(In)-Credibly Green: Which Bonds Trade at a Green Bond Premium? *

Julia Kapraun† Carmelo Latino‡ Christopher Scheins§ Christian Schlag¶

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Abstract

The most important determinant for the existence of a Green premium is the perceived "Green–credibility" of a bond and its issuer. We analyze a sample of more than 1,500 Green bonds with respect to their pricing on the primary and secondary market. On both markets, only certain types of bonds trade at a Green premium (i.e., exhibit lower yields) relative to their conventional counterparts, namely those, which are issued by governments or supranational entities, denominated in EUR, or corporate bonds with very large issue sizes. These bonds and their issuers seem to be viewed as more credible in terms of a better implementation or a greater impact of the Green projects financed with the proceeds. For corporate issues, credibility of the Green label is of particular importance. Investors are more likely to pay a premium for a Green bond, when it is certified as such by a third party, or when it is listed on an exchange with a dedicated Green bond segment and tight listing requirements.

Keywords: Green bonds, Sustainable investing, Green premium, Impact investing

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†Corresponding author. Goethe University Frankfurt, Theodor-W.-Adorno-Platz 3, 60323 Frankfurt, email: julia.kapraun@hof.uni-frankfurt.de.

‡Leibniz Institute for Financial Research SAFE, Theodor-W.-Adorno-Platz 3, 60323 Frankfurt, email: latino@safe-frankfurt.de.

§Goethe University Frankfurt, Theodor-W.-Adorno-Platz 3, 60323 Frankfurt, email: Christopher.Scheins@hof.uni-frankfurt.de

¶Goethe University Frankfurt, Theodor-W.-Adorno-Platz 3, 60323 Frankfurt, email: schlag@finance.uni-frankfurt.de.

1 Introduction

"There's growing demand for Green bonds but no international standard to ensure their Greenness". [1]

Green bonds, i.e., bonds which are supposed to finance environmentally sustainable projects, are considered one of the most innovative financial instruments over the past decade. Although the market for Green bonds is still relatively small, it is by far no longer a niche segment, and Green bonds have been issued by governments and corporates in over 60 different currencies across the globe. Since the first Climate Awareness Bond was issued by the European Investment Bank in 2007, the cumulative issue volume has grown rapidly and has reached \$1tn by the end of 2020. The role of Green bonds to catalyze the shift of capital to a low-carbon global economy has been discussed in several studies. While Glomsrød and Wei (2018) and Flaherty et al. (2017) estimate that the diversion of capital from fossil industries to more sustainable sectors, in particular through Green bonds, will support sustainable economic growth, increase world GDP, and drastically reduce greenhouse gas emissions, Maltais and Nykvist (2020) and Tuhkanen and Vulturius (2020) contribute to a large controversial debate on what "additionality" or real environmental impact Green bonds actually deliver.

Our study is motivated by the ongoing and related debate about the willingness of investors to pay a *premium* (i.e., accept lower yields) for a bond labeled as Green compared to an otherwise identical conventional bond. Generally, recent studies provide evidence that investors value sustainability (Hartzmark and Sussman (2019), Ceccarelli et al. (2019), Ammann et al. (2019)) and are willing to pay for non-pecuniary characteristics of investments (Barber et al. (2021), Riedl and Smeets (2017), Bauer et al. (2019)). Furthermore, Green bonds are found to attract new investor clienteles, and the issuance of Green bonds tends to have positive effects on liquidity, institutional ownership, and stock prices (see, e.g., Flammer (2021), Tang and Zhang (2020)). Yet, the results on the pricing of Green bonds are so far rather mixed and strongly depend on the respective

[1] www.marketwatch.com, published on Oct 14, 2019

sample and empirical methods. Some studies report Green bonds trading at lower yields, i.e., at a premium relative to conventional bonds (see, e.g., Preclaw and Bakshi (2015), Ehlers and Packer (2017), Nanayakkara and Colombage (2019), or most recently, Zerbib (2019) and Baker et al. (2018)) by analyzing credit spreads, options data, or by using matching approaches in primary or secondary markets. However, other studies (e.g., Karpf and Mandel (2017), Hachenberg and Schiereck (2018), Larcker and Watts (2020)) document no significant difference in yields or even higher yields for Green bonds (Karpf and Mandel (2018), Bachelet et al. (2019)). Although most of these studies rely only on a very small set of bonds or focus on special types of bonds (e.g., US municipals) or markets (primary or secondary), they provide guidance for investors and Green bond issuers and are widely cited in practitioners' reports (e.g., by the Climate Bond Initiative, publications like "Institutional Money", or in a Bundesbank report[2]).

With an increasing number of reports and studies on Green bonds providing conflicting evidence, an important question arising among practitioners and researchers alike is *why* there is such a pronounced heterogeneity with respect to results concerning the existence of a Green premium. In this study, we shed more light on the pricing of Green bonds by linking the investors' valuation of the Green label to the *"Green–credibility"* attributes of the corresponding bond and its issuer. From the theoretical side, the existence of the Green bond premium is well justified through a non-pecuniary positive utility of households with preferences for environmental sustainability derived from an investment in Green assets. However, this requires investors having equal preferences for all Green bonds and, most importantly, their trust in the Green credentials of these instruments.

The structure of the Green bonds market leaves room for different considerations, why investors might doubt the Green–credibility of a bond. With the rapidly growing number of Green bond issues and issuers across the globe, the need for more transparency, regulation, and clear standards arises. The issuance of Green bonds is still an unregulated process, and each issuer and country can decide on the criteria making its bonds

[2] See https://www.bundesbank.de/de/publikationen/berichte/monatsberichte/monatsbericht-oktober-2019-811908

“Green”. Although the ICMA Green Bond Principles[3] have become the leading issuance framework for Green bonds, and the European Commission has made a proposal for EU Green Bond Standards, compliance with these guidelines is still voluntary, and there is no harmonized framework for the selection of eligible projects or reporting[4].

Many investors are thus skeptical about Green marketing and “Greenwashing”, i.e., misleading claims regarding Green credentials. Consequently, they have doubts concerning the Green-credibility especially of those issuers, which have a reputation of being major polluters (e.g., from sectors such as transportation or nuclear energy). For example, in 2019, a Green bond issued by the shipping company Teekay Shuttle Tankers failed to raise enough money to build fuel-efficient tankers.[5] Although, so far, there are not many other cases of Green bonds being branded as “oxymoronic”, this example indicate that investors’ scrutiny grows, and that they do not blindly pay a premium for a bond simply because it is labeled as “Green”.

Our main research questions can be formulated as follows: (a) Is there a *premium* for Green bonds, i.e., do Green bonds exhibit lower yields than their conventional counterparts? (b) Is there *heterogeneity* with respect to the yield differential across markets (primary vs. secondary), currencies, issuers, or other characteristics? (c) Are there any Green bonds, which appear to be more “Green-credible” and which can be expected to trade at a premium.

To measure Green-credibility we consider several variables related to the characteristics of the given bond, its issuer and issue country, which might be relevant for investors’ trust in the Green label. At the issue level, we look at the effect of an additional external certification of the “Greenness” of the bond, and the listing of the bond on so-called “Green exchanges”, i.e., exchanges with a dedicated segment for Green bonds and additional listing requirements. At the issuer level, we distinguish between a corporate and a “more official” issuer type, such as national governments, local governments, and supranationals.

[3] See https://www.icmagroup.org/green-social-and-sustainability-bonds/green-bond-principles-gbp/ for the most recent guidelines.

[4] See, for instance, the most recent debate by the European Commission on whether nuclear energy and natural gas qualify as climate–friendly.

[5] See e.g., `https://www.ft.com/content/b1d4201c-f142-11e9-bfa4-b25f11f42901`.

There might be of course also official entities issuing Green bonds from countries with rather low domestic sustainability efforts[6] or large corporate issuers from green sectors such as renewable energy or sustainable transportation. Nevertheless, for a given issue country, Green bonds issued by more official entities might be viewed as more credible in terms of a better implementation and/or greater impact of the Green project to be financed by the bond than bonds issued by corporations.

In the analysis of the sub-sample of corporate bonds further include a sustainability (ESG) rating of the corresponding issuer to account for differences in Green bonds pricing across sectors and to measure the effect of the overall sustainability reputation of the issuer. For a general sentiment towards environmental trends and sustainability efforts in the corresponding issue country, we consider the Environmental Performance Index (EPI) developed at Yale University[7], which ranks 180 countries on 32 performance indicators covering environmental health and ecosystem vitality. For instance, in the 2020 ranking, while most European countries exhibit scores around 80 and rank within the top 20, China, being one of the top three Green bond issuers, has a score of 37.3 and ranks 120th. According to the Yale methodology, low scores on the EPI indicate the need for substantially more national sustainability efforts with regard to several major environmental issues. The investors' trust in Green labels and the willingness to contribute to national environmental efforts could, thus, be particularly high in countries with well-established environmental policy goals.

Finally, we also account for possible heterogeneity across currency markets by splitting our sample by top two currencies in terms of issue volume (EUR, USD). Obviously, there may be other reasons than Green–credibility for the decision to issue in a specific currency. Still, since Green bonds are issued in over 60 different currencies, investors in Green bonds issued by countries with rather low sustainability reputation (e.g., Mexico) might trust and value the Green label more when the issue is denominated in a major currency, compared to when the bond is issued in local currency.

[6] For instance, Nigeria, which ranks #100 out of 180 countries based on the Environmental Performance Index developed at Yale University (see https://epi.envirocenter.yale.edu/) has issued two Green bonds.

[7] https://epi.envirocenter.yale.edu/

To the best of our knowledge, we are the first to collect and analyze such a large and recent global data set on Green bonds with the majority of these bonds issued within the past three years. In our primary and secondary market analysis we consider over 1,500 Green and 20,000 conventional bonds, and find Green bonds to trade at similar yields on average. There is, however, substantial variation of the Green premium across currencies and issuer types. While investors do indeed accept 5 to 18 bps lower yields on bonds issued by governments, local governments or supranationals, or on bonds denominated in EUR, the premia for smaller corporate Green bonds or bonds issued in other currencies than EUR are not significant. Particularly for the pricing of corporate Green bonds, an external certification of the bond's "Greenness" proves to be of utmost importance.

To investigate the drivers of the Green bond premium in greater detail, we consider 431 *matched bond pairs* in our final analysis. We compare Green bonds to conventional bonds of the *same issuer*, with the *same credit rating* and the *same level of seniority*, issued in the *same currency*, and of the *same bond type*. Furthermore, we require the two bonds to have similar issue sizes and maturities.

The results of this analysis clearly indicate the importance of the Green-credibility of the issue and the issuer itself when it comes to the existence of a Green premium. More precisely, the difference in yields between the conventional and the Green bond is substantially more negative for pairs, where the Green bond is listed on an exchange with a dedicated Green market segment with additional requirements regarding sustainable credentials (-3.6 bps), and for pairs, where the Green bond is certified as such (-4 bps). When considering the overall environmental rating of the Green bond issuer, we find that issuers with very high scores to benefit from a yield reduction of 7 to 9 bps compared to corporations with lower scores. This might be particularly driven by investors applying a top-down approach in their asset selection process, in the sense that they first define the pool of eligible companies by considering only those firms with a top ESG or environmental rating, and then choose the corresponding instruments.

2 Theoretical motivation

2.1 Basic considerations

There may be a variety of reasons why a company decides to issue a Green instead of a conventional bond. Although in terms of issuing costs, the process for Green bonds might be more expensive through an additional certification fee or yearly reporting, several studies[8] have shown that there are indeed potential reputation effects for the company (e.g., positive stock price reactions at the issuance announcement, increasing institutional ownership and improved liquidity). Furthermore, through more transparency and disclosure, companies issuing Green bonds improve their overall sustainability reputation and attract new investors.

The results from the empirical literature on the yield differential between Green and conventional bonds are, however, mixed, as stated above in the introduction. From the theoretical side, the existence of the Green bond premium appears well justified. As soon as households have a preference for certain investment products, they are willing to pay a higher price for these, since they are receiving non-pecuniary utility from them.

In the following sections, we will provide a theoretical motivation for the mechanisms which might explain the decision on the part of investors to buy a Green bond at a higher price than an otherwise identical conventional one. To convey the theoretical intuition we apply what we consider one of the simplest possible settings, which is closely related to the model presented in Baker et al. (2020). We extend their setting to allow for the issuance of Green bonds also by firms with a bad sustainability reputation. Finally, and most importantly, we consider a setting where Green bonds have a real impact, i.e., where they finance projects reducing negative externalities of the issuer. Theoretically, with these two utility driving mechanisms, i.e., positive non-pecuniary utility from investments in Green bonds along with the reduction in the disutility from negative externalities, Green bonds issued by polluting companies should have higher prices than Green bonds issued by clean companies.

[8]See, e.g., Flammer (2021), Tang and Zhang (2020)

If we do not see these results in empirical data, a possible explanation can be a much lower demand (or preference) of investors for the Green bonds issued by dirty (polluting) companies than for Green bonds of clean (non–polluting and, thus, more sustainable) firms. In the following sections, we consider a theoretical model which allows us to account for differences in investors' preferences for different Green bonds. A recent line of research highlights trust as an important element guiding the preference of households to invest into risky financial assets and insurance products[9]. If investors do not trust the corresponding issuer actually financing green projects with an environmental impact, the price for such bonds will stay below or at most at the level of the comparable conventional bond.

2.2 Model

2.2.1 Green bonds of a clean company

In this section we investigate the effect of the introduction of a Green bond on households' investment decisions in the setting with two companies and a Green bond correlated with (or issued by) a clean company, as presented by Baker et al. (2020). In the following, we summarize the results stated in Sections 2.1, 3.2 and Appendix C of their paper, using their variables and their notation. There are two firms, C (using a clean technology, non-polluting) and D (using a dirty technology, highly polluting), producing the same final consumption good. There are two points in time periods, $t \in \{0, 1\}$. Firms i ($i = C, D$) issues one unit of equity at price P_i at $t = 0$, and produces output $\mu_i I_i$ at $t = 1$, where I_i denotes investment, and μ_i represents (random) productivity. The stochastic productivity μ_i are normally distributed, $\mu_i \sim N(\mu, \sigma^2)$. The firm's productivities are uncorrelated with each other, i.e., $\rho = 0$. Firm D produces a negative externality proportional to its output $X = \mu_D I_D$.

There are two types of investors, denoted by L and M. Households of type M with population mass $\eta \in (0, 1)$ suffer more from pollution X, while households of type L with mass

[9] See e.g., Bottazzi et al. (2016), Delis and Mylonidis (2015), or Guiso et al. (2009) and references therein.

$(1-\eta)$ suffer less. $-\lambda_j X$ captures disutility from pollution for investor type $j = L, M$, where we assume $0 \leq \lambda_L < \lambda_M$. Furthermore, the type-$M$-household, who cares more for the environment, receives non-pecuniary disutility proportional to her investment in firm D, measured by $-\zeta_D < 0$. Households of both types exhibit exponential utility with common risk aversion parameter α.

At $t = 0$, household j chooses investments $I_{C,j}$ and $I_{D,j}$ into the clean and the dirty firm, respectively. Total investment into firm i is then given as $I_i = (1-\eta)I_{i,L} + \eta I_{i,M}$ for $i = C, D$.

There is a Green bond in zero net supply. At $t = 1$, the bond has a risky payoff denoted by V, which has correlation $\rho_V > 0$ with the clean firm's productivity μ_C. Being environmentalist, household of type M prefers green projects and receives positive non–pecuniary utility from investing in Green bonds, $\zeta_G > 0$.

The price of the bond is denoted by P_V, and it is set such that in equilibrium aggregate demand for the bond is zero, i.e., market clearing is achieved.

This implies that $P_V = (1-\eta)\nu_L + \eta\nu_M$, with ν_L and ν_M being the amounts invested in the bond by households of type L and M, respectively.

The investments in the clean firm C, dirty firm D, and positions in the Green bond are obtained as the solution to the following optimization problems for agents M and L. Household of type M solves

$$\max_{I_{C,M}, I_{D,M}, \nu_M} E[-\exp\{-\alpha(I_{D,M}(\mu_D-1)+I_{C,M}(\mu_C-1)+\nu_M(V+\zeta_C-P_V)-\lambda_M X-\zeta_D I_{D,M})\}], \tag{1}$$

while agent L solves

$$\max_{I_{C,L}, I_{D,L}, \nu_L} E[-\exp\{-\alpha(I_{D,L}(\mu_D-1) + I_{C,L}(\mu_C-1) + \nu_L(V-P_V) - \lambda_L X)\}]. \tag{2}$$

Form the first-order conditions we obtain the bond positions as

$$\nu_L = \frac{-\eta\zeta_G}{\alpha\sigma^2(1-\rho_V^2)}, \quad (3)$$

$$\nu_M = \frac{(1-\eta)\zeta_G}{\alpha\sigma^2(1-\rho_V^2)}. \quad (4)$$

Using the market clearing condition, the bond price is found to be

$$P_V = \mu + \eta\zeta_G - \rho_V(\mu - 1). \quad (5)$$

The aggregate investments in firm C and D are given by

$$I_C = \frac{\mu - 1}{\alpha\sigma^2} \quad (6)$$

$$I_D = \frac{\mu - 1 - \eta\zeta_D}{\alpha\sigma^2(1-(1-\eta)\lambda_L - \eta\lambda_M)} \quad (7)$$

The following conclusions can be drawn from these equations. First, the investment in the Green bond shown in (3) and (4) is motivated purely by agent's M positive non-pecuniary utility ζ_G. As we can see, households of type L take a short position in the bond, while type-M households are long. Second, the bond price increases with the population mass η of households of type M, which care more for environment. Finally, the higher their perceived utility from investing in the Green bond, i.e., the higher ζ_G, the higher the bond price. This in particular provides the theoretical mechanism for the Green bond premium, i.e., for the lower expected returns on the Green bond as compared to the conventional ones.

2.2.2 Green bonds of a polluting company

While in the setting of Baker et al. (2020) the Green bond has a correlation with the clean company only, we find in the data (see Section 3.1) that all types of companies issue Green bonds, in particular, also companies with an overall bad sustainability reputation (low ESG score). In this section, we are interested to see how an introduction of a Green bond correlated with the output of a polluting company changes the results presented above. Of special interest here is the investment decision of households of type M, which have on the one hand preferences for green investments and receive non–pecuniary disutility from investing in the polluting firms, on the other hand.

We consider the same general setting, with two companies, C and D, and two types of households, M and L. The only difference is the correlation of the Green bond's risky payoff V, $\rho_V > 0$, with the stochastic productivity of the dirty company D, μ_D. Both agents solve the same optimizations problems as presented in Equations (1) and (2).

Solving the optimization problem of household M, we obtain the investments in the clean and dirty firm and the position position in the Green bond:

$$
\begin{aligned}
I_{C,M} &= \frac{\mu - 1}{\alpha\sigma^2}, && (8)\\
I_{D,M} &= \frac{\mu - 1 - \zeta_D - \rho_V(\mu + \zeta_G - P_V)}{\alpha\sigma^2(1-\rho_V^2)} + \lambda_M I_D, && (9)\\
\nu_M &= \frac{\mu + \zeta_G - P_V - \rho_V(\mu - 1 - \zeta_D)}{\alpha\sigma^2(1-\rho_V^2)}. && (10)
\end{aligned}
$$

Similarly, for type-L households we obtain

$$
\begin{aligned}
I_{C,L} &= \frac{\mu - 1}{\alpha\sigma^2} && (11)\\
I_{D,L} &= \frac{\mu - 1 - \rho_V(\mu - P_V)}{\alpha\sigma^2(1-\rho_V^2)} + \lambda_L I_D && (12)\\
\nu_L &= \frac{\mu - P_V - \rho_V(\mu - 1)}{\alpha\sigma^2(1-\rho_V^2)}. && (13)
\end{aligned}
$$

With the market clearing condition $(1-\eta)\nu_L + \eta\nu_M = 0$, we obtain reduced expressions for bond positions:

$$
\begin{aligned}
\nu_L &= \frac{-\eta(\zeta_C + \rho_V\zeta_D)}{\alpha\sigma^2(1-\rho_V^2)} && (14)\\
\nu_M &= \frac{(1-\eta)(\zeta_C + \rho_V\zeta_D)}{\alpha\sigma^2(1-\rho_V^2)}. && (15)
\end{aligned}
$$

This pins down the bond price:

$$P_V = \mu + \eta\zeta_G - \rho_V(\mu - 1) + \eta\rho_V\zeta_D. \tag{16}$$

The aggregate investments in firms C and D remain the same as in Equations (6) and (7).

When comparing the bond positions in (14) and (15) with those from the previous case (where the Green bond was correlated with the output of the clean firm, Equations (3) and (4)), we observe that the positions in the Green bond are not only driven by type-M households' non-pecuniary utility ζ_G, but also by the disutility ζ_D from investing in the "dirty" firm D. The higher the correlation of the bond with firm D's productivity and the higher ζ_D, the higher the demand for bonds.

The results for the bond positions remain exactly the same when we consider a setting with *two* Green bonds, one correlated with the production of the clean company, and one correlated with the dirty company. This is due to the fact that the firms' productivities are uncorrelated, which carries over to the bond payoffs. The holdings of the two bonds for type-L households are then given by Equations (3) and (14), with the corresponding quantities for type-M households shown in Equations (4) and (15).

Assuming an analogous correlation of bond payoffs and firm productivities, i.e., $\rho_V^C = \rho_V^D$, and the same non-pecuniary positive utility from investing in Green bonds ζ_G for the two bonds, a household of type M holds more bonds of the dirty company as soon as $\zeta_D > 0$, i.e., as soon as the household receives disutility from investing in the dirty company. In this case, the Green bond of the dirty company also has the higher price. Denoting the price in (5) by P_V^C and the one in (16) by P_V^D, we find that

$$P_V^D - P_V^C = \eta\rho_V\zeta_D > 0, \tag{17}$$

with the difference increasing in the proportion of households with environmental preferences η.

Let us now assume that the household of type M differentiates between the Green bonds, i.e., it receives lower utility from investing in the Green bond of a dirty company, which is formalized through $\zeta_G^D < \zeta_G^C$. Then, for sufficiently large difference in preferences, i.e., for $\zeta_G^D < \zeta_G^C - \rho_V \zeta_D$, the Green bond of a dirty firm trades at a lower price than the Green bond of a clean firm. On the other hand, a significantly lower preference for Green bonds of a polluting firm might indicate lower trust of investors in their Green credentials.

2.2.3 Green bonds with a real impact

In the cases discussed in the previous two sections the Green bond had no real impact on the externalities (pollution) and, hence, no effect on the environment. With rapidly developing Green bond markets, concerns about labeling and green washing effects become more relevant. In particular, the real impact and/or additionality of a Green asset has become the focus of attention for investors, researchers, and regulators.

In the following, we model such a Green bond with a real impact in a setting, where an investment in the bond reduces disutility from negative externality (or pollution). Since in our setting, a firm C produces no negative externalities, the bond's payoff is correlated with firms D productivity as given in Section 2.2.2.

In this setup, the household of type M, suffering more from pollution and receiving positive non–pecuniary utility from investing in Green bonds and disutility from investing in firm D, optimizes

$$\begin{aligned}\max_{I_{C,M}, I_{D,M}, \nu_M} E[-\exp\{&-\alpha(I_{D,M}(\mu_D - 1) + I_{C,M}(\mu_C - 1) + \nu_M(V + \zeta_C - P_V) - \zeta_D I_{D,M} \\ &- \lambda_M \mu_D I_D + \gamma_M \nu_M \mu_D I_D)\}]. \end{aligned} \tag{18}$$

The term $-\lambda_M \mu_D I_D$ represents disutility from pollution, while $\gamma_M \nu_M \mu_D I_D$ gives the reduction of this disutility, which is proportional to the position in the Green bond.

From the first-order conditions we get

$$
\begin{aligned}
I_{C,M} &= \frac{\mu-1}{\alpha\sigma^2} \\
I_{D,M} &= \frac{\mu-1-\zeta_D}{\alpha\sigma^2} + (\lambda_M - \gamma_M \nu_M) I_D - \rho_V \nu_M \\
\nu_M &= \frac{\mu - P_V + \zeta_G - \rho_V(\mu-1-\zeta_D)}{\alpha\sigma^2(1-\rho_V^2)} + \frac{\gamma_M(1+\zeta_D)}{\alpha\sigma^2(1-\rho_V^2)} I_D.
\end{aligned}
$$

Analogously, agent L solves

$$
\max_{I_{C,L}, I_{D,L}, \nu_L} E[-\exp\{-\alpha(I_{D,L}(\mu_D - 1) + I_{C,L}(\mu_C - 1) + \nu_L(V - P_V) - \lambda_L \mu_D I_D + \gamma_L \nu_L \mu_D I_D)\}]. \tag{19}
$$

The first-order conditions now yield

$$
\begin{aligned}
I_{C,L} &= \frac{\mu-1}{\alpha\sigma^2} \\
I_{D,L} &= \frac{\mu-1}{\alpha\sigma^2} + (\lambda_L - \gamma_L \nu_L) I_D - \rho_V \nu_L \\
\nu_L &= \frac{\mu - P_V - \rho_V(\mu-1)}{\alpha\sigma^2(1-\rho_V^2)} + \frac{\gamma_L}{\alpha\sigma^2(1-\rho_V^2)} I_D.
\end{aligned}
$$

With the market clearing condition $\eta\nu_M + (1-\eta)\nu_L = 0$, and assuming an equal reduction in disutility from pollution for both types of households, i.e., $\gamma_L = \gamma_M = \gamma$, we can compute the bond price:

$$
P_V = \mu + \eta\zeta_G - \rho_V(\mu - 1) + \eta\rho_V\zeta_D + \gamma(\eta\zeta_D + 1) I_D. \tag{20}
$$

Note that this price is higher than the price of the Green bond of a clean company in (5) for either $\zeta_D > 0$ or $\gamma > 0$ (assuming equal non–pecuniary positive utility from investing in Green bonds ζ_G for both bonds), and even higher than the price of a bond correlated with the dirty firm's productivity without an impact in (16) for $\gamma > 0$.

Substituting (20) for the equilibrium price into the bond positions gives the following expressions:

$$\begin{aligned}\nu_M &= (1-\eta)\frac{\zeta_G+\rho_V\zeta_D}{\alpha\sigma^2(1-\rho_V^2)}+(1-\eta)\frac{\gamma\zeta_D}{\alpha\sigma^2(1-\rho_V^2)}I_D\\ \nu_L &= -\eta\frac{\zeta_G+\rho_V\zeta_D}{\alpha\sigma^2(1-\rho_V^2)}-\eta\frac{\gamma\zeta_D}{\alpha\sigma^2(1-\rho_V^2)}I_D.\end{aligned}$$

With these reduced expressions we can calculate the aggregate investments in firm C and D, which, however, remain the same as in the case without Green bonds (see Section 2.2.1):

$$I_C = \frac{\mu-1}{\alpha\sigma^2}, \tag{21}$$

$$I_D = \frac{\mu-1-\eta\zeta_D}{\alpha\sigma^2(1-(1-\eta)\lambda_L-\eta\lambda_M)}. \tag{22}$$

2.2.4 Implications and hypotheses

In the above subsections, equilibrium expected returns on Green bonds are lower than returns on conventional assets (here viewed as a direct investment in the issuing company) regardless of the issuing company or their real impact. So for instance, in the case of a Green bond correlated with the dirty firms' productivity in Subsection 2.2.2, we obtain the following expression for the difference in expected returns

$$E\{(\mu_D-1)-(V-P_V)\} = P_V-1 = (\mu-1)(1-\rho_V)+\eta(\zeta_G+\rho_V\zeta_D). \tag{23}$$

In the limiting case with $\rho_V \uparrow 1$, the difference in returns is $\eta(\zeta_G+\zeta_D)$, which is increasing in η. This means, the higher the proportion of households with environmental preferences, the lower the return they are willing to accept on the Green bond. Furthermore, the difference is not only increasing with their preference for green investments, ζ_G, which is intuitive, but also with their disutility of investing directly in the polluting company. Households with environmental preferences, which exclude certain companies from their investment universe, thus, still reward green assets of these companies. This leads to our main hypothesis for the empirical study:

Hypothesis 1. *Green bonds trade at a premium, i.e., at lower yields, than comparable conventional bonds.*

When comparing Green bond prices in the cases when the bond payoff is correlated with the clean and dirty firm's productivity, respectively, we obtain

$$P_V^D - P_V^C = \eta \rho_V \zeta_D + \eta(\zeta_G^D - \zeta_G^C). \tag{24}$$

Households with environmental preferences and receiving non-pecuniary disutility from investing in dirty companies, pay a higher price for the bond of a dirty company, if they do not distinguish between the Green bonds or the difference in preferences (ζ_G^D and ζ_G^C) is sufficiently small. The right-hand side of the above equation is positive for $\zeta_G^C < \zeta_G^D + \rho\zeta_C^D$. Theoretically, if households have preferences for green assets, and these assets are purely, i.e, trustably, green regardless of their issuers' sustainable reputation, then there should be no difference in investors' preference for these assets. With the assumption that households with environmental preferences penalize polluting companies, i.e. $\zeta_D > 0$, we obtain our next hypothesis:

Hypothesis 2. *Households, which care more for the environment, have equal preferences for all Green bonds, and they are willing to pay a higher price for bonds, issued by a company with lower sustainable reputation than for Green bonds, issued by a company with very high environmental standards.*

Following a similar line of argument, Green bonds with a real impact, i.e., reducing negative externalities or, equivalently, (perceived) disutility from pollution, should trade at higher prices than bonds without such an impact (P_V):

$$P_V^I - P_V = \gamma(\eta\zeta_D + 1)I_D \geq 0. \tag{25}$$

Assuming again no differences in preferences (i.e., equal ζ_G for both bonds), the difference in prices is increasing in the disutility coefficient ζ_D from investing in the dirty company.

Furthermore, the larger the aggregate investment in the polluting company, the more Green bonds are held by a household with environmental preferences, and the higher is the price of the bond.

Most importantly, the difference in prices is increasing with the reduction in disutility from pollution coefficient γ (for the case of the same polluting issuer). This means, the higher the environmental impact of the Green bond, the higher the price households are willing to pay for it. Which leads to our final hypothesis:

Hypothesis 3. *Households prefer Green bonds with an environmental impact, and they are willing to pay a higher price for such bonds than for green bonds without an impact for the environment.*

3 Data and variables

3.1 Data

To test our hypotheses, we have collected data on Green bonds from Bloomberg and Thomson Reuters Eikon. The data set contains 3,948 Green bonds with a total issuance volume of around \$1tn. When Green bonds first emerged in 2006, they were considered a niche product for a very particular investor clientele. As shown by the numbers in Figure 1, it took nine years before the annual issuance reached 100 billion USD. In 2021, however, the Green bonds market is by far no longer a niche segment. Governments and corporations issue now Green bonds in over 60 different currencies across the globe, with the cumulative issue volume having reached \$1tn in December 2020.

–Insert Figure 1 here–

We have downloaded main characteristics of these bonds, i.e., the issue date, maturity date, coupon, yield at issuance, amount issued, currency, sector, and credit ratings as well as information on the issuer from Reuters and Bloomberg. In our analysis we consider only fixed coupon plain vanilla bonds with available data on either issue yield or issue price. Next, we have collected ISINs of conventional bonds, issued by the same companies between January 2009 and February 2021. This gives us a universe of 21,872 conventional bonds and 2,099 Green bonds with available data in total. In some specifications, our sample is further reduced due to the unavailability of data on, e.g., credit rating or seniority. Table 1 provides descriptive statistics for the Green and conventional bonds used for our empirical analysis.

–Insert Table 1 here–

The average Green bond in our sample has a maturity of 8 years, an issuance volume of around $410m and is issued at prices slightly below par. The corresponding conventional bonds in Panel B have similar issue prices, slightly higher issue sizes ($635m), and lower average coupons and yields.

In a sub-sample analysis we consider bonds issued in different currencies to reveal possible differences across currency markets, and obtain 509, 408, and 1,182 Green bonds denominated in EUR, USD and other currencies respectively. We further include an analysis for different issuer types such as corporates, government and supranational entities. Out of the 2,099 Green bonds in our sample with issuer information available, 1,374 were issued by corporates, 317 by supranationals such as, e.g., European Investment Bank, and 408 by government entities.

3.2 Matching

As a robustness test, we also provide an analysis for *matched* bond pairs. Similar to Zerbib (2019), we consider for each Green bond one comparable conventional bond, issued by the *same* company, in the *same* currency, with the *same* credit rating, featuring the *same* bond structure, the *same* seniority, and the *same* coupon type. Since we cannot match the other bond characteristics (issue date, maturity, issue size) *exactly*, we define acceptable maximum differences within a pair of bonds with respect to these variables.

In particular, we only include conventional bonds, when the issue is no longer than two years away from the issue date of the Green bond, with an analogous restriction on the maturity date. With respect to the issue size, we only consider those bonds, where the size of the issue is between 1/2 and 2 of the issue size of the Green bond. In contrast to Zerbib (2019) we do not construct a synthetic conventional bond, but consider an existing tradable counterpart using a more restrictive matching method. Using more strict bounds on the maturity and issue size we, nevertheless, were able to find 658 bond pairs. Out of 658 Green (and, hence, also conventional) bonds in these pairs, 234 were issued in EUR, 128 in USD and 59 in CNY. 454 are issued by corporations. Around one third (228) have very large issue sizes within the top quintile across all bonds issued in the same year. Interestingly, 512 out of 658 Green bonds have a third-party certification of Green credentials. Table 2 provides descriptive statistics for the Green and conventional bonds used for this analysis. In fact, in our final data set conventional bonds are matched with Green bonds very closely. The average ratio of issue sizes (Green bond divided by conventional bond issue sizes) is 1.04 (median 1.0), the average differences in maturity dates is around one year (mean 357 days, median 301 days), and the average difference in issuance dates is 270 days (median 233 days).

–Insert Table 2 here–

3.3 Measuring Green–credibility

The first Green bonds were issued by supranationals[10] to finance projects from traditionally sustainable sectors, e.g., renewable energy. In 2021, however, corporations from different sectors (e.g., energy, transportation, financials) and government entities are among the largest issuers. Also the list of eligible Green project categories has been extended over the past years.[11] Now, also companies and countries contributing to global greenhouse gas (GHG) emissions can issue Green bonds to finance projects related to

[10]European Investment Bank (EIB) and World Bank

[11]See for instance, the list of eligible Green project categories provided in the ICMA Green Bond Principles.

e.g., sustainable water, energy or waste management, or to build so-called green buildings. So for instance, in 2016, the Mexico City Airport Trust issued a $6bn Green bond in order to finance the construction of a new airport, which attracted significant public attention and caused discussions, whether airports, being one of the biggest polluting industries, are suitable for Green bonds projects in the first place. With increasing number of Green bonds and their issuers, the market transparency suffers, so it is often challenging for investors to assess the Green-credibility of the bond and the corresponding project. One of the driving factors for the existence of the Green bond premium is the investors' preference for Green instruments, which is, however, based on their trust in the Green–credentials of the corresponding bond. While some bonds and their issuers might appear more Green–credible, for others, additional verifications might be required in order to increase investors' preference for these instruments. To measure Green–credibility, we consider several variables related to the characteristics of the bond, its issuer and its issue country, which are potentially relevant for investors' acceptance of the Green label.

The trust of investors in Green labels can be increased through a third party's verification of the issuer's Green bond framework and its related project. A large number of so-called approved verifiers (such as for instance, Sustainalytics, Cicero, Vigeo Eiris etc.) provide a pre- or post-issuance certification based on different Green bond standards. In particular, the use and management of proceeds as well as allocation and impact reporting are reviewed.[12] To estimate potential differences in pricing of certified and non-certified Green bonds, we include a dummy variable *Certified* in our primary and secondary market analyses.

Another confirmation of credibility of the Green bond and its label can be provided through a listing of the bond on exchanges with a dedicated Green bonds segment. In the last few years many exchanges have launched dedicated segments exclusively for Green bonds, which have improved the liquidity and transparency of the Green bonds market and provided access to different types of investors. More importantly, Green exchanges have the potential to increase credibility of the Green label, since bonds listed in dedi-

[12] An example for such a certification file can be found for bonds listed on the Luxembourg Green exchange.

cated segments are usually required to meet certain standards with respect to reporting and external reviews. For instance, the Luxembourg Green exchange, one of the first dedicated Green bond platforms, requires issuers to follow the Green Bond Principles, the CBI Climate Bonds Standard eligibility taxonomy, or other related frameworks[13]. In 2019, the London Stock Exchange tightened its Green bonds listing standards by introducing mandatory annual post-issuance reporting requirements for issuers, to "provide transparency to investors on the ongoing use of proceeds and demonstrate continued eligibility over the lifetime of the bonds".[14] We, thus, expect that bonds listed on such exchanges appear more credible to investors, or at least, suffer less from any Greenwashing concerns. To investigate the determinants of the Green bond premium, in our secondary market analysis we, therefore, include a dummy variable *GreenEx*, which is 1 for Green bonds traded on such Green exchanges.

In addition to the attributes of the bond, we further consider variables related to the general sustainability reputation of the issuer. To this end, we include the sustainability (ESG) rating of the issuing entity provided by Sustainalytics. The Sustainalytics ESG rating is a quantitative score on a scale of 1-100, measuring "how well issuers proactively manage the environmental, social and governance issues that are the most material to their business".[15] It classifies firms as Laggards, Underperformers, Average Performers, Outperformers and Leaders, with a score above 70 indicating Leaders and a score below 40 indicating Laggards.[16]

In our analysis we consider the effect of the sustainability rating for corporate issuers with available ESG scores at the date of the Green bonds' issue. We obtain ESG scores for 432 Green bonds issued by 192 corporate issuers in our sample. These issuers are located in over 30 different countries with around 50% based in the US, Japan, France and China. Also in terms of sectors our sample is well diversified, with issuers representing 11 different

[13]See `https://www.bourse.lu/sustainability_standards_and_labels` for an overview of various Green bond standards.

[14]See `https://www.lseg.com/resources/media-centre/press-releases/london-stock-exchange-launches-green-economy-mark-and-sustainable-bond-market`.

[15]Please note that Sustainalytics adjusted its rating methodology in 2018, switching from ESG ratings to ESG risk ratings and, hence, inverting the scale. In this analysis we use the Sustainalytics ESG ratings. See `https://www.sustainalytics.com/` for more details.

[16]Exact thresholds for the cut-offs are industry-specific and can vary.

sectors. Interestingly, while most of the issuers in our sample have a solid reputation of sustainability in general (with an average ESG score of 66), there are several Green bonds issued by companies with rather low sustainability rankings (the minimum score is 38). As illustrated in Figure 2, nearly 25% of all issuers with ESG rating data available have a score below 60, which indicates underperforming companies.

–Insert Figure 2 here–

For this analysis, we include two dummy variables *LowESG* and *TopESG*, for companies with an ESG score below or equal to 60 and above or equal to 85 respectively. These allow us to investigate how investors evaluate the Green label of bonds, issued by companies with a very good and a very bad sustainability reputation compared to the average. From a rational point of view, when looking at companies with top ESG ratings, there should be only a small, if at all, significant effect of the Green label on the bond price, since the conventional bonds of these companies already finance predominantly Green projects. On the other hand, institutional investors trying to avoid negative headlines due to possible Greenwashing issues or "shades of Green"[17] of bonds from other sectors, would particularly demand Green bonds issued by companies with an excellent reputation. The evaluation of Green bonds issued by companies with very low ESG scores can also be insightful. While, on the one hand, such bonds are sometimes branded "oxymoronic", and investors might question the sustainability of related projects, on the other hand, so-called "impact investors" might nevertheless particularly reward companies, which try to improve their business practices, e.g., by significantly reducing Green House Gas (GHG) emissions through projects financed by Green bonds. In addition, we also consider only the environmental (E) score of the corresponding issuer, and include two variables *LowE* and *TopE*. Since the overall ESG score takes different aspects of sustainability into account, issuers might have high ESG scores by performing well on social and governance indicators, but still have rather bad environmental performance.

[17] See e.g., `https://www.globalcapital.com/article/b1dpvkz9g111vw/light-green-bonds-throw-no-shade-on-the-dark-green-market`

Investors, which substantially care for the environment would, thus, have rather a closer look on the E score and not on the overall ESG score.

Further, investors' preferences for Green assets might vary across countries, with strong preference in countries with high awareness for environmental issues, and rather weak preference in countries with low national efforts to reduce CO2 emissions. To account for these differences, we include the Environmental Performance Index (*EPI*) developed at Yale University, which measures environmental trends and the progress of the corresponding country. It ranks 180 countries on 32 performance indicators covering environmental health and ecosystem vitality.[18] Figure 3 displays the EPI scores for 2020. The top three countries are Denmark, Luxembourg and Switzerland, while Myanmar and Liberia are at the bottom of the list. According to the EPI methodology, low scores on the EPI indicate the need for national sustainability efforts with regard to several major environmental issues, such as the improvement of air quality and the reduction of GHG emissions. The trust of investors in Green labels, and the willingness to contribute to national environmental efforts could thus, be particularly high in countries with well established environmental policy goals.

–Insert Figure 3 here–

Our efforts on finding a variable to measure the real impact or additionality of a Green bond were, however, not successful. We started with the use of proceeds description to extract the information on whether the bond finances a new project or refinances an existing one. Yet the corresponding description field is formulated very general, including both, financing and refinancing terms[19]. We further checked the corresponding information provided directly by Green bond issuers on e.g., Luxembourg Green bond exchange. Also these files contain only general formulation like "... intends to use the net proceeds of green finance instruments issued under this Framework to finance or refinance, in whole or in part, sustainable and energy efficient projects". We, next, focused on Green bonds

[18]See `https://epi.envirocenter.yale.edu/` for more details on the calculation methodology.

[19]The description contains, e.g., the following text: "General Corporate Purposes, Refinance, Green Bond/Loan", "Project Finance, Refinance, Green Bond/Loan".

with an external certification to see, whether we could retrieve any useful information from the second opinion files. Also here, we find only general evaluation of the corresponding Green bond framework of the issuer. Further, these files are usually not single bond specific, but are used for all Green bonds of the corresponding issuer issued according to the defined framework (usually for a certain time period for e.g., three years). Our final effort was to map the avoided CO2 or GHG emissions through financed Green bond projects as reported in the impact reports (provided e.g., on Luxembourg Green bond exchange). Yet, also these reports are usually not Green bond specific but report the numbers of all single projects financed by the company in a corresponding year. Some of them contain more than 70 pages describing over 80 different projects across the globe[20], so it is hardly possible for investors to retrieve any useful information on the real impact of a specific Green bond. To assess the value of the Green bond, investors, thus, can only rely on some, rather subjective, proxies such as e.g., the size of a bond (the larger the higher the impact), or the issuer type and its green reputation, or the currency.

Apart from the full sample analysis of the Green bond premium, we also perform subsample analyses by splitting the sample with respect to the issuer type and issue currency. At the issuer type level, we distinguish between a corporate and "more official" entities, such as governments, local governments, and supranationals. We expect bonds issued by the latter to have lower yields, all else equal, since it seems reasonable to associate lower information asymmetries with them than with corporations. At the same time there might of course also be official entities issuing Green bonds from countries with rather low domestic sustainability efforts (such as e.g., Nigeria or Mexico) or large corporate issuers from more sustainable sectors such as renewable energy or sustainable transportation. Yet, after controlling for the country of issue, Green bonds issued by governments and supranational entities tend to have larger issue sizes and might be viewed as more credible in terms of a better implementation, clearer documentation and a greater impact of the Green project to be financed by the bond.

Similar argumentation can be applied to the samples split with respect to different cur-

[20]See e.g., a report of the Worldbank for the year 2019, bond isin US45905UX338

rencies. Obviously, there may be other reasons than Green–credibility for the decision to issue in a specific currency. Still, since Green bonds are issued in over 60 different currencies, and some issuers do offer Green bonds in different currencies on the same markets[21], investors in some countries (e.g., China or Mexico) with rather low sustainability reputation might trust and value the label of Green bonds denominated in major currencies (EUR, USD) more than of those denominated in their local currency.

4 Empirical Analysis

4.1 Primary market analysis

To reveal possible differences in yields between Green and conventional bonds, we focus on yields at issue following the regression

$$Y_{i,t,b} = \alpha_i + \beta \cdot Green_{i,t,b} + Controls, \tag{26}$$

where $Y_{i,t,b}$ is the yield at issuance of bond b, issued by the issuer i in month t. The dummy $Green_{i,t,b}$ is the main variable of interest and is equal to 1 if the bond is labeled as Green, and 0 otherwise. We control for maturity (in years), size (ln of issue volume in bn USD), credit rating (lowest rating across main rating agencies such as Moody's, S&P and Fitch, expressed in the S&P equivalent, coded with 1 equal to CCC-and 18 equal to AAA rated bonds). We further control for differences across seniority types, currencies, time (year-month) of issuance, and issuer ids.

Table 3 presents our main results for the primary market analysis. After including all above stated fixed–effects and controls except the credit rating, the regression specification (1) suggests that Green bonds are issued at a lower yield of around 12.8 basis points (bps) than comparable conventional bonds. However, when we include the credit rating for all bonds with available data (1,555 out of 2,099 Green bonds) in column (2), the

[21] For instance, Kreditanstalt für Wiederaufbau (KfW) or European Bank for Reconstruction and Development (EBRD).

result fundamentally changes. The difference in yields between Green and conventional bonds is no longer significant, while the coefficient on the credit rating variable is negative though insignificant. Without accounting for credit risk, one could thus misleadingly come to a conclusion of a high Green premium at primary markets, while there are actually no differences in prices, on average. For primary markets, we, therefore, have to reject our main Hypothesis 1 on the general existence of the Green bond premium, which in turn, means rather a weak preference of investors for Green bonds, or their low trust in the Greenness of these types of Green assets.

–Insert Table 3 here–

One way to increase investors' trust in Green bond label is a verification of the Green credentials by a third party. In column (3) we include an interaction dummy of a Green bond with available Green certification, and observe a significant premium of around 16 bps for such bonds, while the premium for not certified bonds is still insignificant. Investors, thus, do not blindly trust all Green labels and have preferences only for reliable Green assets. We have, therefore, to partly reject our Hypothesis 2 on equal preferences of investors for all Green labeled assets.

Further, investors might have higher preferences for Green assets that have a higher environmental impact, e.g., by financing projects, where more tons of CO2 equivalents are avoided. However, such information is hardly available at the time of issuance. Investors have, thus, to rely on some rather subjective proxies, for instance the issuance size (i.e., large Green bonds finance more sustainable projects and, this way, have a higher impact). In column (4), we include an interaction variable for Green bonds and conventional bonds with an issue size within the top quintile across all issues in the corresponding year of issuance, and find the coefficient on large Green bonds to be significantly negative, while it is insignificant for conventional bonds. Investors are willing to accept 14 bps lower yields, on average, for very large Green bonds, while the premium on mid–sized and small bonds is insignificant. Though it might also be liquidity issues, which drive the demand for large bonds, in the absence of reliable measures for the environmental impact, investors can use size of the project as a proxy for it. When looking at the sample of large Green bonds, we have to account, that most of these bonds have been certified as Green by a third party (479 out of 592 bonds, i.e., 81%). It is, thus, can be the case that it is the effect of certification, as presented in column (3), driving the result, and not the size of the bond. So, in column (5), we consider a dummy for certified Green bonds with very large issue sizes and a dummy for certified small and midsize Green bonds, and find a significant negative effect of certification on the yield of large bonds, and an insignificant effect for others (though it is only slightly insignificant, with t-stat -1.64). Further, it column (6), we consider dummies indicating large certified and non–certified Green bonds. Notably, only certified large Green bonds trade at a premium (21 bps), while the premium on non-certified bonds is strongly insignificant (t-stat -0.77). Certification effect, thus, overweight the size effect, and it is particularly important for very large bonds. This is a strong indication for our Hypothesis 3, stating that investors do value bonds with a higher impact (here using size as a proxy), but only if this potential impact is credible, i.e., verified by a third party.

Finally, in column (7), we investigate how investors' preferences vary with the environmental matters in the country of issue. To this end, we consider the interaction effect between the Green dummy and countries within the top quintile with respect to the corresponding EPI score. Here, we observe, that investors in countries with high political awareness and efforts on sustainable issues, as indicated by high EPI scores, have a higher willingness to contribute to global actions on preserving environmental health and ecosystem vitality by accepting, on average, 22 bps lower yields on Green bonds.

In our next analysis of primary markets, we investigate how investors' preference and their trust in the Green label vary across issuer types and currencies. To shed more light on this issue, we present in Table 4 the results of specification (2) of Table 3 for different sub-samples with respect to issue currencies and issuer type. First, in columns (1) to (3) we observe a significant heterogeneity in premia across currencies. While Green bonds denominated in EUR trade at a significant premium of 9 bps, bonds issued in USD and all other currencies trade at similar yields as their conventional counterparts. Interestingly, 90% (375 out of 416 bonds) of Green bonds denominated in EUR have a third-party verification of Green credentials, so it can be rather an effect of the certification and not a currency effect. However, when we split the EUR sample in certified and non–certified bonds, we find the coefficient on the Green bond for both samples significant (though for non–certified only at 10% level, which might be due to the very small sample of 41 bonds)[22].

–Insert Table 4 here–

In specifications (4) and (5), we consider Green bond premia for different types of issuers. After accounting for the credit rating, we find very high premia of around 18.5 bps for Green bonds issued by governments and supranationals, while corporate Green bonds trade at significant discounts of around 6 bps. Investors thus rely more on the Green label and strict implementation of Green projects by official entities rather than by corporations. To disentangle the issuer type effect from general currency effects, in specifications (6) and (7) we add currency dummies for Green bonds denominated in EUR, and find, that currency plays an important role especially for corporate bonds. For government and supranational bonds the coefficient on the Green bond dummy is significant for all currencies, though it is higher (in absolute terms) and more significant for EUR bonds. For corporations, only EUR denominated bonds trade at a huge premium of up to 35 bps, while others trade at a significant discount. This might be an indication that it is particularly Green corporate bonds issued in Europe, which align with European or acknowledged international (and not, e.g., local Chinese) Green Bond Principles are in higher demand among investors. Further, as we can see from the EPI scores for 2020, most of the European countries rank within the top 25, indicating higher awareness and higher political efforts on mitigating environmental issues. Corporations, issuing bonds in European countries might be, thus, under tighter legal constraints and regulation and have higher public pressure on actually implementing Green projects.[23]

[22]Results are not reported here, but are available upon request.

[23]It should be noted, that 96% of Green corporate bonds denominated in EUR have an external certification. Nevertheless, when we split the sample in certified and non–certified bonds, coefficients on both Green dummies are significant. Results are available upon request.

In a further analysis we investigate, which characteristics of a corporate Green bond or its issuer might increase its valuation relative to a conventional one. For a better comparison, we display the base result for the full corporate sample in specification (4) of Table 4 again in column (1) of Table 5. Specification (2) shows that corporate Green bonds which are certified as Green, trade at significantly lower yields of around 24 bps than comparable conventional bonds. Notably, bonds without such a certification, are even penalized by investors, and trade at significant discounts of around 24 bps. Also here, 316 out of 382 Green corporate bonds with large issue size have a Green certification. However, when we consider large certified and small and midsize certified Green bonds in column (3), we find the effect of certification to be significant for both sub-samples, though the coefficient for very large bonds is much larger. Similarly to the full sample, the coefficient on the non-certified large bonds in column (4) is strongly insignificant. For a corporate Green bond, certification of the green credentials obviously has a substantial impact on the yield at issuance. Investors are willing to pay a premium for corporate Green bonds only, when the eligibility of the related Green project has been approved by an external company, and, consequently, the bond has a pronounced verified environmental impact.

–Insert Table 5 here–

In columns (5) and (6) we investigate the effect of the sustainability reputation of the corresponding issuer on the bond yield at issuance. While the results in (5), using the total ESG score, are slightly insignificant for the high ESG score, they nevertheless indicate that investors prefer bonds of issuers with high sustainable reputation (ESG score >85), while they penalize bonds of corporations with bad overall sustainable reputation (ESG score below 60). The results for the pure environmental score in (6) are even more pronounced for top performer across corporations. In contrast to our theoretical discussion, investors do distinguish between Green bonds and their issuers, and they prefer only bonds issued by companies with high environmental efforts. This leads to a final rejection of our Hypothesis 2.

In a further analysis of the primary markets, we present a robustness check for the main results in Table 3 and Table 4. To this end, we use a spread over the corresponding risk-free government rate as the dependent variable. Table 6 summarizes our results. Though the levels of coefficients are smaller now, the directions of the effects remain the same. In column (1) we observe a small but (now) significant reduction in the spread for Green bonds of 3 bps. However, when we split the sample with respect to different currencies in columns (2) to (4), we again, find only EUR denominated bonds trading at significantly lower yields, while there are no differences in prices for other currencies. Similarly, in column (5), we observe no differences in yields for corporate Green bonds, on average, but significantly lower yield spreads for bonds issued by governments and supranationals.

–Insert Table 6 here–

In our final analysis of the primary markets, we consider the characteristics of the difference in yields at issuance of the matched bond pairs as described in subsection 3.2. Figure 4 presents a histogram for the differences in yields (greenium). With the mean of -7.2 bps (median -2), the Green bonds in our matched sample trade at lower yields than their conventional counterparts, on average.

–Insert Figure 4 here–

We could not find any direct measures for the real environmental impact of the specific Green bond to explicitly test our Hypothesis 3. However, if we use proxies such as e.g., issuer type (government or supranational entity) or the size (large) of the bond, we do see an indication that investors value Green bonds with a higher (verified) impact and are, thus, willing to accept lower yields on such bonds.

To summarize, the results of this section reveal insignificant premia for Green bonds on primary markets, on average. However, the willingness of investors to pay higher prices for Green than for conventional bonds depends on the Green–credibility of the bond. In particular, investors do accept lower yields for bonds denominated in EUR, issued by a government or a supranational entity, or for large corporate bonds with an external certification of its green credentials.

4.2 Secondary market analysis

In this section we shed more light on possible differences in pricing between primary and secondary markets for Green bonds. To this end, we analyze over 10 million of daily trading data including Ask and Bid prices and the mid–yield of corresponding bonds. On average, we have around 790 days with trading data available for each Green bond in our sample.

4.2.1 Yield to Maturity Analysis

We adapt our regression analysis from Section 4.1, where we now regress the *Yield to Maturity* on the *Green* dummy variable. Here, we also include the corresponding Bid-Ask spread as a liquidity control, as this is particularly important on the secondary market. We further include all fixed effects specified in Section 4.1. Specification (1) in Table 7 presents our main result, while specifications (2) to (6) present sub-sample analyses. Similar to our main result from the primary market (column (2) in Table 3), we again find the coefficient for the *Green* dummy to be insignificant for the full sample. On the secondary market, Green bonds trade at *similar* yields as comparable conventional bonds, on average. Also for bonds denominated in major currencies we do not find any significant premia (sub-samples in columns (2)–(4)).

–Insert Table 7 here–

In specifications (5) and (6) we, split our sample w.r.t. the issuer type, and in line with our findings in primary market analysis, we find a significant difference in terms of pricing across the two groups (Corp vs. Govt+Supr). Only Green bonds issued by governments or supranational entities trade at a small but significant premium of around 4.5 bps, while corporate bonds trade, on average, at similar yields as conventional bonds. It is, thus, once again Green bonds, issued by more official entities, which enjoy higher demand and appear to be more Green–credible.

In a robustness analysis, we present the same regressions for the spread over the corresponding risk-free government rate as the dependent variable. Table 8 confirms our previous results on the insignificant premia for the full sample, and a premium of around 4.5 bps for Green bonds issued by governments and supranational entities.

–Insert Table 8 here–

4.2.2 Matching Analysis

In our final analysis we investigate the determinants of the difference in yields between Green and conventional bonds in greater detail by analyzing *matched* bond pairs. Though we use highly restrictive matching method, we were able to match 658 bond pairs, out of which we finally have 431 pairs with available trading data (nearly 185 thousand daily observations). We have deleted all observations with the ask price below the bid price and all lines, where one of the prices or the mid–yield of one of the bonds were not available. We then, follow Zerbib (2019) approach, and regress the yield differential of matched bond pairs ($\Delta Yield_{i,t}$) on the differences in Bid–Ask spreads ($\Delta Liquidity_{i,t}$):

$$\Delta Yield_{i,t} = p_i + \alpha \Delta Liquidity_{i,t} + \epsilon_{i,t}. \tag{27}$$

Thereby, the green bond premium is isolated as the unobserved effect in the fixed-effect panel regression p_i. Table 9 presents results of this regression. The effect of the differences in Bid-Ask spread is significant at 10% level, with an increase of 1 bp increase in the spread inducing 1.38 bps decrease in the yield differential.

–Insert Table 9 here–

More interesting are the characteristics of the Green premia, i.e., 431 fixed–effects p_i. Table 10 and Figure 5 present the distribution characteristics of the "Greenium". In line with our previous results, the mean of 0.0035 is not significantly different from 0 (t–stat 0.3873). The minimum is -0.60 bps, the maximum 0.62 and the median is 0.0044.

–Insert Table 10 here–

–Insert Figure 5 here–

In a next step, we investigate the drivers of the Green bond premium. To this end, we regress the estimated fixed-effects p_i on a set of credibility variables described in Section 3.3, using an OLS regression with robust estimation of the standard errors

$$p_i = \alpha_0 + \sum_{j=1} Controls_j + \epsilon_{i,t}, \tag{28}$$

where we use as controls dummies indicating whether the corresponding Green bond is issued in EUR, issued by a corporation, has a large issue size compared to all other bonds issued in the same year (Large), has an external certification (Certified), is traded on a green exchange (GreenEx), and whether its issuer has a high or low overall environmental reputation as measured by a high (≥ 85) or low (≤ 60) Environmental score provided by Sustainalytics. Table 11 presents our results. In column (1) we observe that either currency nor issuer type have a significant effect on the size of the premium, which also do not changes after including further controls. Columns (2) and (3) confirm our previous result, that particularly large Green bonds are in high demand, and thus, trade at approx. 6 bps lower yields that midsize and small Green bonds. After including the certification effect in column (4), the significance of the size effect remains. It should be mentioned, however, that out of 219 large Green bonds in our sample, 176 have an external certification. Notably, the coefficient on large Green bonds without an external certification (43 bonds in our sample) is not significant.[24]. This again, confirms our finding from primary market analysis and our Hypothesis 3, that size is only relevant to investors, when the related bond project has a confirmed environmental impact.

Furthermore, in column (4), we observe a considerable impact of the listing of the Green bond. The difference in yields for pairs containing Green bonds listed on the exchanges with a dedicated Green market segment is significantly lower by around 3.6 bps. Green

[24] with t-stat -0.90, result not reported here but available upon request

exchanges (such as for instance, those in Luxembourg or London) thus provide higher visibility and transparency for those bonds and increase the reliability of the overall Green bonds label.

–Insert Table 11 here–

Specifications (3), (4) and (7) highlight the relevance of the external certification. The yield difference is, on average, around 4 bps lower for Green bonds with confirmed Green credentials. Though in column (4) the coefficient is slightly insignificant (t-stat is -1.61), there is a strong correlation between certification and Green exchange listing effects. Most of the exchanges, and particularly, Luxembourg Green exchange and London Stock exchange do expect such a certification for Green bonds to be listed there. So, in our sample, 165 of Green bonds are listed on a green exchange and have a certification.

Finally, in columns (5) to (7), we consider Green-conventional bond pairs issued by corporate institutions with available data on ESG ratings (106 bond pairs in total), and find the environmental reputation of bond issuers to be highly important. More specifically, corporations with very high scores (over 85) benefit from a reduction of the yield differential by around 7–9 bps. This might be particularly driven by investors, who apply a top-down approach in their asset selection process, and first specify the pool of suitable companies by considering only top ratings, and then select the corresponding instruments. Similarly to our findings in primary market analysis (Table 5, column (6)), the overall sustainability rating (ESG score) seems to be less relevant for the decision of investors.[25].

Interestingly, the impact of the environmental reputation becomes less significant when we include more companies from the middle, e.g., E score above 75. This is well in line with previous findings by e.g., Hartzmark and Sussman (2019), that investors mostly react to extreme ratings.

[25]with t-stats below -1.6, not reported in Table 11, but available upon request

5 Conclusion

With booming Green bond markets, the need for more transparency, uniform standards regarding eligibility of Green projects, external certification, and reporting becomes more urgent. Many investors have become skeptical about Green credentials or the actual environmental impact of bonds issued by certain companies or countries, and do to trust Green labels without additional verification.

Although there is evidence that investors generally value sustainability and are willing to pay for non-pecuniary characteristics of investments, the existing results on so-called Green bond premium are mixed. In this paper, we shed more light on the existence of the Green premium by linking the investors' valuation of the Green label to the *"Green–credibility"* attributes of the corresponding bond and its issuer.

Using data on more than 1,500 Green and 20,000 conventional bonds we find, ceteris paribus, no difference in yields at issuance for Green bonds. The existence and significance of the Green premium, however, varies substantially across currencies and issuer types. It is high and significant for bonds issued by official entities such as governments or supranationals, or for bonds denominated in EUR. For corporate Green bonds, however, additional verification of Green credentials is required.

This is true also for secondary markets, where we consider over 431 matched Green-conventional bond pairs of the same issuer. In particular we find the Green–credibility of the bond, indicated e.g., by a listing on a Green exchange, the size of the issue (and this way, indirectly, the environmental impact of the Green bond), as well as the sustainable reputation of the bond's issuer significantly reducing the Green-conventional yield differential.

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Table 1: Descriptive statistics

Panel A: Green Bonds

	5%	25%	50%	Mean	75%	95%	N
Coupon(%)	0.11	0.62	1.87	2.55	3.92	7.3	2,099
Issue Price	99.02	99.77	100	99.74	100	100.05	2,099
Issue Yield	0.11	0.63	1.87	2.55	3.92	7.3	2,099
Maturity(Years)	3	4.99	6	7.95	10.00	20.01	2,099
Volume($Million)	7.92	54.29	171.27	410	546.97	1173.75	2,099

Panel B: Conventional Bonds

	5%	25%	50%	Mean	75%	95%	N
Coupon(%)	0.1	0.77	1.8	2.36	3.37	6.5	21,872
Issue Price	99.21	100	100	99.78	100	100	21,872
Issue Yield	0.1	0.78	1.8	2.37	3.38	6.5	21,872
Maturity(Years)	2.75	5	9	10.06	10.67	30.02	21,872
Volume($Million)	3.54	27.745	82.21	634.49	300	1750	21,872

Coupon (%) is the annual coupon; *Issue Price* is the price of the bond at issuance; *Issue Yield* is the yield to maturity of the bond at issuance; *Maturity (Years)* is the difference between the Issue Date and Maturity Date in Years; *Volume ($Million)* is the issue volume of the bond converted in Million USD.

Table 2: Descriptive statistics for matched bonds

Panel A: Green Bonds

	5%	25%	50%	Mean	75%	95%	N
Coupon(%)	0.07	0.42	1.18	1.88	2.88	5.5	658
Issue Price	99.03	99.76	100	99.83	100	100	658
Issue Yield	0.07	0.42	1.18	1.88	2.88	5.5	658
Maturity(Years)	3	5	7	9	10	30	658
Volume($Million)	11.85	59.12	209.93	473.65	577.6	1,240	658

Panel B: Conventional Bonds

	5%	25%	50%	Mean	75%	95%	N
Coupon(%)	0.125	0.39	1.25	1.93	3	5.45	658
Issue Price	99.07	99.75	100	99.77	100	100	658
Issue Yield	0.12	0.39	1.26	1.94	3	5.45	658
Maturity(Years)	3	5	7	9.16	10.01	30.02	658
Volume($Million)	11.02	59.37	224.33	509.86	597.5	1,458	658

Coupon (%) is the annual coupon; *Issue Price* is the price of the bond at issuance; *Issue Yield* is the yield to maturity of the bond at issuance; *Maturity (Years)* is the difference between the Issue Date and Maturity Date in Years; *Volume ($Million)* is the issue volume of the bond converted in Million USD.

Table 3: *Primary Market Analysis (Full Sample)*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Green	-0.128***	-0.0355	0.0842	0.0416	0.0848	0.0297	-0.00164
	(0.0398)	(0.0366)	(0.0643)	(0.0480)	(0.0643)	(0.0466)	(0.0367)
Green-Certified			-0.157**				
			(0.0639)				
Green-Large				-0.138**			
				(0.0562)			
Conv-Large				0.0897			
				(0.0586)			
Green-Certified-Small					-0.0920		
					(0.0676)		
Green-Certified-Large					-0.263***	-0.209***	
					(0.0678)	(0.0485)	
Green-nCertified-Large						-0.0687	
						(0.0897)	
Green-HighEPI							-0.223***
							(0.0784)
Credit Rating		-0.0217	-0.0217	-0.0220	-0.0222	-0.0223	-0.0218
		(0.0256)	(0.0256)	(0.0253)	(0.0257)	(0.0257)	(0.0256)
Maturity	0.0311***	0.0336***	0.0336***	0.0337***	0.0335***	0.0335***	0.0336***
	(0.00302)	(0.00294)	(0.00294)	(0.00288)	(0.00294)	(0.00294)	(0.00292)
Size	-0.100***	-0.0890***	-0.0888***	-0.101***	-0.0877***	-0.0876***	-0.0886***
	(0.0257)	(0.0260)	(0.0260)	(0.0319)	(0.0261)	(0.0261)	(0.0260)
Constant	10.43***	10.51***	10.50***	10.67***	10.49***	10.49***	10.49***
	(0.684)	(0.843)	(0.842)	(0.904)	(0.842)	(0.842)	(0.840)
Green Bonds	2,033	1,555	1,555	1,555	1,555	1,555	1,277
Observations	23,873	21,311	21,311	21,311	21,311	21,311	16,672
R-squared	0.796	0.819	0.819	0.819	0.819	0.819	0.819

The table shows results of the regressions of Yield at issuance for Green and conventional bonds. The Issue Yield of Green and conventional fixed coupon plain vanilla bonds is regressed against a *Green* dummy variable, which is 1 if the bond is a Green bond and 0 otherwise. We control for maturity (in years), size (ln of issue volume in bn USD), credit rating (lowest rating in the S&P equivalent, coded with 1 equal to CCC-and 18 equal to AAA rated bonds). We further control for differences across seniority types, currencies, time (year-month) of issuance, and issuer ids. *Green–Certified* is a dummy variable, which is 1, if the corresponding Green bond has been certified as such by a third party, and 0 else. *Green–Large* is an interaction variable, identifying Green bonds within the top quintile with respect to the issue size within the corresponding year of issuance. *Conv–Large* is an interaction variable, identifying conventional bonds within the top quintile with respect to the issue size within the corresponding year of issuance. *Green–Certified–Small* is an interaction variable, identifying Green bonds within the first four quintiles with respect to the issue size within the corresponding year of issuance and with a third party certification. *Green–Certified–Large* is an interaction variable, identifying Green bonds within the top quintile with respect to the issue size within the corresponding year of issuance and with a third party certification. *Green–nCertified–Large* is an interaction variable, identifying Green bonds within the top quintile with respect to the issue size within the corresponding year of issuance and **without** a third party certification. *Green–HighEPI* is an interaction variable, identifying Green bonds, issued in countries with the highest (top 20%) EPI score. *Green Bonds* gives the number of Green bonds used for an analysis. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: *Primary Market Analysis (Sub-samples)*

	Currency			Issuer Type			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Subsample	EUR	USD	OTHER	CORP	GOVT/SUPR	CORP	GOVT/SUPR
Green	-0.0869**	-0.0854	0.0474	0.0627*	-0.185***	0.163***	-0.124*
	(0.0392)	(0.0842)	(0.0490)	(0.0355)	(0.0597)	(0.0399)	(0.0697)
Green–EUR						-0.356***	-0.221**
						(0.0574)	(0.0900)
Maturity	0.0355***	0.0484***	0.0306***	0.0412***	0.0287***	0.0412***	0.0287***
	(0.00463)	(0.00416)	(0.00361)	(0.00371)	(0.00386)	(0.00371)	(0.00384)
Size	-0.128***	-0.0710	-0.0405	-0.0952***	-0.0769**	-0.0940***	-0.0757*
	(0.0352)	(0.0486)	(0.0258)	(0.0358)	(0.0384)	(0.0358)	(0.0385)
Credit Rating	-0.0274	0.00327	0.00467	-0.0404	0.0105	-0.0413	0.0108
	(0.0540)	(0.0442)	(0.0194)	(0.0295)	(0.0275)	(0.0293)	(0.0274)
Constant	6.310***	6.109***	8.802***	11.03***	9.319***	10.99***	9.293***
	(1.526)	(1.176)	(0.995)	(1.060)	(1.117)	(1.055)	(1.115)
Green Bonds	416	288	851	1041	514	1041	514
Observations	6,990	3,181	11,140	13,538	7,773	13,538	7,773
R-squared	0.760	0.766	0.858	0.852	0.796	0.852	0.796

The table shows results of the regressions of Yield at issuance for Green and conventional bonds. The Issue Yield of Green and conventional fixed coupon plain vanilla bonds is regressed against a *Green* dummy variable, which is 1 if the bond is a Green bond and 0 otherwise. We control for maturity (in years), size (ln of issue volume in bn USD), credit rating (lowest rating in the S&P equivalent, coded with 1 equal to CCC-and 18 equal to AAA rated bonds). We further control for differences across seniority types, currencies, time (year-month) of issuance, and issuer ids. *Green–EUR* is a dummy variable, which is 1, if the corresponding Green bond is denominated in EUR, and 0 else. *Green Bonds* gives the number of Green bonds used for an analysis. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5: *Primary Market Analysis for Corporate Bonds*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Green	0.0627*	0.237***	0.238***	0.142***	-0.0291	0.154*
	(0.0355)	(0.0594)	(0.0594)	(0.0423)	(0.0839)	(0.0834)
Green-Certified		-0.239***				
		(0.0684)				
Green-Certified-Small			-0.162**			
			(0.0756)			
Green-Certified-Large			-0.353***	-0.257***		
			(0.0728)	(0.0588)		
Green-nCertified-Large				-0.0413		
				(0.108)		
Green-TopESG					-0.206	
					(0.166)	
Green-LowESG					0.215*	
					(0.112)	
Green-LowE						-0.0165
						(0.123)
Green-TopE						-0.431***
						(0.136)
Maturity	0.0412***	0.0412***	0.0411***	0.0412***	0.0473***	0.0473***
	(0.00371)	(0.00370)	(0.00370)	(0.00370)	(0.00512)	(0.00514)
Size	-0.0952***	-0.0947***	-0.0937***	-0.0935***	-0.0841*	-0.0840*
	(0.0358)	(0.0358)	(0.0360)	(0.0360)	(0.0444)	(0.0443)
Credit Rating	-0.0404	-0.0402	-0.0411	-0.0415	-0.0400	-0.0400
	(0.0295)	(0.0294)	(0.0295)	(0.0295)	(0.0274)	(0.0276)
Constant	11.03***	10.98***	10.97***	11.01***	9.340***	9.403***
	(1.060)	(1.058)	(1.056)	(1.057)	(0.927)	(0.926)
Green bonds	1,041	1,041	1,041	1,041	366	366
Observations	13,538	13,538	13,538	13,538	4,853	4,840
R-squared	0.852	0.852	0.852	0.852	0.831	0.831

The table shows results of the regressions of Yield at issuance for Green and conventional bonds. The Issue Yield of Green and conventional fixed coupon plain vanilla bonds is regressed against a *Green* dummy variable, which is 1 if the bond is a Green bond and 0 otherwise. We control for maturity (in years), size (ln of issue volume in bn USD), credit rating (lowest rating in the S&P equivalent, coded with 1 equal to CCC-and 18 equal to AAA rated bonds). We further control for differences across seniority types, currencies, time (year-month) of issuance, and issuer ids. *Certified* is a dummy variable, which is 1, if the corresponding Green bond has been certified as such by a third party, and 0 else. *Green–Certified–Small* is an interaction variable, identifying Green bonds within the first four quintiles with respect to the issue size within the corresponding year of issuance and with a third party certification. *Green–Certified–Large* is an interaction variable, identifying Green bonds within the top quintile with respect to the issue size within the corresponding year of issuance and with a third party certification. *Green–nCertified–Large* is an interaction variable, identifying Green bonds within the top quintile with respect to the issue size within the corresponding year of issuance and **without** a third party certification. *Green–TopESG* is an interaction variable, identifying Green bonds, issued by companies with an ESG score larger or equal to 85. *Green–LowESG* is an interaction variable, identifying Green bonds, issued by companies with an ESG score smaller or equal to 60. *Green–TopE* is an interaction variable, identifying Green bonds, issued by companies with an Environmental score larger or equal to 85. *Green–LowE* is an interaction variable, identifying Green bonds, issued by companies with an Environmental score smaller or equal to 60. *Green Bonds* gives the number of Green bonds used for an analysis. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 6: *Primary Market Analysis (Yield spread)*

Subsample	(1) Full	(2) EUR	(3) USD	(4) OTHER CUR	(5) CORP	(6) GOVT/SUPR
Green	-0.0309**	-0.0609***	0.0225	0.00202	-0.0210	-0.0540***
	(0.0143)	(0.0204)	(0.0285)	(0.0167)	(0.0166)	(0.0196)
Maturity	0.0102***	0.0122***	0.0177***	0.00481**	0.0162***	0.00514***
	(0.00186)	(0.00212)	(0.00169)	(0.00203)	(0.00148)	(0.00183)
Size	-0.0183***	-0.0224***	0.00250	-0.0171**	0.00475	-0.0312**
	(0.00684)	(0.00857)	(0.00768)	(0.00741)	(0.00640)	(0.0127)
Credit Rating	-0.0461**	-0.0568***	-0.0755***	-0.00683	-0.0807***	-0.00368
	(0.0204)	(0.0167)	(0.0283)	(0.0123)	(0.0140)	(0.0104)
Constant	3.447***	1.720***	2.819***	2.085***	1.931***	1.767***
	(0.532)	(0.406)	(0.499)	(0.264)	(0.287)	(0.652)
Green Bonds	952	353	223	376	635	317
Observations	9,733	3,533	1,949	4,251	6,058	3,675
R-squared	0.847	0.815	0.924	0.849	0.844	0.831

The table shows results of the regressions of Yield spread at issuance over the corresponding risk-free government rate for Green and conventional bonds. The spread of Green and conventional fixed coupon plain vanilla bonds is regressed against a *Green* dummy variable, which is 1 if the bond is a Green bond and 0 otherwise. We control for maturity (in years), size (ln of issue volume in bn USD), credit rating (lowest rating in the S&P equivalent, coded with 1 equal to CCC-and 18 equal to AAA rated bonds). We further control for differences across seniority types, currencies, time (year-month) of issuance, and issuer ids. *Green Bonds* gives the number of Green bonds used for an analysis. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 7: *Secondary Market: Yield to Maturity Analysis*

Subsamples	(1) Full	(2) EUR	(3) USD	(4) OTHER CUR	(5) CORP	(6) GOVT/SUPR
Green	-0.006	0.010	0.001	-0.021	0.022	-0.045^{*}
	(0.015)	(0.020)	(0.031)	(0.022)	(0.020)	(0.026)
Liquidity	8.156^{**}	6.819	5.947	4.737^{***}	8.634	4.980^{**}
	(3.494)	(5.552)	(6.290)	(1.471)	(5.873)	(1.936)
Maturity	0.039^{***}	0.039^{***}	0.040^{***}	0.042^{***}	0.045^{***}	0.034^{***}
	(0.003)	(0.003)	(0.005)	(0.003)	(0.004)	(0.002)
Observations	9,813,117	3,817,388	2,197,114	3,798,615	6,188,924	3,624,193
Adjusted R^2	0.877	0.798	0.834	0.883	0.881	0.882

The table shows results of the regressions of Yield to maturity for Green and conventional bonds. The Yield to maturity of Green and conventional fixed coupon plain vanilla bonds is regressed against a *Green* dummy variable, which is 1 if the bond is a Green bond and 0 otherwise. We include Issuer fixed effects, YearMonth fixed effects, Currency fixed effects, Seniority, Credit rating and Issue size fixed effects, to take into account substantial differences between issuers, the yield curve, different interest rate environments in different countries and the influence of ratings on the yield at issuance. The Issue Size fixed effects are the deciles of the issue (in USD) in comparison to all other issues that occurred in the same year as the Issue. We use the corresponding BidAsk spread as a control for Liquidity and years to redemption as control for Maturity.

Table 8: *Secondary Market: Spread Analysis*

Subsamples	(1) Full	(2) EUR	(3) USD	(4) OTHER CUR	(5) CORP	(6) GOVT/SUPR
Green	-0.011	0.008	-0.061^{**}	0.000	0.018	-0.048^{**}
	(0.014)	(0.023)	(0.025)	(0.019)	(0.018)	(0.022)
Liquidity	25.078	32.068	29.865	9.598^{***}	34.153	9.012^{***}
	(16.453)	(22.493)	(27.896)	(1.960)	(26.443)	(2.516)
Maturity	0.008^{*}	0.001	0.014^{***}	0.010^{***}	0.007	0.008^{***}
	(0.005)	(0.008)	(0.005)	(0.002)	(0.009)	(0.002)
Observations	9,813,117	3,817,388	2,197,114	3,798,615	6,188,924	3,624,193
Adjusted R^2	0.389	0.235	0.615	0.517	0.334	0.524

The table shows results of the regressions of Yield spread to maturity over the corresponding risk-free government rate for Green and conventional bonds. The spread of Green and conventional fixed coupon plain vanilla bonds is regressed against a *Green* dummy variable, which is 1 if the bond is a Green bond and 0 otherwise. We include Issuer fixed effects, YearMonth fixed effects, Currency fixed effects, Seniority, Credit rating and Issue size fixed effects, to take into account substantial differences between issuers, the yield curve, different interest rate environments in different countries and the influence of ratings on the yield at issuance. The Issue Size fixed effects are the deciles of the issue (in USD) in comparison to all other issues that occurred in the same year as the Issue. We use the corresponding BidAsk spread as a control for Liquidity and years to redemption as control for Maturity.

Table 9: *Secondary Market: Matched bond pairs analysis*

	$\Delta Yield$
$\Delta Liquidity$	-1.38*
	(0.799)
Observations	184,577
R-squared	0.732
Number of bond pairs	431

The table shows results of the regressions of the first-step regression $\Delta Yield_{i,t} = p_i + \alpha \Delta Liquidity_{i,t} + \epsilon_{i,t}$. The dependent variable $\Delta Yield_{i,t}$ is obtained subtracting the yield of the Green and conventional bonds of company i at each period of time t. The independent variable $\Delta Liquidity_{i,t}$ is the differential of the Bid-Ask spreads of Green and conventional bonds in percent of the Ask price.

Table 10: *Secondary Market: Distribution of the estimated Green bond premia*

Variable	Obs	Mean	Std. Err.	Std. Dev.	[90% Conf.Interval]	
Greenium	431	0.0035	0.0089	0.1857	-0.0113	0.1821

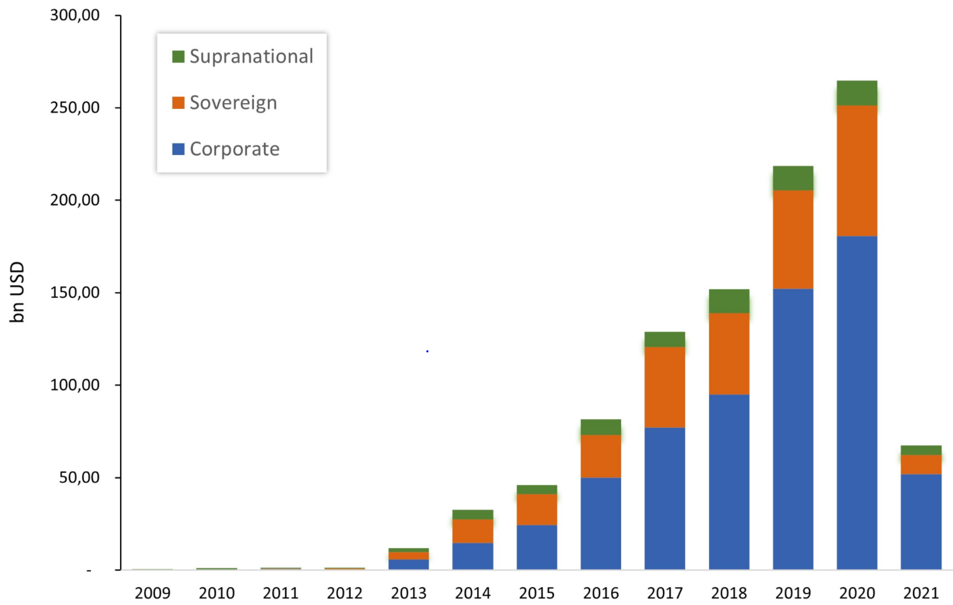
The table summarizes the distribution of the estimated Green bond premia (greenium), i.e., the fixed effect p_i of the following regression: $\Delta Yield_{i,t} = p_i + \alpha \Delta Liquidity_{i,t} + \epsilon_{i,t}$.

Table 11: *Secondary Market: Determinants of the Green bond premium*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
EUR	0.000879	0.0201	0.0318	0.0225	0.00413	0.0205	0.0315
	(0.0180)	(0.0192)	(0.0205)	(0.0186)	(0.0178)	(0.0191)	(0.0202)
CORP	-0.00121	-0.00336	-0.00436	-0.0146	0.0118	0.00763	0.00602
	(0.0177)	(0.0175)	(0.0175)	(0.0194)	(0.0188)	(0.0184)	(0.0185)
Large		-0.0603***	-0.0616***			-0.0535***	-0.0551***
		(0.0193)	(0.0194)			(0.0195)	(0.0197)
Certified			-0.0431*	-0.0364			-0.0401*
			(0.0222)	(0.0227)			(0.0222)
GreenEx				-0.0358*			
				(0.0190)			
LowE					-0.0509	-0.0432	-0.0394
					(0.0333)	(0.0331)	(0.0324)
TopE					-0.0885**	-0.0717*	-0.0687*
					(0.0373)	(0.0400)	(0.0402)
Constant	0.00393	0.0278	0.0576**	0.0482*	0.00275	0.0241	0.0521**
	(0.0157)	(0.0171)	(0.0243)	(0.0253)	(0.0157)	(0.0172)	(0.0245)
Observations	431	431	431	431	431	431	431
R-squared	0.000	0.024	0.032	0.015	0.016	0.034	0.042

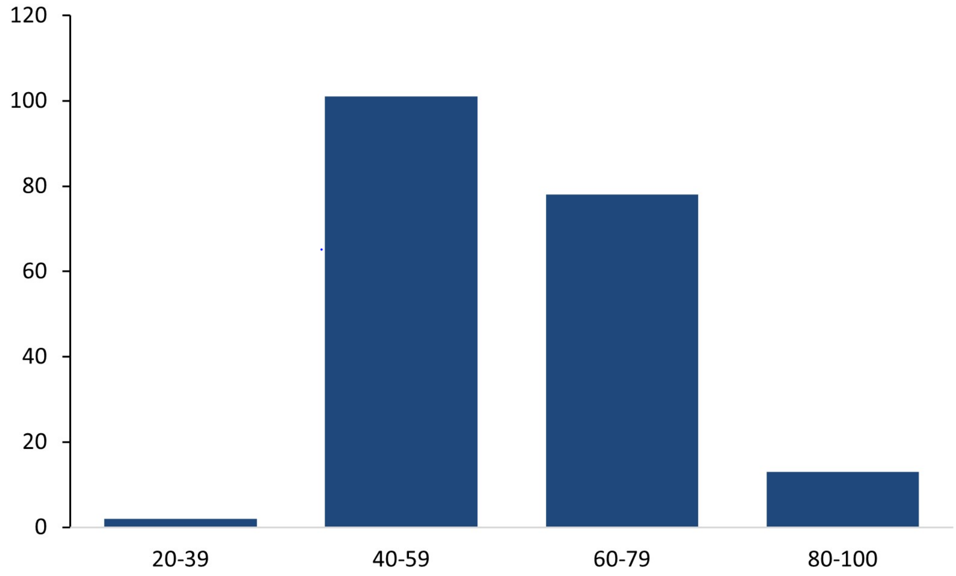
The dependent variable Greenium is the fixed effect of the regression of the mid yield spread of matched bond pairs on the differences in Bid-ask spreads of Green and conventional bonds of corresponding bond pair. *EUR* is an indicator which is one, if the Green bond is denominated in EUR; *Corp* is an indicator which is one, if the Green bond is issued by a corporation; *Large* is an indicator which is one, if the Green bond's issue size is within the top quintile with respect to all bonds issued in the corresponding year; *Certified* is a dummy variable, which is 1 if the Green bond has an external review confirming its sustainability credentials; *GreenEx* is a dummy variable, which is 1, if the corresponding Green bond is listed either on the Luxembourg Green exchange or London Stock exchange with a Green bond segment. These are the largest Green exchanges with tightest requirements on the Green bond listing. *LowE* is an indicator which is one, if the issuers' Sustainalytics Environmental Score is below or equal 60; *TopE* is an indicator which is one, if the issuers' Sustainalytics ESG Score is above or equal 85.

Figure 1: Volume of Green bonds by issuer type



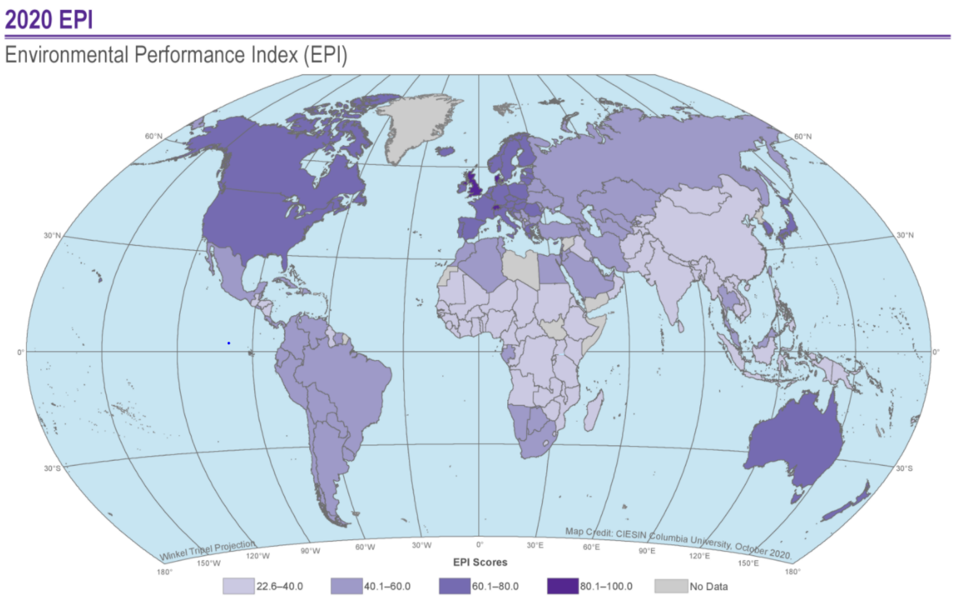
Yearly issuance volumes (in bn USD) split by issuer types Sovereign (governments, local governments), Supranational entities, such as e.g. European Investment Bank and Corporations.

Figure 2: Sustainability ratings of Green bonds issuers



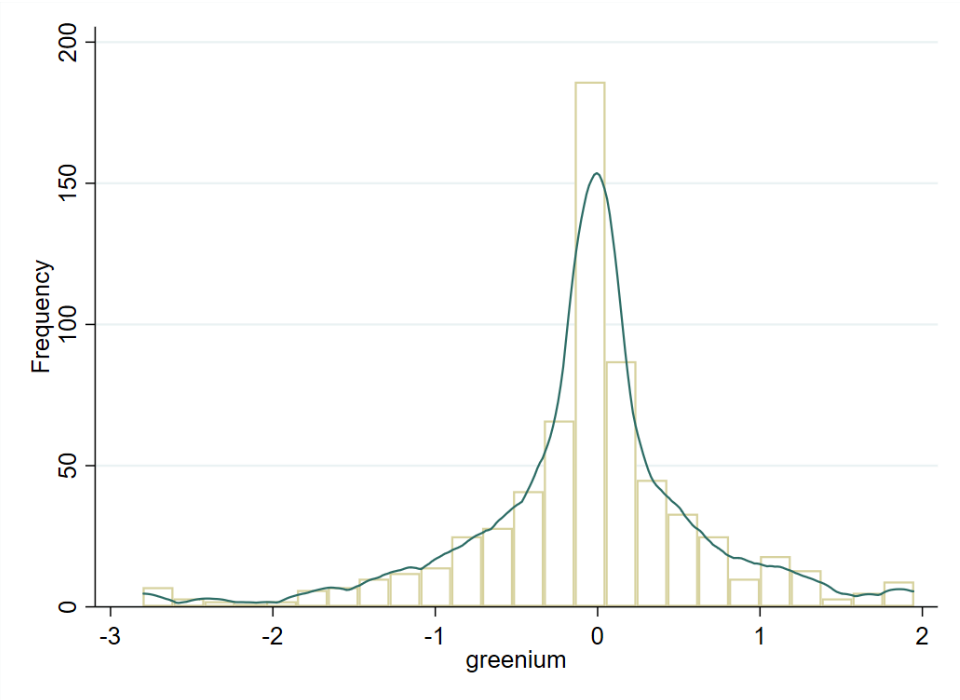
Histogram of Sustainalytics sustainability (ESG) scores for a sample of corporate issuers with available data (432 Green bonds in total issued by 192 companies).

Figure 3: Environmental Performance Index



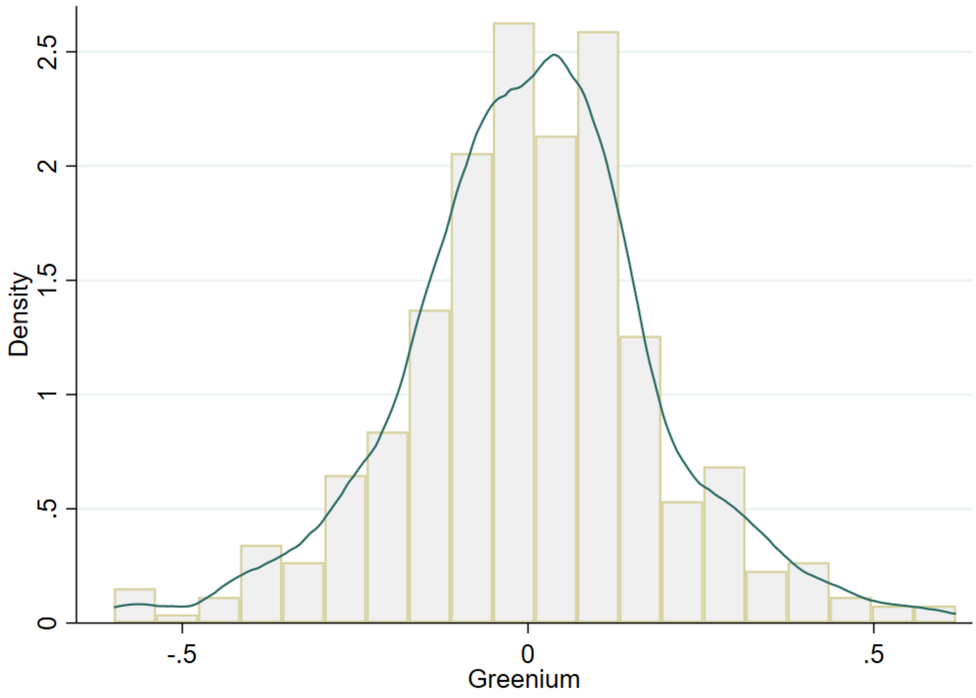
Environmental Performance Index developed by the Yale university, which measures environmental trends and progress of the corresponding country in 2020. Source: `https://epi.envirocenter.yale.edu/`.

Figure 4: Difference in yields of matched bond pairs



Histogram of differences in yields (greenium) of matched bond pairs (green–conventional yield at issuance) for 658 Green and conventional bonds.

Figure 5: Histogram of the estimated Green bond premia



This graph displays the histogram of the estimated Green bond premia, i.e., the fixed effect p_i of the following regression: $\Delta Yield_{i,t} = p_i + \alpha \Delta Liquidity_{i,t} + \epsilon_{i,t}$