), around 17% from Germany, 11% from Sweden, and 10% from Luxembourg. The currencies were mainly USD (about 44%) and Euros (23%). Concerning the rating, the vast majority of bonds in our sample were top rated (AAA) (around 62%). A synthesis of these sample statistics is provided in Figure 2.

Table 3. Descriptive statistics for green and brown bonds. Perc. = percentile.

Green Bonds	Count	Mean	SD	1st Perc.	25th Perc.	50th Perc.	75th Perc.	99th Perc.
Yield	39,333	2.03	2.55	−0.45	0.39	1.54	2.45	11.82
Price ask	38,435	100.87	4.71	79.68	99.55	100.62	102.40	115.53
Price bid	38,513	100.64	4.69	79.63	99.41	100.41	102.16	115.02
Liquidity	38,435	−0.22	0.34	−1.75	−0.26	−0.13	−0.08	−0.011
ZTD	39,333	0.053	0.225	0	0	0	0	1
Yield SD	39,329	0.06	0.074	0.01	0.033	0.049	0.075	0.42
Coupon	39,333	1.93	1.66	0.12	0.75	1.62	2.3	8.5
Amount ($)	39,333	0.169	1.32	0.0003	0.00032	0.005	0.006	4.45
Time to Maturity	39,333	3219.02	2833.80	77	862	2743	2745	9936

Brown Bonds	Count	Mean	SD	1st Perc.	25th Perc.	50th Perc.	75th Perc.	99th Perc.
Yield	39,333	2.01	3.21	−0.45	0.44	1.51	2.32	11.93
Price ask	38,869	101.14	4.71	80.94	99.67	100.70	102.16	116.08
Price bid	38,964	100.85	4.85	79.02	99.50	100.51	101.94	115.82
Liquidity	38,869	−0.27	0.44	−2.5	−0.27	−0.13	−0.07	−0.01
ZTD	39,333	0.056	0.23	0	0	0	0	1
Yield SD	39,329	0.11	1.80	0.01	0.032	0.049	0.08	0.49
Coupon	38,778	2.01	1.66	0.12	0.75	1.62	2.5	8.5
Amount ($)	39,333	0.26	3.07	0.00013	0.0031	0.0075	0.011	0.78
Time to maturity	39,333	3248.82	3102.90	45	700	2292	4322	11,360

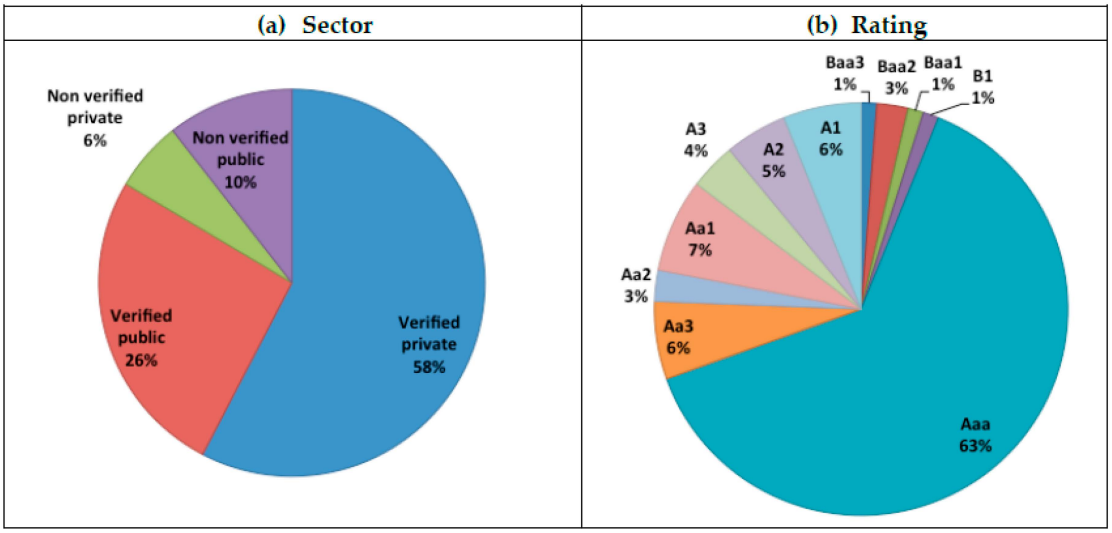

Figure 2. *Cont.*

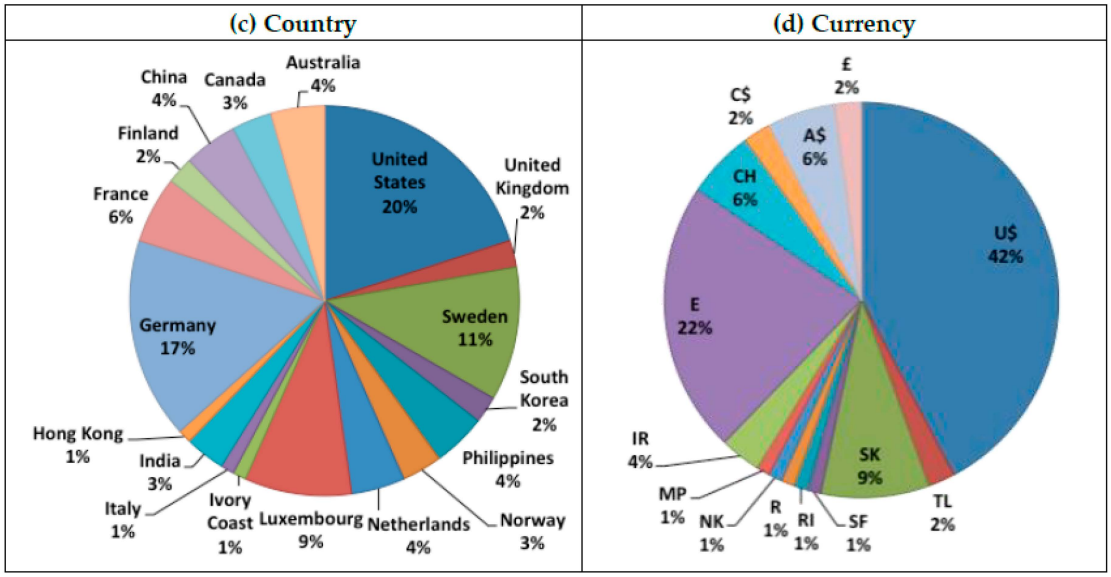

Figure 2. Sample statistics for green bonds only. Breakdown for sector (**a**), rating (**b**), country (**c**), currency (**d**). Currency legend: -£: Pound; A$: Australian Dollar; C$: Canadian Dollar; CH: Swiss Franc; E: Euro; IR: Indian Rupee; MP: Mexican Pesos; NK: Norwegian Krone; R: Russian Ruble; RI: Indonesian Rupiah; SF: Romanian Leu; SK: Slovak Koruna; TL: Turkish Lira; U$: US Dollar.

3.2. Differences in Yields, Liquidity, and Volatility: The Green-Brown Bond Puzzle

Our main research question including asking whether the green characteristic of a bond can per se create a difference in terms of bond returns, liquidity, and volatility.

In order to study the difference between a green bond and its closest brown bond correspondent, we started by looking at the matched yield pairs for the days on which both were traded (i.e., excluding zero trading days for at least one of the two bonds). The specification used in order to estimate the green effect on returns is

$$\Delta y_{i,t} = \alpha_0 + \alpha_1 \Delta Liq_{i,t} + \alpha_2 \Delta ZTD_{i,t} + \alpha_3 \Delta \sigma_{i,t} + \sum_j \beta_j \Delta B_{ji} + \eta_i + \varepsilon_{i,t} \quad (1)$$

where $\Delta y_{i,t}$ is the daily yield spread for the ith bond couple on day t, which is given by the difference between the green bond ask yield and the ask yield of its closest brown bond neighbor according to the matching criteria discussed in the previous paragraph. Among the regressors, α_o was our main parameter of interest that captures the time invariant green effect; ΔLiq is the daily difference in liquidity between a green bond and its brown bond twin, where the variable is computed for each bond as a difference between the bid and the ask price. The validity of this measure as a proxy for liquidity is supported by Van Loon et al. [32], Dick-Nielsen et al. [30], and Chen et al. [33]. ΔZTD is the difference in no trading days between the green and brown bond and is included as additional measure of (il)liquidity; $\Delta \sigma_{i,t}$ is the difference in bond yield variance computed ex post in a 20-day moving window. B-variables are bond characteristics that are not exactly matched (coupon, amount issued, and maturity), in order to control for factors not fully captured by our matching.

The equation was first estimated with ordinary least squares (OLS) and afterward, with fixed effects (FE) (η_i) in order to control for any bond couple unobservable time invariant characteristic. In this last case, ΔB variables disappear as the considered differences in bond characteristics are time invariant for each bond couple.

Regression findings on the overall sample identify a positive green premium between 2.06 and 5.9 bps (Table 4). Note that the R^2 is extremely low, especially in the non-augmented specification, as expected and consistent with the literature [1] (in the specification with fixed effects and just the intercept without other controls the variance of the residuals is equal to the total variance, and for this

reason the R^2 is equal to 0 (Table 4, column 4). We used this specification (in which we compute the mean and the variance) only as a first benchmark for comparison with the augmented specifications that follow). This is reasonable considering that our dependent variable measures differences in yields between twins. The positive premium was larger in OLS when we controlled for both of our two liquidity measures and for the standard deviation (Table 4, columns 3 and 6 for OLS and FE estimates, respectively) with the augmented specification accounting for a substantial increase in goodness of fit (R^2 = 0.2). As expected, the yield differential was also positively correlated with differences in coupon, maturity, and standard deviation.

Table 4. Determinants of the green bond yield differential.

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	**OLS**	**OLS**	**OLS**	**FE**	**FE**	**FE**
Δ Coupon	0.184 ***	0.178 ***	0.123 ***			
	(0.00980)	(0.0109)	(0.00887)			
Δ Amount	−11.07 **	−13.01 **	−15.33 ***			
	(5.091)	(5.629)	(5.774)			
Δ Maturity	0.134 ***	0.136 ***	0.124 ***			
	(0.00227)	(0.00262)	(0.00230)			
Δ σ		0.499 *	0.500 *		0.501 ***	0.502 ***
		(0.255)	(0.255)		(0.00169)	(0.00169)
Δ Liquidity			−0.106 ***			−0.0153
			(0.0118)			(0.0420)
Δ ZTD			−0.136 *			−0.0897
			(0.0700)			(0.0906)
α_0	0.0360 ***	0.0590 ***	0.0465 ***	0.0206 **	0.0433 ***	0.0305 ***
(green premium)	(0.0107)	(0.00369)	(0.00261)	(0.00991)	(7.64e-05)	(0.00251)
Observations	37,802	37,798	36,673	39,333	39,329	38,204
R-squared	0.007	0.206	0.208	0.000	0.206	0.202
Number of bond couples				89	89	88

OLS (Ordinary Least Squares). Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Our second test is on H2: the difference in liquidity between a green bond and its brown bond twin. We cannot perform an independent *t*-test on the equality of means for green and brown bonds since observations are not independent. We therefore estimated differences in liquidity spread between brown and green bonds using a simple fixed effect approach:

$$\Delta Liq_{i,t} = \alpha_o + \eta_i + \varepsilon_{i,t} \quad (2)$$

where the dependent variable is the difference in liquidity for the *i*th (green-brown) bond couple on day *t*, calculated as the difference between price bid and price ask of the green bond minus the same difference for its brown bond closest neighbor. Given variable construction, a significant and positive coefficient for α_o implies that green bonds are more liquid. As shown in the first column of Table 5, we found that green bonds are generally (around 5 bps) more liquid with respect to their matched twins.

Our third null hypothesis on the equality of volatility between green and brown bonds was tested using the same simple fixed effect approach. We therefore estimated the following specification:

$$\Delta\sigma_{i,t} = \alpha_0 + \eta_i + \varepsilon_{i,t} \quad (3)$$

where volatility in yields in the secondary market is calculated as the ex post standard deviation of bond yields by considering a spanning period of 20 days ($\Delta\sigma_{i,t}$).

Estimated findings showed that green bonds are significantly less volatile than brown bonds, even though the difference in magnitude is small (Table 5, column 2).

Table 5. Testing the difference in liquidity and volatility for green and brown bonds.

	(1)	(2)
Variable	**Liquidity FE**	**SD FE**
α_0	0.0549 ***	−0.0453 ***
	(0.00138)	(0.00897)
Observations	38,207	39,329
R^2	0.000	0.000
Number of bond couples	88	89

FE (Fixed Effects). Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Our findings on returns, liquidity, and volatility outline a puzzle. Green bonds have uncompensated advantages with respect to their brown twins since they have higher returns and are simultaneously more liquid and slightly less volatile. In what follows, we propose an interpretation of it by considering the characteristics of the issuer (its private or institutional nature) and the presence or absence of a green label that can reduce asymmetric information and greenwashing (reputational) risk.

3.3. The Institutional–Private Issuer Breakdown

As mentioned in Section 3, the better reputation of the institutional issuer could be one of the rationales for the rejection of the null. We therefore split the sample into private and institutional issuers.

When re-estimating Equation (1) for the private issuer subsample, we found that green bonds have significantly higher returns with respect to their brown twins (Table 6) and exhibit a premium between 2 and 3 bps. If we limit the estimate to the private issuers without a green label, the premium is much higher and between 3.2 and 12.4 bps according to the different specifications (Table 7).

When estimating the same model for the institutional issuers subsample, we found that the green bond premium is now negative and statistically significant, and when we controlled for liquidity. In terms of magnitude, green bonds from institutional issuers exhibited a yield lower in a range between 0.9 and 1.87 bps according to the different estimates. (Table 8, columns 2 and 4). The premium was positive only when we corrected for the yield standard deviation.

To analyze further differences in characteristics between green and brown bonds from private versus institutional issuers, we re-estimated the liquidity and variance specifications in Equations (2) and (3) for the two different groups. Results on liquidity differences are shown in Table 9. Green bonds from private issuers were significantly but slightly (18 bps) more liquid with respect to their brown twins (Table 9, column 2), except when green bonds were not green certified (Table 9, column 3). In the latter case, green bonds were less liquid then their brown twins. Green bonds issued by domestic or supranational institutions were significantly more liquid (around 10 bps) with respect to their brown twins (Table 9, column 1).

Table 6. The determinants of the green bond yield differential: private issuers.

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	**OLS**	**OLS**	**OLS**	**FE**	**FE**	**FE**
Δ Coupon	0.0512 ***	0.0488 ***	0.0499 ***			
	(0.00568)	(0.00369)	(0.00378)			
Δ Amount	−9.615 **	−11.07 **	−10.68 **			
	(4.437)	(5.008)	(4.992)			
Δ Maturity	0.114 ***	0.115 ***	0.113 ***			
	(0.00189)	(0.00183)	(0.00174)			
Δ σ		0.107	0.106		0.144 ***	0.140
		(0.146)	(0.146)		(0.00881)	(0.0960)
Δ Liquidity			−0.118 ***			−0.113 ***
			(0.00755)			(0.0172)
Δ ZTD			0.00226			0.00722
			(0.0201)			(0.0131)
α_0	0.0323 ***	0.0328 ***	0.0319 ***	0.0237 ***	0.0248 ***	0.0246 ***
(green premium)	(0.00170)	(0.00166)	(0.00155)	(0.00131)	(0.00131)	(0.000961)
Observations	22,347	22,345	22,094	22,902	22,900	22,649
R^2	0.161	0.164	0.193	0.000	0.012	0.026
Number of bond couples				58	58	57

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7. Determinants of the green bond yield differential: private issuers without third-party verification.

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	**OLS**	**OLS**	**OLS**	**FE**	**FE**	**FE**
Δ Coupon	2.867 ***	2.800 ***	2.744 ***			
	(0.0810)	(0.0685)	(0.0719)			
Δ Amount	−965.3 ***	−1128 ***	−1074 ***			
	(74.16)	(67.89)	(68.60)			
Δ Maturity	0.415 ***	0.358 ***	0.359 ***			
	(0.0149)	(0.0136)	(0.0135)			
Δ σ		−0.281 ***	−0.264 ***		−0.154 ***	−0.122 **
		(0.0150)	(0.0120)		(0.0151)	(0.0338)
Δ Liquidity		−0.0104	−0.0104		−5.45e-05	0.000137
		(0.0104)	(0.00814)		(0.00181)	(0.00394)
Δ ZTD			0.992 ***			1.258 *
			(0.125)			(0.595)
α_0	0.0370 ***	0.0340 ***	0.0321 ***	0.124 ***	0.112 ***	0.111 ***
(green premium)	(0.00445)	(0.00362)	(0.00371)	(0.00182)	(0.00102)	(0.00110)
Observations	3097	3071	3070	3097	3071	3070
R^2	0.521	0.591	0.625	0.000	0.062	0.239
Number of bond couples				7	7	7

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8. The determinants of the green bond yield differential: institutional issuers.

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	**OLS**	**OLS**	**OLS**	**FE**	**FE**	**FE**
Δ Coupon	1.196 ***	0.945 ***	0.960 ***			
	(0.0263)	(0.0135)	(0.0105)			
Δ Amount	−123,659 ***	−121,066 ***	−122,438 ***			
	(3956)	(2938)	(2670)			
Δ Maturity	0.165 ***	0.155 ***	0.145 ***			
	(0.00579)	(0.00669)	(0.00351)			
Δ σ		−0.106 **	−0.189 ***		0.0447 **	0.0387 *
		(0.0501)	(0.0152)		(0.0195)	(0.0210)
Δ Liquidity		−0.0755	−0.282 **		−0.191	−0.192
		(0.127)	(0.138)		(0.183)	(0.176)
Δ ZTD			0.502 *			0.504 ***
			(0.256)			(0.00144)
α_0	−0.0960 ***	−0.0947 ***	−0.0355 ***	0.0163	−0.0187 ***	0.0324 ***
(green premium)	(0.0250)	(0.0320)	(0.00514)	(0.0236)	(0.00425)	(0.00335)
Observations	15,455	14,580	14,579	16,431	15,556	15,555
R-squared	0.019	0.010	0.216	0.000	0.000	0.204
Number of bond couples				31	31	31

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9. Liquidity difference for green and brown bonds in different subsamples.

	(1)	(2)	(3)	(4)
Variable	**Institutional Issuers**	**Private Issuers**	**Private Issuers Non-Certified**	**Private Issuers Green Certified**
α_0	0.108 ***	0.0186 ***	−0.0657 ***	0.0319 ***
	(0.00271)	(0.00141)	(0.00291)	(0.00157)
Observations	15,556	22,651	3071	19,580
Number of bond couples	31	57	7	50

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Results on the differences in volatility for the same subgroups are shown in Table 8. Again, the standard deviation in yields was smaller for green bonds when considering the private–institutional breakdown, except for private non-verified bonds (where, however, the difference in standard deviation was not significant). This finding is consistent with the assumption that non-verified green bonds from private issuers have worse reputations and higher risk of green washing (Table 10). Notably, the strongest negative difference in SD between green and brown bonds (almost 10%) was for green bonds from institutional issuers.

Table 10. Volatility difference for green and brown bonds in different subsamples.

Variable	(1) Institutional Issuers	(2) Private Issuers	(3) Private Issuers Non-Certified	(4) Private Issuers GREEN Certified
α_0	−0.0976 ***	−0.00774 ***	0.000755	−0.00907 ***
	(0.0214)	(0.000980)	(0.000659)	(0.00113)
Observations	16,429	22,900	3096	19,804
Number of bond couples	31	58	7	51

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4. Robustness Checks

To check whether our results hold even when we departed from the normality assumption, we provide bootstrapped estimates of the specification on the determinants of yield differences between green and brown bonds. Our findings were substantially unchanged since private green bonds exhibited a positive premium, whereas institutional green bonds a negative premium, versus their closest brown counterparts (Table 11). As well, private bonds displayed a (slightly) lower premium.

Table 11. The determinants of the green bond yield differential (bootstrapped ordinary least squares (OLS) estimates with 500 replications).

Variable	(1) OLS All Sample	(2) OLS Institutional Issuers	(3) OLS Private Issuers	(4) OLS Private Issuers No Verification
Δ Coupon	0.123 ***	0.960 ***	0.0499 ***	2.744 ***
	(0.00888)	(0.0106)	(0.00396)	(0.0737)
Δ Amount	−15.33 ***	−122,438 ***	−10.68 **	−1074 ***
	(5.899)	(2684)	(4.768)	(70.99)
Δ Maturity	0.124 ***	0.145 ***	0.113 ***	0.359 ***
	(0.00243)	(0.00348)	(0.00176)	(0.0139)
Δ σ	−0.106 ***	−0.189 ***	−0.118 ***	−0.264 ***
	(0.0126)	(0.0156)	(0.00775)	(0.0122)
Δ Liquidity	−0.136 *	−0.282 *	0.00226	−0.0104
	(0.0710)	(0.148)	(0.0205)	(0.00769)
Δ ZTD	0.500 *	0.502 **	0.106	0.992 ***
	(0.256)	(0.250)	(0.156)	(0.121)
α_0	0.0465 ***	−0.0355 ***	0.0319 ***	0.0321 ***
(green premium)	(0.00279)	(0.00509)	(0.00145)	(0.00375)
Observations	36,673	14,579	22,094	3070
R-squared	0.208	0.216	0.193	0.625

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, in order to control for outliers in our dependent variable, especially on the right side of the distribution, we propose a Tobit specification by censoring observations at the 1st and at the 99th percentiles, controlling for the unmatched bond characteristics and splitting the sample for institutional, private, and private issuers with no third-party verification (note that when using this model, we could not control for fixed effects because the Tobit specification is a non-linear function). Our main results were substantially unchanged. Green bonds had significantly lower yields for the institutional issuers sample, with positive yields from the private issuers sample, and still more positive for private issuers of unlabeled bonds (Table 12).

Table 12. The determinants of the green bond yield differential (TOBIT estimates censoring the data at the 1st and 99th percentiles).

Variable	(1)	(3)	(5)
	TOBIT Public Issuers Sample	**TOBIT Private Issuers Sample**	**TOBIT Private Issuers and Non-Verified Bonds**
Δ Coupon	−122.430 ***	−10.79 **	−1.082 ***
	(2570)	(4.425)	(68.73)
Δ Amount	0.979 ***	0.0481 ***	2.746 ***
	(0.0116)	(0.00156)	(0.0716)
Δ Maturity	0.149 ***	0.115 ***	0.363 ***
	(0.00312)	(0.00124)	(0.0136)
Δ σ	−0.188 ***	−0.112 ***	−0.252 ***
	(0.0148)	(0.00454)	(0.0115)
Δ Liquidity	−0.0900 ***	0.000692	−0.0102
	(0.0232)	(0.00861)	(0.00793)
Δ ZTD	0.194 ***	0.122 ***	0.764 ***
	(0.0456)	(0.0267)	(0.0987)
α_0	−0.0310 ***	0.0317 ***	0.0332 ***
(green premium)	(0.00383)	(0.00122)	(0.00372)
Observations	14,579	22,094	3070
Sigma	0.471 ***	0.181 ***	0.107 ***
	(0.00803)	(0.00216)	(0.00177)

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5. Conclusions

Understanding the characteristics and financing conditions of green bonds is of great importance in a world that struggles to convert its production system into a more sustainable and circular economy in order to tackle environmental challenges and the threat of climate change.

The literature aiming to provide answers in this field has so far only partially investigated green bond yield premia and mixed findings have been produced. We contribute to the literature by examining issuer characteristics and the presence or absence of green verification to better understand green versus brown bond features.

We collected a sample of 89 bond couples and found that, overall, green bonds have surprisingly higher yields coupled with higher liquidity and are simultaneously slightly less volatile than their closest brown bond correspondents. We helped explain these findings by analyzing the institutional/private issuer breakdown and considering the verification variable. Institutional green bonds display a negative premium and are far more liquid, whereas private green bonds have a positive premium and a much narrower liquidity advantage with respect to their brown bond twins. When we further decomposed private issuer green bonds into certified and non-certified categories, we found that the positive premium is very strong for the latter.

Our findings mainly suggest that green bonds may enjoy a negative premium and therefore green investment may be financed at a discount (either for the existence of a willingness of investors to pay for environmental sustainability, or due to the lower exposition to stakeholder risk of green investment). However, the premium requires either the established reputation of the (institutional) issuers or a green verification in order to reduce asymmetric information and provide guarantees to investors against bond greenwashing.

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Appendix A

Table A1. The bond sample.

Couple	Green	Isin	Amount	Coupon	Issue Date	Maturity Date	Currency
1	0	US45950KCH14	500,000	1.25	27/11/2015	27/11/2018	U$
1	1	US45950VHE92	500,000	1.25	27/11/2015	27/11/2018	U$
2	0	US61746BDX10	2,000,000	2.45	27/01/2016	01/02/2019	U$
2	1	US6174468B80	500,000	2.20	08/06/2015	07/12/2018	U$
3	0	XS1399311064	1,200,000	0.5	26/04/2016	26/04/2021	SK
3	1	XS1494406074	3,000,000	0.5	22/09/2016	22/09/2023	SK
4	0	US00850XAC20	500,000	2.75	21/05/2015	21/05/2020	U$
4	1	XS1303791336	500,000	2.75	20/10/2015	20/10/2020	U$
5	0	US459058CY72	750,000	2.125	13/02/2013	13/02/2023	U$
5	1	US45905URL07	600,000	2.125	03/03/2015	03/03/2025	U$
6	0	US500769HH04	4,000,000	1.75	07/03/2017	31/03/2020	U$
6	1	US500769GF56	1,500,000	1.75	15/10/2014	15/10/2019	U$
7	0	US45950KCE82	500,000	0.625	03/10/2014	03/10/2016	U$
7	1	US45950VCJ35	1,000,000	0.5	22/02/2013	16/05/2016	U$
8	0	US500769FH22	3,000,000	2	04/10/2012	04/10/2022	U$
8	1	US500769HP20	1,000,000	2	05/10/2017	29/09/2022	U$
9	0	US500769FH22	3,000,000	2	04/10/2012	04/10/2022	U$
9	1	US500769HD99	1,500,000	2	30/11/2016	30/11/2021	U$
10	0	DE000NWB17W8	500,000	0.5	07/06/2017	07/06/2027	E
10	1	DE000NWB0AE6	500,000	0.5	13/09/2017	13/09/2027	E
11	0	XS0965428799	350,000	4.17	11/09/2013	11/09/2018	MP
11	1	XS1508504526	75,000	4.1	16/11/2016	16/11/2019	MP
12	0	US045167CX94	2,250,000	1.875	18/02/2015	18/02/2022	U$
12	1	US045167EB56	750,000	1.875	10/08/2017	10/08/2022	U$
13	0	US30216BGN64	1,250,000	1.625	19/01/2017	17/01/2020	U$
13	1	US30216BGU08	500,000	1.625	01/06/2017	01/06/2020	U$
14	0	XS1043504452	4,924,000	2	11/03/2014	18/01/2017	CH
14	1	XS1080036939	500,000	2	26/06/2014	26/06/2017	CH
15	0	XS0993228534	1,000,000	0.375	13/11/2013	15/12/2016	E
15	1	XS1047440448	550,000	0.25	20/03/2014	20/03/2017	E
16	0	XS1371532117	600,000	1.875	01/03/2016	01/03/2019	U$
16	1	XS1437622548	500,000	1.875	12/07/2016	12/07/2019	U$
17	0	XS1346287748	1,000,000	1.5	22/01/2016	22/01/2019	U$
17	1	XS1383831648	600,000	1.5	22/03/2016	23/04/2019	U$
18	0	SE0005880143	200,000	2.45	15/04/2014	15/04/2019	SK
18	1	SE0005798816	500,000	2.473	19/03/2014	19/03/2019	SK
19	0	DE000NWB16P4	500,000	0.75	05/02/2014	05/02/2018	E
19	1	DE000NWB0AA4	250,000	0.75	28/11/2013	28/11/2017	E
20	0	US06051GES49	1,000,000	1.25	11/01/2013	11/01/2016	U$
20	1	US06051GEZ81	500,000	1.35	21/11/2013	21/11/2016	U$
21	0	XS1221967042	1,000,000	2.125	23/04/2015	23/04/2025	U$
21	1	XS1188118100	500,000	2.125	11/02/2015	11/02/2025	U$

Table A1. *Cont.*

Couple	Green	Isin	Amount	Coupon	Issue Date	Maturity Date	Currency
22	0	US45950KCE82	500,000	0.625	03/10/2014	03/10/2016	U$
22	1	US45950VCP94	1,000,000	0.625	15/11/2013	15/11/2016	U$
23	0	XS1074055770	600,000	2.5	04/06/2014	04/06/2026	E
23	1	XS1038708522	750,000	2.5	26/02/2014	26/02/2024	E
24	0	DE000A168Y55	5,000,000	0.375	09/03/2016	09/03/2026	E
24	1	XS1612940558	2,000,000	0.25	16/05/2017	30/06/2025	E
25	0	XS1165130219	500,000	2.75	12/02/2015	12/08/2020	U$
25	1	XS1209864229	500,000	2.75	01/04/2015	01/04/2020	U$
26	0	US00254EMC39	1,000,000	1.875	17/06/2014	17/06/2019	U$
26	1	US00254EMD12	500,000	1.875	23/06/2015	23/06/2020	U$
27	0	XS1257176914	150,000	1.85	15/07/2015	15/07/2020	U$
27	1	XS1618289802	500,000	1.875	23/05/2017	01/06/2021	U$
28	0	XS1640903537	14,000,000	5.9	06/07/2017	20/12/2022	IR
28	1	XS1618178567	3,000,000	6	24/05/2017	24/02/2021	IR
29	0	XS1669155209	500,000	1.375	23/08/2017	23/11/2018	U$
29	1	XS1508672828	500,000	1.375	26/10/2016	26/10/2020	U$
30	0	XS1369614034	750,000	0.75	19/02/2016	19/02/2021	E
30	1	XS1324923520	500,000	0.75	25/11/2015	25/11/2020	E
31	0	US302154CJ68	500,000	2.125	25/01/2017	25/01/2020	U$
31	1	US302154BZ10	400,000	2.125	11/02/2016	11/02/2021	U$
32	0	XS0840673858	58,020	0.5	31/10/2012	24/10/2017	TL
32	1	XS0536541005	65,000	0.5	29/09/2010	29/09/2017	TL
33	0	SE0008963920	1,250,000	1.205	24/10/2017	24/04/2023	SK
33	1	SE0010494351	1,250,000	1.205	24/10/2017	24/04/2023	SK
34	0	SE0009345630	515,000	1.0075	29/08/2016	15/12/2021	SK
34	1	SE0009983810	830,000	1.083	24/05/2017	24/05/2022	SK
35	0	US298785HP47	5,000,000	2.5	17/01/2018	15/03/2023	U$
35	1	US298785GQ39	1,000,000	2.5	15/10/2014	15/10/2024	U$
36	0	US302154CB33	1,000,000	1.75	26/05/2016	26/05/2019	U$
36	1	US302154BG39	500,000	1.75	27/02/2013	27/02/2018	U$
37	0	DE000A1RET72	2,000,000	0.375	15/04/2013	18/04/2017	E
37	1	XS1087815483	1,500,000	0.375	22/07/2014	22/07/2019	E
38	0	US037833DK32	1,500,000	3	13/11/2017	13/11/2027	U$
38	1	US037833CX61	1,000,000	3	20/06/2017	20/06/2027	U$
39	0	AU3CB0223592	250,000	4	27/05/2014	27/11/2019	A$
39	1	AU3CB0226090	300,000	4	16/12/2014	16/12/2021	A$
40	0	XS1197351577	1,500,000	1.125	04/03/2015	04/03/2022	E
40	1	XS1636000561	500,000	0.875	27/06/2017	27/06/2022	E
41	0	US00828EBE86	1,100,000	1.375	12/02/2015	12/02/2020	U$
41	1	US00828EBJ73	500,000	1.375	17/12/2015	17/12/2018	U$
42	0	CA298785GT79	1,400,000	1.125	18/02/2015	18/02/2020	C$
42	1	XS1490971634	500,000	1.125	16/09/2016	16/09/2021	C$
43	0	US459058FF56	1,000,000	1.75	19/04/2016	19/04/2023	U$
43	1	US45905UZT41	500,000	1.75	22/11/2016	22/11/2021	U$

Table A1. *Cont.*

Couple	Green	Isin	Amount	Coupon	Issue Date	Maturity Date	Currency
44	0	FR0013231743	1,000,000	1.125	18/01/2017	18/01/2023	E
44	1	FR0013067170	300,000	1.125	14/12/2015	14/12/2022	E
45	0	AU3CB0241891	400,000	3.25	17/01/2017	17/01/2022	A$
45	1	AU3CB0243657	450,000	3.25	31/03/2017	31/03/2022	A$
46	0	US45905UQ233	750,000	2	30/10/2017	30/10/2020	U$
46	1	US45905UG408	300,000	2	12/04/2017	12/04/2022	U$
47	0	XS1688390068	300,000	3	25/09/2017	25/05/2023	U$
47	1	XS1589873097	300,000	3	24/04/2017	21/10/2022	U$
48	0	XS0167422871	200,000	1	19/05/2003	17/05/2018	U$
48	1	US045167DQ35	800,000	1	16/08/2016	16/08/2019	U$
49	0	XS1481017520	500,000	0.875	25/08/2016	27/08/2018	U$
49	1	US30216BER96	300,000	0.875	30/01/2014	30/01/2017	U$
50	0	US459058ER04	4,000,000	1	07/10/2015	05/10/2018	U$
50	1	US45905UWE09	280,000	1.005	21/04/2016	01/10/2018	U$
51	0	CA298785GT79	1,400,000	1.125	18/02/2015	18/02/2020	C$
51	1	XS1314336204	500,000	1.25	05/11/2015	05/11/2020	C$
52	0	XS1346287748	1,000,000	1.5	22/01/2016	22/01/2019	U$
52	1	US50046PAU93	600,000	1.5	22/03/2016	23/04/2019	U$
53	0	XS1368576572	1,250,000	0.75	22/02/2016	22/02/2021	E
53	1	XS1324217733	500,000	0.75	24/11/2015	24/11/2020	E
54	0	US459058FQ12	300,000	1.2	30/09/2016	30/09/2019	U$
54	1	XS1517268105	100,000	1.181	14/11/2016	15/12/2019	U$
55	0	CH0180006113	305,000	1.625	02/04/2012	02/04/2026	SF
55	1	CH0233004172	350,000	1.625	04/02/2014	04/02/2025	SF
56	0	US44987DAE67	1,000,000	2.05	17/08/2015	17/08/2018	U$
56	1	US44987DAJ54	800,000	2	24/11/2015	26/11/2018	U$
57	0	SE0009580186	250,000	0.35	31/01/2017	31/07/2019	SK
57	1	SE0009607013	490,000	0.38	14/02/2017	28/08/2019	SK
58	0	US459058DY63	4,300,000	1.625	12/02/2015	10/02/2022	U$
58	1	US45905ULF92	5000	1.5	12/07/2012	12/07/2022	U$
59	0	DE000NWB12F4	75,000	4.32	24/08/2009	28/12/2017	E
59	1	DE000NWB0AB2	500,000	4.25	04/11/2014	05/11/2018	E
60	0	XS1405911576	1,350,000	0.83	10/05/2016	10/05/2021	SK
60	1	XS1433082861	1,000,000	0.885	15/06/2016	15/06/2022	SK
61	0	XS1399311064	1,200,000	0.5	26/04/2016	26/04/2021	SK
61	1	XS1347786797	1,000,000	0.625	20/01/2016	20/01/2021	SK
62	0	XS0858366098	3,550,000	1.375	27/11/2012	15/09/2020	E
62	1	LU0953782009	3,000,000	1.375	18/07/2013	15/11/2019	E
63	0	AU3CB0236727	175,000	3.25	07/04/2016	07/04/2021	A$
63	1	AU3CB0230100	6.000e+08	3.25	29/06/2015	03/06/2020	A$
64	0	CND100009HY3	5.000e+08	3.4	NA	14/03/2021	CH
64	1	CND10000G4D6	1.000e+09	3.4	NA	24/09/2021	CH
65	0	INE296A07LC6	2.000e+08	8.55	NA	28/04/2021	IR
65	1	INE296A07LL7	2.000e+08	8.55	NA	14/07/2021	IR

Table A1. *Cont.*

Couple	Green	Isin	Amount	Coupon	Issue Date	Maturity Date	Currency
66	0	CND100005DQ6	2.500e+10	3.87	NA	28/06/2019	CH
66	1	CND10000G602	1.000e+10	3.79	NA	23/12/2019	CH
67	0	CND10000H8S4	2.000e+09	4.68	NA	10/05/2020	CH
67	1	CND10000H6C2	2.000e+09	4.79	NA	11/04/2020	CH
68	0	DE000BHY0BA8	500,000	0.125	22/10/2015	22/10/2020	E
68	1	DE000BHY0GP5	500,000	0.125	05/05/2015	05/05/2022	E
69	0	DE000BHY0MT5	500,000	0.125	05/09/2017	05/01/2024	E
69	1	DE000BHY0GH2	500,000	0.125	14/06/2017	23/10/2023	E
70	0	XS0849420905	2,000,000	2.5	31/10/2012	3/11/02022	£
70	1	XS1051861851	1,800,000	2.25	08/04/2014	07/03/2020	£
71	0	XS1351517260	1.800e+08	8.46	18/02/2016	19/02/2019	RI
71	1	XS1324201497	1.700e+08	8.66	14/12/2015	17/12/2018	RI
72	0	XS1417412506	142,800	2.5	29/11/2016	29/11/2021	A$
72	1	XS1367226385	49,100	2.3	24/06/2016	18/06/2020	A$
73	0	XS1014678053	2,500,000	3.45	16/01/2014	16/01/2017	CH
73	1	XS1437844100	1,500,000	3.6	12/07/2016	12/07/2018	CH
74	0	XS1254823682	412,000	5.71	30/07/2015	05/08/2020	IR
74	1	XS1241051967	260,000	5.6	25/06/2015	25/06/2020	IR
75	0	DE000NWB18E4	500,000	0.25	04/07/2017	04/07/2025	E
75	1	DE000NWB0AD8	500,000	0.375	17/11/2016	17/11/2026	E
76	0	XS1138501918	400,000	1.34	18/11/2014	18/11/2019	SK
76	0	XS1697577556	1,000,000	0.98	11/10/2017	11/10/2022	SK
76	1	XS1436518606	1,000,000	1.048	23/06/2016	23/06/2021	SK
77	0	XS1401196958	500,000	1.125	28/04/2016	28/04/2027	E
77	0	XS1523192588	500,000	0.875	22/11/2016	21/02/2025	E
77	1	XS1218319702	500,000	1	15/04/2015	14/03/2025	E
78	0	US30216BFZ04	1,000,000	1.25	02/02/2016	04/02/2019	U$
78	1	US30216BFY39	300,000	1.25	08/12/2015	10/12/2018	U$
79	0	DE000A168Y06	5,000,000	0.125	03/09/2015	01/06/2020	E
79	1	XS1311459694	1,500,000	0.125	27/10/2015	27/10/2020	E
80	0	XS0995130712	2,250,000	8.5	22/11/2013	25/07/2019	TL
80	1	XS1198278175	275,000	8.5	12/03/2015	27/03/2019	TL
81	0	AU3CB0204402	1,200,000	3.5	24/01/2013	24/01/2018	A$
81	1	AU3CB0220424	300,000	3.5	29/04/2014	29/04/2019	A$
82	0	XS1346200055	1,450,000	1.375	18/01/2016	01/02/2021	£
82	1	XS1268337844	1,000,000	1.625	30/07/2015	05/06/2020	£
83	0	XS0544798167	1,250,000	7	06/10/2010	06/10/2015	R
83	1	XS0994434487	2,300,000	6.75	19/11/2013	15/09/2017	R
84	0	XS1040151315	750,000	0.75	05/03/2014	05/03/2018	E
84	1	XS1083955911	500,000	0.625	03/07/2014	03/07/2019	E
85	0	DE000NWB17G1	1,000,000	0.625	11/02/2016	11/02/2026	E
85	1	DE000NWB0AC0	500,000	0.875	10/11/2015	10/11/2025	E
86	0	NO0010724743	1,500,000	2.45	24/11/2014	24/05/2023	NK
86	1	NO0010752702	1,500,000	2.35	04/12/2015	04/09/2024	NK

Table A1. *Cont.*

Couple	Green	Isin	Amount	Coupon	Issue Date	Maturity Date	Currency
87	0	US06050TME90	1,250,000	2.05	07/12/2015	07/12/2018	U$
87	0	US06050TMC35	1,750,000	1.75	05/06/2015	05/06/2018	U$
87	1	US06051GFR56	600,000	1.95	12/05/2015	12/05/2018	U$
88	0	XS1128264758	350,000	4.125	23/10/2014	23/04/2020	U$
88	1	XS1325600994	350,000	4.25	30/11/2015	30/11/2020	U$
89	0	XS1422841202	500,000	0.625	31/05/2016	31/05/2022	E
89	1	XS1244060486	500,000	0.75	09/06/2015	09/06/2020	E

Amount: thousands of local currency.

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