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Abstract

We propose a synthetic green indicator incorporating several dimensions contributing to the definition of greenness at the bond level. We include information on the presence of a green label attributed by a data provider based on the use of proceeds of the funds raised and certifications by external institutions. Variables regarding how the proceeds of green bonds are managed and whether a commitment exists to ongoing reporting on the funded projects are also added to account for the transparency of the bond issuance. To establish its role among the determinants of green bond yields, we perform a regression analysis consistent with the literature on measuring the greenium. The study comprehends a sample of European corporate green bonds between 2013 and 2024, and results highlight a significant negative premium, indicating that, *ceteris paribus*, "the more green" a bond is, the higher its greenium.

Keywords: corporate green bonds, green premium, sustainable finance, climate policy, multilevel models.

JEL Classification: G12, G28, Q5, C21.

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1 Introduction

In 2007, the European Investment Bank (EIB) launched the Climate Awareness Bond, the first bond to be defined as *green*. Other supranational, Sovereign, and government-related entities soon followed it. In 2013, the first corporate green bond was issued by Vasakronan, a Swedish property company. In the same year, the state of Massachusetts issued its first municipal bond. Since these first initiatives, the market of green bonds expanded, starting slowly, but growing faster after 2014, to reach $3.5 trillion in cumulative issuance in 2024 (according to the Climate Bonds Initiative, CBI, Database).[1] The strong boost to this expansion may be attributed to the increased sensitivity towards climate-related issues after the 2015 Paris Agreement and the launch of ICMA's Green Bond Principles in 2014.[2] These principles established voluntary guidelines to be followed in the issuance process of green bonds and represented a first step towards better integrity and transparency in the green bond market.

Before the definition of these principles, the lack of consistent issuing standards for green bonds represented a significant obstacle in the evolution of this market. A green bond can be described as a fixed-income security whose proceeds are used for environmentally friendly purposes, specifically to finance eco-sustainable projects that yield environmental benefits. Since the primary difference between a regular bond and a green bond is the issuer's commitment to exclusively use the raised funds to finance green projects, for a bond to be labeled as green, it is sufficient for the issuer to promote and label it as such. As long as a universally recognized system for determining the green status of a bond was not introduced, the green bond market was hindered by the problem of information asymmetry and the threat of greenwashing behaviors.

In this sense, the ICMA's Green Bond Principles have been the first set of non-binding rules proposed as issuing standards for the fixed-income industry. They are organized around four core components: *i*) the Use of Proceeds: the proceeds of the bond should be used for eligible Green Projects providing clear environmental benefits, and they should be appropriately described in the legal documentation of the security;[3] *ii*) The Process for Project Evaluation and Selection: the issuer should communicate to investors the environmental sustainability objectives of the eligible Green Projects and how the issuer determines that the projects fit within the eligible Green Projects categories; *iii*) The Management of Proceeds: the net proceeds of the Green Bond should be appropriately tracked by the issuer to reassure investors that they are indeed used for green projects; *iv*) Reporting: Issuers should keep readily available up-to-date

[1] The Climate Bonds Initiative is an investor-focused not-for-profit organisation, promoting large-scale investments that will deliver a global low-carbon economy.

[2] ICMA (International Capital Market Association) is a not-for-profit association, whose members are private and public sector issuers, banks and securities houses, asset managers and other investors. Its purpose is to define rules and recommendations governing the operations in the international capital and securities market. `https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/`.

[3] The eligible Green Projects categories include, but are not limited to: renewable energy, energy efficiency, pollution prevention and control, sustainable management of natural resources and land use, biodiversity conservation, clean transportation, sustainable water and wastewater management, climate change adaptation, eco-efficient and/or circular economy, green buildings.

information on the use of proceeds.

With the market's growth, additional certified standards and independent external reviewers have emerged. One of the most widely accepted is the Climate Bonds Standard and Certification Scheme by the CBI. These guidelines fully integrate ICMA's Green Bond Principles but also offer the opportunity for certification through rigorous scientific criteria, ensuring that certified investments are consistent with the climate mitigation objective of $1.5°C$ warming limit in the Paris Agreement.

Despite progress in developing common standards for the green bond market, the attribution of the green label to a bond remains a critical issue. The absence of a regulatory framework for these instruments raises the question of who decides and how to decide that a bond is green.[4] At present, the green label may still be attributed by the issuer itself without further verification by third-party entities. In such a case, the threat of greenwashing behavior is high. To contrast the effect of this kind of asymmetric information, companies may rely on organisations that provide external verifications. Second-party opinions (SPOs) are assessments of the issuer's green bond framework provided by ESG service experts, such as Sustainalytics and CICERO, among others. Major rating agencies also judge the bond's alignment with the Green Bond Principles by attaching a rating to green bonds. The CBI certification, instead, confirms that the use of proceeds adheres to sector-specific criteria and the Climate Bonds Standard, which is aligned with the Paris Agreement. Lastly, data providers themselves, such as Bloomberg and FactSet, to mention a few, verify the green label provided by the issuer through their own evaluation procedures.

Given the diversity of possible sources for the green label, some questions arise about the coherence of the labels collected through different sources. Are the resulting valuations comparable, or do they account for different characteristics of green bonds? Can we entirely rely on the assessment from a single organisation to study the characteristics of green bonds and their market, or should a robust approach encompass evaluations assigned by several different entities?

Literature on green bonds generally focuses on their differences with respect to conventional bonds in terms of pricing differentials. To do so, a yield difference is computed between green and comparable conventional bonds selected through a matching strategy. Tests for significance are performed, or a regression framework is adopted, where a dummy variable identifying green bonds is among the explanatory variables for bond yields, thus providing evidence of a pricing difference if its coefficient is estimated to be significant. In such a context, identifying a bond as green becomes crucial in the subsequent comparison of its specific characteristics and behaviors with those of conventional bonds. The identification is usually achieved by relying on information sourced from data providers such as Refinitiv's Thomson Reuters Eikon, Dealogic DCM, or Bloomberg, to name a few of the most popular. Each of these institutions has its own methodology for classifying a bond as green, and, despite their similarities,

[4]The European Green Bonds Standard Regulation, approved in 2023, aims at setting a gold standard for green bonds issuance in the EU and relies on the criteria of the EU taxonomy to define green economic activities. It also promotes transparency and establishes supervision by the ESMA of companies' pre- and post-issuance processes. Nonetheless, the Standard is still voluntary and issuers may decide whether to adhere to get a certified review or not.

they generate discrepancies in the resulting samples of green bonds. For example, Fatica et al. (2021) verify that a noticeable portion of bonds defined green in Bloomberg are considered conventional in Dealogic DCM. In conducting our study, we confirm such disagreement of valuations. We find that the Bloomberg sample of green bonds is different from that identified by FactSet. These facts lead to the conclusion that the choice of the provider becomes determinant in the development of the research because different green labelling schemes may lead to different outcomes or generate bias in the results. Thus, the idea we exploit in our analysis is as follows: rather than relying on a single green label, we collect as many valuations as possible and aggregate them to construct a grade for the greenness of bonds.

In many studies, the importance of a third-party certification is stressed because it signals a more trustworthy evaluation of greenness and a lower risk of greenwashing. Additionally, we consider CBI reviews in implementing our measure of greenness. Furthermore, we follow the guidelines from ICMA in assessing not only the eligibility of the green project funded by the debt instrument, but also the transparency requirements, including reporting standards and sustainable frameworks adopted by the issuer. Indeed, Bloomberg indicates a bond as green if the net proceeds of the fixed-income instrument will be applied toward green projects or activities that promote climate change mitigation or adaptation, or other environmental sustainability purposes, but there is no mention of the other components of the GBP. Thus, we consider additional variables that provide information on the project evaluation and selection process, the management of proceeds, and reporting.

Since we decided to assess bond greenness through several dimensions, rather than adopting a binary approach to classify a green bond as compared to a brown one, we follow the idea of the shades of green. We propose an indicator of a bond's greenness that incorporates diverse evaluations of its greenness derived from various classification procedures, along with information on its transparency and disclosure of management practices.

Thus, we compute the indicator for a sample of European corporate green bonds and test its importance among the determinants of the green bond yields through a regression analysis, building on the literature related to the measurement of the greenium. The debate on the existence of the greenium centres on whether a pricing difference between green bonds and their conventional equivalents is realised in the market. The evidence on this subject is mixed. Through regression analysis, we aim to shed light on this aspect from a different perspective, specifically investigating whether a premium exists for darker shades of green rather than for not being brown.

The rest of the paper is organised as follows. After the review of related literature in Section 2, Section 3 describes the sample of green bonds and variables used in the study. Section 4 introduces the strategy we adopt to construct the Green Indicator, while Section 5 presents the econometric methodology used for the regression analysis. Section 6 discusses the results, and Section 7 reports some robustness exercises. Finally, Section 8 concludes by summarising our findings and their implications.

2 Literature Review

Given the contrasting theories about the existence (and sign) of the greenium, empirical studies tried to shed light on the matter, without reaching a consensus. Mixed evidence may be due to differences in the sample selection, as well as the observation period. One of the first studies on this subject was conducted by Zerbib (2019). He uses yield differentials between green bonds and their counterfactual conventional bonds from July 2013 to December 2017 to estimate the greenium, and find a small negative premium both for EUR- and USD-denominated securities: on average, the yield of a green bond is 2 bps lower than that of a conventional bond, becoming more pronounced for financial and low-rated bonds. In line with these findings are also the results by Baker et al. (2022), who determine, on a sample of yields on the period 2010-2016, that US green municipal bonds are issued at a (moderate) premium, or, in other words, that they are priced as if they were "half a notch" more highly rated. Karpf and Mandel (2018) as well show that, in the same period, US municipal green bonds on average pay a lower interest rate and hence provide better financing conditions than conventional bonds, but they argue that this spread can be mainly explained by the characteristics of the issuing entity, irrespectively of the green nature of the bond, giving rise to a "reputational" green premium. The authors also highlight the fact that the premium has been negative in the first five years of their sample, while it turned positive in the last two years of observations, when the relative credit quality of green bonds has improved. Nonetheless, other studies are in accordance with previous results of a statistically significant negative premium: Dorfleitner et al. (2022) and Wang et al. (2020) analyse prices in the secondary market between 2011 and 2020, and in the Chinese primary market in the period 2016-2019, respectively, providing evidence in favor of this argument. In addition, Fender et al. (2019) investigate the existence of a greenium from a reserve management perspective. They verify the eligibility of green bonds as reserve assets by evaluating how a portfolio of green bonds is likely to behave with respect to one composed of conventional bonds with similar characteristics. The authors focus on returns of fixed income indices between 2014 and mid-2019 and estimate a negative "portfolio greenium" for euro-based investors, but find a positive "portfolio greenium" for US dollar investors in the green index. They also show that the portfolio greenium narrowed over time with the evolution of the green bonds market. A positive premium is also found by Bachelet et al. (2019), who estimate higher yields for green bonds between January 2013 and December 2017. They find a negative premium only for institutional issuers.

Other works provide scarce evidence of the existence of the greenium, except for specific categories of issuers or depending on the market. Doronzo et al. (2021) study sovereign green bonds issued in 14 countries worldwide (mainly European) between end-2016 and 2020: in the primary market sovereign green bonds are on average slightly more expensive for the issuers than their conventional peers, but the lower performance may be attributed to poorer liquidity conditions, and in secondary markets green bonds do not substantially outperform their non-green counterparts. Analogous results are presented by Larcker and Watts (2020), who, after demonstrating that the greenium in the US municipal bond market between 2013 and 2018 is essentially zero, point out that investors view green and non-green securities by the same issuer as almost exact substitutes. Similar outcome from the study by Ma et al. (2020) on a sample of EUR-denominated corporate bonds in the years 2016-2020, where the estimation of the greenium as bond asset swap spread exhibits a level fluctuating near zero over time. In part in line with these findings are those of Hachenberg and Schiereck (2018), who estimate in the period 2015Q4-2016Q1 that pricing differences are not economically and statistically significant, except for single A-rated and financial green bonds, while government-related green bonds trade at a positive premium. On the contrary, Fatica et al. (2021) find a premium for green bonds issued by supranational institutions and corporates but no yield differences in the case of issuances by financial institutions on a global sample of securities from 2007 to 2018.

Other attributes, rather than greenness, may produce such contrasting evidence. Hachenberg and Schiereck (2018) verify through a panel random-effects regression that industry and ESG rating have a significant influence on differences in pricing, while issue size, maturity, and currency do not. Another peculiar feature of green bonds is important in determining the magnitude of the greenium. Dorfleitner et al. (2022) find that the estimated premium increases with external greenness evaluations, and Bachelet et al. (2019) highlight that issuers' reputation and green third-party certifications are essential to reduce informational asymmetries, avoiding suspicion of greenwashing, and producing relatively more convenient financing conditions. Fatica et al. (2021) also show that external verifications are significant for non-financial institutions. Allman and Lock (2024) examine the certification role of external parties in the corporate green bond market by using a sample of corporate green bonds issued between 2013 and 2020. They find that external reviews have a significant average effect on the green bond premium only for issuers domiciled in common law countries, and the impact is larger when issuers obtain reviews from more reputable reviewers.

Very recent literature more directly addresses the problem of the shades of green. Huynh et al. (2022) measure an overall negative green bond premium on a sample of worldwide green bonds between 2016 and 2021. The premium is more pronounced for green bonds with a lower credit rating, in the presence of an ESG rating, and for bonds with a higher shade of green. Ghitti et al. (2023) investigate the informative content of Second Party Opinions (SPOs) by collecting a global sample of corporate green bonds for the period 2013-2023 and find that SPO external reviews can reduce information asymmetry between issuers and investors in case of absence of a credit rating, but they are not informative for rated green bonds.

3 Data Description

We built a dataset of European corporate green bonds by collecting data from Bloomberg's fixed-income database. The data set encompasses the entire universe of corporate green bonds tracked by Bloomberg, issued by public and private companies across Europe, from the early days of this market in 2013 to 2024. We collect a sample of 4,354 green bonds. For each bond, we gather issuance and maturity dates, yields to maturity, coupons, credit ratings, issued amount, currency, options, and issuers' balance sheets.

Bloomberg classifies a bond as green according to the eligibility principle of the project the proceeds are used to finance. However, non-binding guidelines on the issuance process of green bonds focus not only on the sustainability of the project, but also on the selection strategy, environmental impact, and transparency of the management of proceeds, as well as reporting standards. A thorough assessment of the green credentials of a bond should therefore take into account not only the type of project but also these other quality features. Information on such characteristics is available in Bloomberg through binary variables signalling the commitment of the issuer in providing reports and pre/post-issuance documentation on the bond or the compliance with sustainable frameworks for green securities.

To explore the coherence of the green bond definition across different data providers, while accounting for the largest number of green bond characteristics, we also collect information on labeled green bonds from FactSet. Furthermore, since literature has shown that external verifications by third-party entities are also important in explaining the level of greenness of a bond, we collect from the CBI database a binary variable indicating whether the bond has received a CBI certification. We also merge information from MSCI, collecting data on the environmental ratings of companies and the corresponding industries. The industry classification of economic activities is based on NACE, which is the official industry classification used in the European Union.[5] Rev. 2 with details for 64 emitting industries.

Using the collected information, we compute the following variables: *Tenor* is the difference in years between maturity and issue date, *Size* is the logarithmic transformation of the issued amount[6], the *Credit rating* is rescaled from 0 to 21 (where 0 corresponds to the worst and 21 to the higher credit quality). The *Call option* is represented by a dummy variable equal to 1 if it is available for the bond and 0 otherwise. We also define the *Yield spread* as the difference between the bond yield at issuance and the yield curve spot rate at the date of issuance for a comparable maturity, accounting for inflation and interest rates. Yield curve data are gathered from the ECB database for maturities ranging from 3 months to 30 years.

Company-specific variables are associated with both the balance sheet and the environmental dimension of firms. A *Solvency ratio* measures a company's ability to meet its long-term debt obligations, providing insight into its overall financial health and creditworthiness. We use the *Environmental score* available in the MSCI database to account for a firm's propensity for greenness. MSCI ESG ratings provide an assessment of companies' management of financially relevant ESG risks and opportunities, taking into account the company's exposure to material ESG risks and the quality of management and governance in mitigating these potential risks. The Environmental rating focuses on four themes: climate change (i.e., carbon emissions and footprint), natural capital (i.e., biodiversity, land and water use), pollution/waste (i.e., electronic waste, packaging and toxic emissions) and environmental opportunities (in green building, clean technology and renewable energy).

[5]Since 1970, NACE, derived from the French *Nomenclature statistique des activités économiques dans la Communauté européenne* NACE Rev. 2 is a revised classification adopted at the end of 2006.

[6]This transformation allows us to rescale the distribution so that is comparable with the other variables of our sample.

In the Appendix A, we provide details on the sample involved in the analysis. Table A.1 lists the variables included in our sample, their description, and sources. Table A.2 specifically shows how the green features, captured by binary variables, used to construct the indicator, are distributed in the sample. We find evidence of the lack of agreement between data providers in the classification of green bonds. Indeed, 13% of bonds defined as green by Bloomberg are not flagged as such by FactSet. We also notice that 22% of bonds do not fully allocate the proceeds to green projects, and for nearly 70% of the sample, no reports on the allocation of funds or the project's impact are provided. As previously observed in the literature, a small number of bonds hold a CBI certification.

The final dataset reveals a significant coverage issue. Indeed, the information collected is not always available for every variable on every bond. We observe a large proportion of missing information for yields and rating data. In fact, we only obtain the yield at issuance for 3,261 green bonds, and only 1,491 of them have a rating, leaving a cross-section of 1,312 green bonds issued by 383 companies between 2014 and 2024.

Table A.3 provides the distributions of the data with respect to the categorical variables *Call option* and *Currency*. In Figures A.1 and A.2 in the Appendix, we also report, respectively, the distribution of the sample by country and by the Climate-Policy-Relevant Sectors (CPRS)[7]. The distributions are provided over the reduced sample of 1,312 bonds. 50% of green bonds in the sample are issued by financial companies. Finally, Table A.4 provides the descriptive statistics for the quantitative variables characterising the sample of bonds. We also show the correlation matrix of the numeric variables included in the regressions in a graphical representation (see Figure A.3). We observe a mild correlation across all variables. As expected, *ROA* and *ROE* are the most positively correlated, while the correlation between the *Yield spread* and the rating of the bond is quite high and negative.

4 The Green Indicator for bonds

In this section, first, we explain the motivations behind the introduction of the green indicator for bonds. Then, we propose the green indicator, and we provide its insight characteristics in the sample.

There are several considerations that support the usefulness of a synthetic indicator to measure the greenness of a bond. First, very mixed evidence on the existence of the greenium may be due to the inadequacy of the classic "dummy approach" in detecting the greenness of a bond. A vast part of the literature adopts a binary variable to identify

[7]The Climate Policy Relevant Sector classification has been proposed by Battiston et al. (2017) to better address the challenge of identifying companies' financial exposure to green risk. It is based on the NACE sections and divisions, which are rearranged into broader sectors suitable for sustainability analysis. More specifically, it remaps the NACE Rev 24-digit standard classification of economic activities into five CPR sectors based on their GHG emissions, their role in the energy supply chain, and the presence of related climate policy institutions in their countries. CPR sectors are fossil fuel, utilities, energy-intensive, transport and housing.

a green bond as opposed to a brown one (see, for example, Baker et al., 2022; Fatica et al., 2021; Immel et al., 2022). However, Dorfleitner et al. (2022); Huynh et al. (2022); Ghitti et al. (2023), among others, highlight the importance of the shades of green rather than a unique green level. Thus, providing an evaluation on a scale range may help recognise that greenness is not a uniform characteristic of all "non-brown" bonds. Second, being greenwashing a threat to the trustworthiness of a green issuance, external reviews and third-party opinions acquire importance in the correct assessment of the green attribute by investors.[8] The more so when classification criteria in the assignment of the green label differ substantially between providers. So, the need to incorporate information from different sources and external certifications in the evaluation. Third, following the guidelines from ICMA and CBI, the necessity of a comprehensive approach that not only considers the eligibility of the funded project but also the transparency of the management of the bond. This requirement also helps contrast greenwashing behaviours. Finally, another aspect to consider, mostly neglected in the literature, is the portion of the net proceeds that is allocated to the green project. ICMA defines green a bond whose proceeds are exclusively applied to finance an eligible project, but this definition is not mandatory and is not universally applied. Thus, many green bonds only partially allocate the proceeds to such projects. We regard these bonds as "less green" than those whose funds are entirely assigned to sustainable projects.

In this paper, we adopt a "shades of green" approach. Thus, a bond may be greener than another along several dimensions rather than being green or not green. If a bond is rated green by more than one provider, or receives third-party certification, we expect its greenness to be more robust, based on the idea that if a bond passes satisfactorily through multiple verification systems, its rating will be more accurate. We also expect a commitment to report on the impact of the project and the use of the funds raised to signal the company's efforts to follow best practices in transparency. Similarly, the existence of a project selection process and a pre-issuance impact framework indicates a genuine intention to pursue sustainable objectives. We believe that bonds with such additional features are of higher quality and less susceptible to greenwashing.

Based on the binary variables available in our dataset, we develop a green indicator G_i for each bond by aggregating the information. The indicator is defined as a score counting how many green features each bond possesses, i.e., each variable is equal to 1 when it indicates a benefit in terms of greenness, and 0 otherwise. As a result, we obtain an indicator G with possible values g = 0,1,...,10, where 0 denotes a very low level of robustness of the green label, while a bond with the Green Indicator equal to 10 shows a very high guarantee of greenness. Figure 1 provides the distribution of the green bonds w.r.t. the green indicator. The figure is built over the 1,312 European bonds, and the green indicator includes the information provided by the 10 binary variables listed in Table A.2. The distribution of the indicator confirms that bonds included in the sample are green with different "shades". We observe that more than half of the sample collects almost 6 out of 10 variables describing the green properties of the security. However, 49% of bonds count at a maximum of 4 out of 10 "green"

[8]Greenwashing is the practice of giving a false impression of the environmental impact or benefits of a product, which can mislead consumers.

characteristics of the bond.

In particular, when disentangling the components contributing to the computation of the green indicator for different levels of the score, we can notice that bonds showing a very low level of grenness (G_i = 1,2) have only the FactSet green flag and, in addition, the assurance provider mentioned in their documentation (or a pre-issuance impact framework), while characteristics such as the CBI certification, the allocation and impact reports, and the commitment to allocate all funds raised to the green project become relevant in order to achieve the highest levels of greenness ($G_i = 7, 8$ and beyond). Thus, these last features appear to be those on which to rely to attain a more robust evaluation of the greenness of bonds.

We also study graphically the distribution of the yield spread for each level of greenness (see Figure 2), noticing an average decrease in the yields as the shade of green of bonds becomes darker. On the contrary, there seems to be no relevant differences in the distribution of the green indicator depending on the CPR sector to which the issuer belongs (see Figure 3).

[FIGURES 1, 2, 3 AROUND HERE]

5 Empirical Model

To assess the contribution of the green indicator in explaining bond greenness, we propose an analysis that examines the role of the indicator among the usual determinants of bond yields. In doing so, we build on previous literature on the greenium, but rather than treating all green bonds as equivalent to conventional bonds, we focus on the importance of the "shades of green", as motivated in the previous section. The common approach in the literature is to run OLS regressions where the response variable is the bond yield at issuance, and a dummy variable representing the distinction between green and brown bonds is included among the covariates controlling for heterogeneous characteristics of bonds (see, e.g., Baker et al., 2022; Fatica et al., 2021; Immel et al., 2022).

One of the main assumptions behind the OLS approach is the homoskedasticity of the errors. Whenever this assumption is violated, standard error estimates are biased, consequently causing inference to produce spurious conclusions. In our setting, we observe green bonds as units of observation, but the same company may issue more than one bond. The result is the existence of groups of observations that may be more similar within the same group, and more dissimilar between groups. In other words, such a phenomenon gives rise to a variability structure that can be described as clustered, because observations group together depending on the issuer, and heteroskedastic, because each group may provide a different contribution to the variability of the entire model. Solutions to these criticalities have been proposed in the literature. A first approach adopts OLS estimation applying corrections to the classical estimators of variance to account for heteroskedasticity and clustered units (see MacKinnon and White, 1985; Cameron and Miller, 2015). An alternative approach to model heterogeneity between groups is provided by the fixed-effects model, widely used in the econometric literature. The success of this model resides in the simplicity of its assumptions, specification, and usage. Indeed, the heterogeneity among groups is simply accounted for through the addition of a specific intercept for each group. In this way, whatever drives group variability is all gathered in these coefficients, and there is no need to model it otherwise. This is the basic idea behind the fixed-effects approach, which allows solving the problem of heteroskedasticity without compromising the error structure and maintaining intact the OLS assumptions thanks to the addition of an indicator variable for each group. Nonetheless, two main drawbacks arise when using this method. The first implies some limitations in the analysis, i.e., in the possible scenarios that a researcher can investigate. Indeed, being all the variation between groups accounted for by the intercepts, other group-constant variables (i.e., variables that are fixed within each specific group) cannot be included in the regression. In our setting, for example, we would not be allowed to analyse the relationship between the green bond yields and the environmental rating of firms or the sector to which the issuers belong. The second potential issue arises when the data are divided into many groups with very few observations in each group, which is particularly so in our framework. In such a case, the loss of degrees of freedom caused by the inclusion of a dummy variable for each group may be burdensome. More specifically, when controlling for fixed effects by considering an intercept for each group, multiple additional parameters need to be estimated. Thus, since the degrees of freedom of the model are calculated as the difference between the number of observations and the number of estimated parameters, this procedure reduces the available degrees of freedom and negatively affects the statistical power of inference tests. In other words, a substantial loss in degrees of freedom may cause variance estimates to be less reliable and the failure to detect significant effects of the variables. Moreover, estimating a different intercept for each group may cause overfitting if the number of groups is large relative to the number of observations (notice that in our sample, we observe 383 companies and 1,312 bonds). To avoid these drawbacks, we decided to follow a third approach, the so-called multilevel (or hierarchical) modelling.[9] A multilevel model is defined as a regression model in which the parameters are given a probability model. This second-level model has parameters of its own, which are also estimated from the data (Gelman, 2007). Thus, the two distinguishing features of a multilevel model are varying coefficients, and the assignation of a model to those coefficients[10]. Contrary to fixed-effects models, in multilevel models, estimated parameters are assumed to be realizations from a probability distribution. Thus, systematic unexplained variation between groups is not set aside as a fixed intercept for each group, but it is itself modelled, possibly through group-level covariates, while fitting the regression at the individual level. The result is a model with more than one variance component (in our case, bond-level and issuer-level variation). In this setting, we account for heterogeneity between groups, without being overwhelmed by overfitting and collinearity of group-constant predictors. Indeed, hierarchical models can be thought of as a compromise between the two extremes of a "complete pooling" approach, where variation

[9]It is also known as mixed-effects model, and it falls under the Random-Effects framework.

[10]The term "mixed effects" by which these models are also called refers to the fact random effects (or factors), i.e., coefficients that are modelled so that they can vary by group, coexist with fixed effects/factors, i.e., parameters that do not vary and are not assigned a probability model).

between groups is ignored and group indicators are excluded from the model, and a "no pooling" approach, where a separate model or intercept is estimated within each group. In other words, while complete pooling neglects to account for heterogeneity between groups, the no-pooling analysis overstates it. Thus, if variation among groups is overestimated, then such an approach tends to make the groups look more different than they actually are. Multilevel models are considered a compromise because, by assigning a probability distribution to the coefficients, they achieve a "partial pooling" effect on the estimates of the coefficients, which are still different for each group but are pulled towards the mean of the distribution. Groups with smaller sample sizes carry less information, so the multilevel estimates of the coefficients are closer to the distribution mean, while for groups with larger sample sizes, there is more information on which to estimate the group-specific coefficient.

Due to the characteristics of our sample (i.e., small number of observations for each group, and large number of groups), we consider the multilevel approach the most efficient way to address the problem of modelling unexplained variation between companies, with the additional benefit of the possibility of including issuer-specific variables in the analysis.

Thus, we propose the following model for the yield at issuance of green bond i, issued by company j:

$$\text{Yield}_{ij} = \alpha_j + \beta G_i + \gamma' X_i + \delta_k + \varepsilon_i, \quad \text{with } \varepsilon_i \sim N(0, \sigma_\varepsilon^2) \text{ and } E(\varepsilon_i \varepsilon_j) = 0, \tag{1}$$

where $i = 1, ..., N$, $j = 1, ..., n$ (with $n < N$), and G_i is the green indicator computed for bond i, X_i is a vector including a set of controls, i.e., bond characteristics such as tenor, credit rating, call option and size. Then, since the heterogeneity in the sample, as shown in Table A.3, we introduce variables δ_k clustering the bonds by currencies. Model (1) allows for the intercept α_j to vary by issuer assuming that companies are realizations from a random variable following a probability distribution $\alpha_j \sim N(\mu_\alpha, \sigma_\alpha^2)$, where the mean can be assumed to be

$$\mu_\alpha = a_0 + a_1 Z_j, \tag{2}$$

with Z_j containing company-specific variables that contribute to explaining variation at the issuer level (see, for example, Gelman, 2007). The error terms ε_i are assumed to be uncorrelated with the varying intercepts α_j.

As in previous literature, we also investigate if the financial sector shows a separate behaviour with respect to bond greenness. We go further into this line of research by specifically focusing on Climate-Policy-Relevant sectors (CPRS), which are industries particularly exposed to climate risk and mitigation policies, and for this reason may exhibit a more pronounced effect of greenness practices. This classification is due to Battiston et al. (2017), who remap the NACERev24-digit standard classification of economic activities into five CPRS based on their GHG emissions, their role in the energy supply chain, and the presence of related climate policy institutions in their countries. CPRS are fossil fuel, utilities, energy-intensive, transport, and housing (see Figure A.2 in the Appendix).

6 Results

In this section, we gather the empirical results of the analysis. The baseline analysis compares the model in eq. (1) by including the green indicator and excluding it. In particular, Table 1 shows results of three specifications based on different versions of model (1). Model 1 considers the standard regression for the study of bond yields determinants, including control variables at the bond level and company-specific intercepts α_j. Model 1 does not include the green indicator. Model 2 includes among the covariates the equity ratio as company-specific variable in eq. (2). Model 3 includes in the analysis the green indicator to test its validity as a determinant of yields of green bonds (Model 3, third column). Likelihood ratio tests between nested models are performed to justify the increased complexity of the specifications derived from the addition of new variables (see Table A.5 in the Appendix).

[TABLE 1 AROUND HERE]

The estimated coefficients of control variables are coherent with economic theory. A higher credit quality indicates a lower risk of default for investors and so a lower yield, while the yield is higher for longer maturities since longer durations are usually associated with more uncertainty. Solvency is found negatively related to yield spreads (see, e.g., Arnould et al., 2022) as the larger the equity ratio, the healthier a company is valued due to its ability to cover debt by equity in case the company needs to liquidate. When adding the green indicator among the covariates, it appears to be a significant determinant of green bond yields, with a negative estimated coefficient. The negative sign is in line with previous findings of a negative premium for corporate green bonds, the so-called greenium (see, e.g., Zerbib, 2019; Fatica et al., 2021; Caramichael and Rapp, 2024). It also demonstrates that, ceteris paribus, on average, "the greener" a bond is, the higher the premium at which it sells, so confirming the effect on bond pricing of undergoing external reviews and achieving a darker green rating, as reported in Huynh et al. (2022), Ghitti et al. (2023) and Allman and Lock (2024). The economic interpretation of this result may be manyfold. Investors may accept lower risk compensation if they consider green bonds an opportunity of hedging against climate-related financial risks[11], or if they believe that disclosure on environmental activities increases the green bond transparency, thus reducing uncertainty and idiosyncratic risk. Moreover, it has been stressed that investors also follow non-pecuniary motives in their allocation choices. If their preferences for pro-social and pro-environmental attitudes enter their utility function in addition to their expectations regarding return and risk, investors' tastes modify equilibrium prices (Fama and French, 2007). Furthermore, the

[11]Climate-related financial risks can be divided into three categories: *physical risks* that include the consequences of droughts, floods or storms for the value of investments and productive capacity; *transition risks* that are "stranded assets", or potential financial losses from investments losing value as a result of climate mitigation, or shifting consumer and investor preferences to greener products and technologies; *liability risks* arising from the potential impact of legal action taken by parties who have been adversely affected by climate change against firms and other economic agents that are held responsible (Carney, 2015).

issuance of green bonds may signal to socially responsible investors the commitment to promote the transition towards a sustainable economy, so producing an important reputational benefit for the issuer. In these cases, environmentally concerned investors may be willing to receive a lower yield for funding environmentally responsible projects.

In the greenium literature, contrasting evidence has been found regarding the existence and magnitude of the negative premium for bonds issued by financial firms. Zerbib (2019) and Hachenberg and Schiereck (2018) measure a more pronounced greenium for the financial sector, while no statistically significant pricing differences are reported by Fatica et al. (2021). Since in our sample 50% of bonds are issued by financial institutions, we try to shed light on this matter by including a binary variable identifying companies belonging to this sector. Based on our sample of European corporate green bonds, regression estimates reported in Table 2 (column 1), where a dummy variable identifying the non-financial companies is introduced, show that the sector *per se* is a significant determinant of the yield spreads, leading to the conclusion that green bonds issued by non-financial firms obtain on average a lower yield than those issued by financial institutions.

[TABLE 2 AROUND HERE]

To dig deeper into this result, we further analyse bonds belonging to non-financial sectors by separately considering each of the five CPRS by Battiston et al. (2017), which are industries particularly exposed to climate risk and mitigation policies, and for this reason may exhibit a more pronounced effect in response to greenness practices. As expected, estimated coefficients associated with each of these sectors are negative and nearly all significant. Green bonds issued by non-financial European corporates on average sell at a premium with respect to their counterparts issued by financial institutions, and it is especially so for bonds issued by firms belonging to industries that are more concerned with climate risks (see, for example, energy-intensive, fossil-fuel and the utility sectors in Model 5, Table 2). A reasonable explanation of this outcome may be attributed to a problem of information asymmetry. For investors may be more difficult to trace their funds when investing in a green bond issued by a financial institution because the proceeds go into a green portfolio of assets rather than directly to fund a green project. The absence of a direct link between the proceeds and the specific project may undermine the credibility of financial institutions in committing to support eco-sustainable activities. On the other hand, when a company is more involved in activities that have a direct impact on the environment, the issuance of green bonds to fund environmentally responsible projects may be an effective signal for investors, communicating that such a company is striving to promote the transition to a more sustainable economy. Thus, environmentally concerned investors are more willing to fund such companies at the cost of receiving a lower yield.

Another important theme highlighted in some recent works points to the importance of ESG evaluations on the pricing differential between green and brown bonds (Immel et al., 2022; Huynh et al., 2022). ESG ratings refer to companies' attitude towards environmental, social responsibility, and governance matters, but they are not specifically assigned to green projects. Yet, some researchers claim that the credibility of the projects underlying green bonds has little impact on the greenium (Caramichael and Rapp, 2024). This may be because only a few green bonds are project bonds, where claims are on the cash flows of the financed green project itself, but rather their environmentally related credit risk is a function of the entire company's business (Ehlers and Packer, 2017). As a consequence of this remark, it seems appropriate to investigate how firms' environmental assessments contribute to defining the green bonds' yields. Thus, we add the Environmental rating among the covariates in the regression and find it significant with a negative estimated coefficient (Table 2, Model 6). These results are in contrast with previous findings. Immel et al. (2022) affirm that only the presence of the ESG score has an effect on the green premium, while none derives from the magnitude of it. Huynh et al. (2022) also show that it is positive for a firm to have an ESG rating, but they estimate that this result is not driven by the environmental friendliness of the issuer. On the contrary, we find that, when disentangling the determinants of green bond yields, the greenness of the firm itself plays an important role. The way a firm acts towards sustainability issues is perceived and accounted for by investors in green securities. More specifically, a company that is less exposed to environmental risks or that succeeds in better managing such risks is rewarded by a lower borrowing cost when issuing bonds for financing green projects. Nonetheless, the green indicator remains significant, providing evidence that even after taking the greenness of the issuer into account, the level of greenness and transparency of the bond is still decisive in defining the yield value at issuance.

7 Robustness Analysis

In this section, we perform robustness analysis over alternative specifications of the proposed model. First, we provide results over a different set of variables included in Z_j defined in eq. (2). Then, we provide results exploring a different industry classification, and including ESG, S, and G scores in Z_j.

Table 3 reports results including in Z_j other balance sheet variables with respect to the *Equity ratio*. We investigate the effect on green bond yields of profitability (i.e., *ROA* and *ROE*) and solvency measures (i.e., *Debt over Equity* and *Debt over Assets*), as well as the rating and size of the issuer. We notice that they are not statistically significant except for the *Debt on Assets* solvency ratio, which partly conveys complementary information to that of the *Equity ratio* included in Model 2 of Table 1. Including more accounting variables implies a serious decrease in the number of observations available for estimation. For example, if we include *ROA*, *Debt on Assets*, and the *Issuer credit rating*, the number of observations drops to 925 bonds. This could affect the reliability of the outcomes. For this reason, we adopt a parsimonious approach, which is also empirically supported by the results reported in Table 3.

[TABLE 3 AROUND HERE]

In our main application, we collect results by the CPRS classification. In Table 4, Model 1, we report results adopting the NACE code at the Section level. We obtain statistically significant results only for the *Electricity/gas* sector, which corresponds to the *Utilities* and *Fossil fuel* categories in the CPRS classification. We also observe a highly significant result for the *Retail trade* sector, but the number of bonds included in this industry is 8, a lower amount with respect to the other sectors. These remarks lead to the conclusion that the identification of the sectors based on the climate policy relevance is more appropriate in this framework.

[TABLE 4 AROUND HERE]

Let us focus on the role of the ESG metrics in our analysis. In Model 6 of Table 2, we find that the *Environmental rating* plays an important role among the determinants of green bond yields. Previous works in the literature show a similar result for the ESG rating (see e.g. Huynh et al., 2022; Immel et al., 2022), but Immel et al. (2022) point out that such a phenomenon is not driven by the environmental friendliness of the green bond issuer, but rather by the company's governance. Thus, in Table 4, we provide results including the *ESG rating* and the single pillars scores, *Social* and *Governance*, instead of the *E rating*, and report the estimates in Models 2,3, and 4, respectively. We highlight the importance of the environmental conduct of firms rather than their governance practices. ESG and Social Responsibility evaluations display a weakly statistically significant effect on green bond yields. The Governance dimension appears to have no impact in such a context.

8 Conclusion

In this paper, we propose an indicator for measuring the level of greenness of green bonds. The motivation derives from the necessity of a more robust evaluation of their greenness, which does not depend on a specific evaluation process, but comprehends assessments from several reviewers and takes into account all major aspects of the Green Bond Principles defined by ICMA. A higher accuracy in qualifying bond greenness is necessary whenever a study on the green bond market is performed, because it allows a precise identification of their green characteristics and their differences from conventional bonds. Previous literature mainly relies on green labels collected from a single provider, but it shows very mixed evidence on the existence of price differentials between green and brown bonds. Moreover, recent works stress the importance of the shades of green rather than a uniform green level. Thus, we construct the indicator by aggregating verification outcomes from different providers and including information both on the funded green project and on the management of the proceeds. We find that the indicator plays a significant role among the determinants of green bond yields, and its impact aligns with previous findings. However, a key difference should be noted. While a large part of the studies focus on the behaviour of green bonds with respect to ordinary ones, we try to disentangle the differences within the green bonds universe itself. In this sense, the green indicator may result in an efficient synthetic tool for investors and policymakers in effectively measuring the greenness of bonds to avoid information asymmetry problems and to contrast greenwashing behaviours.

Tables

Table 1: Estimation results of specifications for the model in eq. (1). Model 1 is the baseline regression including only bond-specific covariates. Model 2 includes the Equity ratio as a company-specific variable. Model 3 includes the Green Indicator among the covariates. Information criteria such as AIC and BIC are reported, as well as the value of the Log-likelihood at the fitted value of the parameters. Standard deviations of the random-effects terms and the residuals are also reported. Marginal and conditional R^2 are computed as in Nakagawa and Schielzeth (2013). The marginal value refers to the variance explained by fixed factors alone, while the conditional R^2 measures the variance explained by fixed and random factors. Standard errors in parentheses. Satterthwaite's degrees of freedom method is used to compute p-values.

	Model 1	Model 2	Model 3
Intercept	6.754^{***}	6.465^{***}	6.798^{***}
	(0.643)	(0.648)	(0.659)
Callable(Yes)	0.038	0.129	0.124
	(0.071)	(0.071)	(0.071)
Tenor	0.013^{**}	0.014^{***}	0.014^{***}
	(0.004)	(0.004)	(0.004)
Bond Rating	-0.234^{***}	-0.205^{***}	-0.205^{***}
	(0.012)	(0.013)	(0.013)
Issuance Size	0.014	0.004	0.021
	(0.029)	(0.029)	(0.029)
Equity ratio		-0.009^{***}	-0.009^{***}
		(0.002)	(0.002)
Green Indicator			-0.063^{***}
			(0.017)
AIC	3215.999	2989.570	2983.678
BIC	3257.433	3035.690	3034.923
Log Likelihood	−1599.999	−1485.785	−1481.839
Num. obs.	1312	1242	1242
Num. groups: issuer	383	353	353
Num. groups: currency	15	15	15
Var: issuer	0.486	0.346	0.334
Var: currency	5.001	4.997	5.115
Var: Residual	0.421	0.428	0.426
R^2 (marginal)	0.097	0.072	0.072
R^2 (conditional)	0.936	0.931	0.933

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 2: Estimation results of specifications for the model in eq. (1). Model 4 includes a dummy variable identifying non-financial firms (base level: financial sector). Model 5 includes the CPRS classification as a categorical variable. In Model 6, the *Environmental rating* (firm-specific) is included. Information criteria such as AIC and BIC are reported, as well as the value of the Log-likelihood at the fitted value of the parameters. Standard deviations of the random-effects terms and the residuals are also reported. Marginal and conditional R^2 are computed as recommended by Nakagawa and Schielzeth (2013): the marginal value refers to the variance explained by fixed factors alone, while the conditional R^2 measures the variance explained by fixed and random factors. Standard errors in parentheses. Satterthwaite's degrees of freedom method is used to compute p-values.

	Model 4	Model 5	Model 6
Intercept	7.210***	7.160***	6.972***
	(0.656)	(0.655)	(0.664)
Callable(Yes)	0.117	0.141*	0.170*
	(0.068)	(0.069)	(0.073)
Tenor	0.016***	0.018***	0.021***
	(0.004)	(0.004)	(0.004)
Bond Rating	−0.224***	−0.220***	−0.201***
	(0.012)	(0.012)	(0.013)
Issuance Size	0.018	0.019	0.029
	(0.029)	(0.028)	(0.031)
Equity ratio	0.005	0.001	0.001
	(0.003)	(0.003)	(0.003)
Green Indicator	−0.068***	−0.070***	−0.058**
	(0.016)	(0.016)	(0.019)
Non-financial	−0.774***		
	(0.102)		
Energy-intensive		−0.517**	−0.492**
		(0.166)	(0.176)
Fossil-fuel		−0.795**	−0.708**
		(0.261)	(0.266)
Utilities		−0.849***	−0.818***
		(0.119)	(0.131)
Transport		−0.238	−0.285
		(0.283)	(0.320)
Housing		−0.443**	−0.356*
		(0.159)	(0.172)
Other		−0.862***	−0.818***
		(0.136)	(0.156)
Environmental rating			−0.065**
			(0.021)
AIC	2935.781	2939.335	2398.905
BIC	2992.150	3021.326	2482.472
Log Likelihood	−1456.890	−1453.667	−1182.452
Num. obs.	1242	1242	1008

	Model 4	Model 5	Model 6
Num. groups: issuer	353	353	271
Num. groups: currency	15	15	15
Var: issuer	0.253	0.241	0.197
Var: currency	5.108	5.111	4.999
Var: Residual	0.428	0.429	0.439
$R^2(marginal)$	0.077	0.078	0.078
$R^2(conditional)$	0.932	0.932	0.928

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 3: Estimation results of alternative specifications for Model 2 in Table 1. Company-specific variables are included in the baseline model instead of the *Equity ratio*: *Company size* is the logarithm of total assets, *ROA* and *ROE* are returns over assets and over equity, respectively, *Debt od Assets* and *Debt on Equity* are solvency ratios of total debt over assets and equity, respectively, and the *Issuer rating* is the credit rating of the issuer on a 0-21 scale where 0 corresponds to the worst and 21 to the higher credit quality. Information criteria such as AIC and BIC are reported, as well as the value of the Log-likelihood at the fitted value of the parameters. Standard deviations of the random-effects terms and the residuals are also reported. Marginal and conditional R^2 are computed as in Nakagawa and Schielzeth (2013). The marginal value refers to the variance explained by fixed factors alone, while the conditional R^2 measures the variance explained by fixed and random factors. Standard errors in parentheses. Satterthwaite's degrees of freedom method is used to compute p-values.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	5.752***	6.056***	6.083***	6.231***	6.242***	7.125***
	(0.677)	(0.646)	(0.647)	(0.645)	(0.648)	(0.688)
Callable(Yes)	0.098	0.089	0.068	0.077	0.066	0.024
	(0.071)	(0.072)	(0.072)	(0.071)	(0.071)	(0.081)
Tenor	0.013***	0.014***	0.014***	0.014***	0.013***	0.013***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Bond Rating	−0.200***	−0.191***	−0.193***	−0.198***	−0.189***	−0.222***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.018)
Issuance Size	0.002	0.009	0.003	0.002	0.010	−0.039
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.035)
Company size	0.043					
	(0.022)					
ROA		−0.020				
		(0.015)				
ROE			0.004			
			(0.004)			
Debt on Equity				−0.000		
				(0.000)		
Debt on Assets					−0.005**	
					(0.002)	
Issuer Rating						−0.023
						(0.022)
AIC	2997.172	2900.802	2878.425	2997.060	2997.170	2426.062
BIC	3043.292	2946.635	2924.228	3043.144	3043.283	2470.141

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Log Likelihood	−1489.586	−1441.401	−1430.212	−1489.530	−1489.585	−1204.031
N. obs.	1242	1203	1199	1237	1241	990
N. groups: issuer	353	335	333	350	352	272
N. groups: currency	15	15	15	15	15	15
Var: issuer	0.359	0.358	0.356	0.361	0.354	0.326
Var: currency	4.968	4.993	5.004	5.005	5.041	4.807
Var: Residual	0.430	0.429	0.423	0.424	0.430	0.452
R^2(*marginal*)	0.071	0.067	0.069	0.071	0.075	0.083
R^2(*conditional*)	0.931	0.931	0.932	0.932	0.932	0.926

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 4: Estimation results of alternative specifications for model 6 in Table 2. Model 1 includes a categorical variable identifying the NACE sector classification. Models 2 to 4 include the *ESG*, *Social*, and *Governance rating*, respectively. Standard deviations of the random-effects terms and the residuals are also reported. Marginal and conditional R^2 are computed as recommended by Nakagawa and Schielzeth (2013): the marginal value refers to the variance explained by fixed factors alone, while the conditional R^2 measures the variance explained by fixed and random factors. Standard errors in parentheses. Satterthwaite's degrees of freedom method is used to compute p-values.

	Model 1	Model 2	Model 3	Model 4
Intercept	6.534^{***}	6.955^{***}	7.026^{***}	6.746^{***}
	(0.666)	(0.654)	(0.661)	(0.661)
Callable(Yes)	0.165^{*}	0.174^{*}	0.168^{*}	0.174^{*}
	(0.071)	(0.069)	(0.069)	(0.070)
Tenor	0.020^{***}	0.020^{***}	0.020^{***}	0.019^{***}
	(0.004)	(0.004)	(0.004)	(0.004)
Bond Rating	-0.217^{***}	-0.197^{***}	-0.201^{***}	-0.204^{***}
	(0.013)	(0.013)	(0.013)	(0.013)
Issuance Size	0.029	0.015	0.017	0.018
	(0.030)	(0.029)	(0.029)	(0.029)
Equity ratio	0.000	0.001	−0.000	0.000
	(0.003)	(0.003)	(0.003)	(0.003)
Green Indicator	-0.052^{**}	-0.057^{**}	-0.057^{**}	-0.061^{***}
	(0.019)	(0.018)	(0.018)	(0.018)
E rating	-0.056^{**}			
	(0.021)			
ESG rating		-0.054^{*}		
		(0.022)		
Social rating			-0.074^{*}	
			(0.032)	
Governance rating				−0.004
				(0.027)
Real estate	−0.250			
	(0.136)			

	Model 1	Model 2	Model 3	Model 4
Electricity/gas	-1.285^{***}			
	(0.301)			
Manufacturing	-0.184			
	(0.325)			
Construction	-0.153			
	(0.417)			
Water supply	0.271			
	(0.255)			
Transportation	0.477			
	(0.623)			
Communication	-0.012			
	(0.257)			
Retail trade	0.633^{***}			
	(0.139)			
Administrative	0.218			
	(0.151)			
Accomodation/food	0.986			
	(0.557)			
Energy-intensive		-0.485^{**}	-0.463^{**}	-0.414^{*}
		(0.161)	(0.160)	(0.165)
Fossil-fuel		-0.623^{*}	-0.415	-0.676^{*}
		(0.260)	(0.284)	(0.263)
Utilities		-0.818^{***}	-0.784^{***}	-0.863^{***}
		(0.123)	(0.126)	(0.124)
Transport		-0.358	-0.295	-0.339
		(0.309)	(0.311)	(0.315)
Housing		-0.307	-0.247	-0.300
		(0.162)	(0.164)	(0.165)
Other		-0.765^{***}	-0.721^{***}	-0.777^{***}
		(0.133)	(0.136)	(0.135)
AIC	2372.912	2594.018	2593.807	2599.366
BIC	2476.142	2679.239	2679.028	2684.587
Log Likelihood	-1165.456	-1280.009	-1279.903	-1282.683
N. obs.	1008	1111	1111	1111
N. groups: issuer	271	296	296	296
N. groups: currency	15	15	15	15
Var: issuer	0.140	0.189	0.193	0.202
Var: currency	5.018	4.901	4.919	4.915
Var: Residual	0.447	0.425	0.424	0.423
$R^2(marginal)$	0.081	0.078	0.078	0.076
$R^2(conditional)$	0.927	0.929	0.929	0.929

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Figures

Figure 1: Green Indicator distribution (N = 1,312). The green indicator is constructed as the sum of each dummy variable representing a specific label/aspect of the greenness of a bond. Variables contributing to its construction are reported in Table A.1.

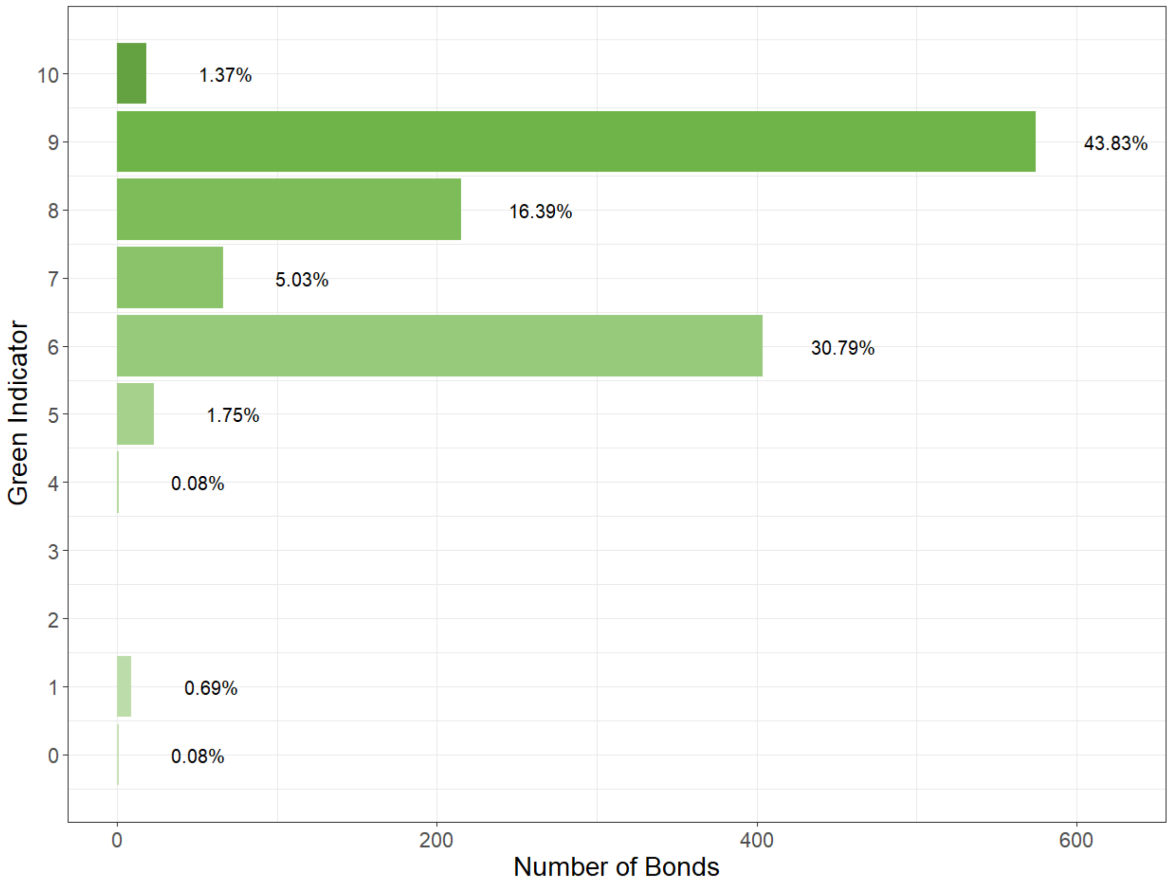


Figure 2: Yield spread distribution according to the level of greenness of the bond (N = 1,312).

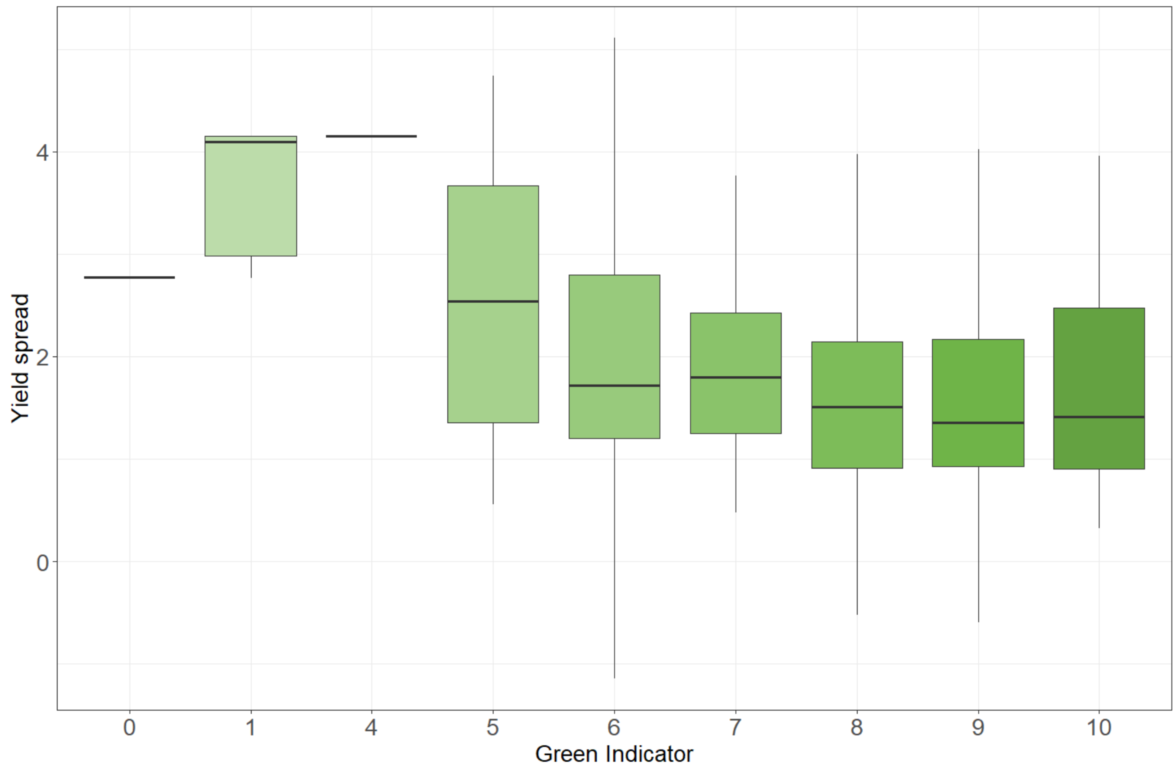
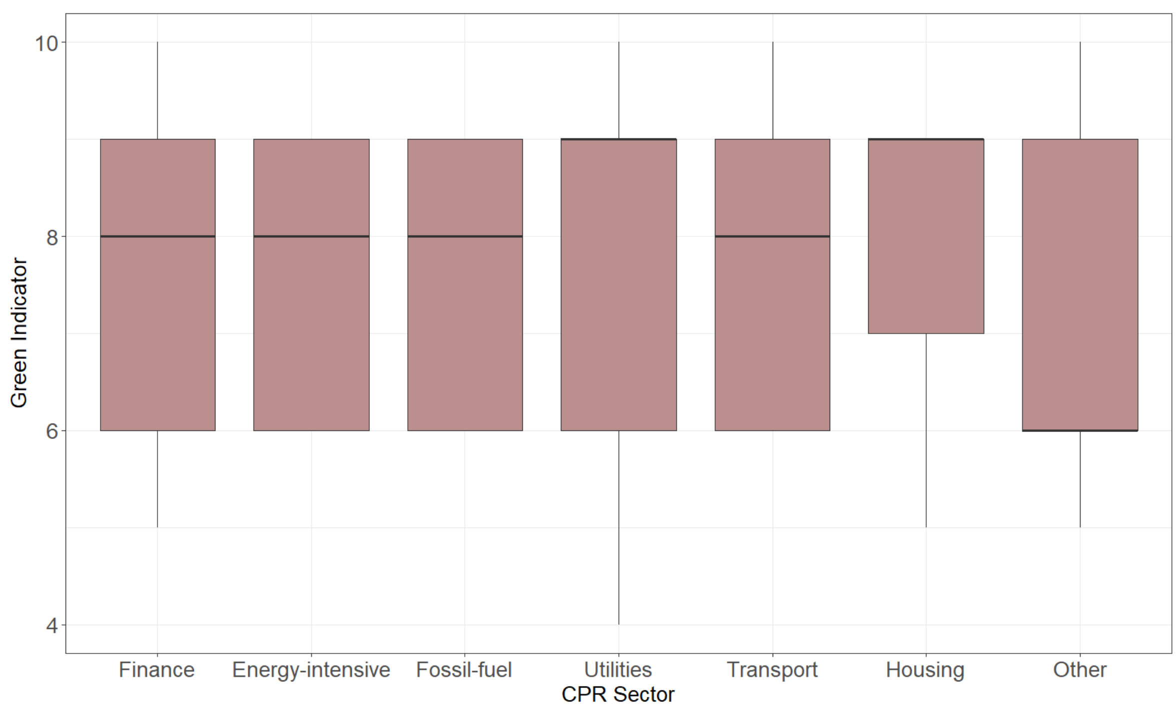


Figure 3: Green Indicator distribution according to the CPR Sector to which the bond issuer belongs (N = 1,312).



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A Appendix

A.1 Additional Tables

Table A.1: Variables included in the dataset. This table lists the variables included in the dataset. For each variable, we provide the description, its source and type.

Variable	Description	Source	Type
Panel A: *General Bond-specific Variables*			
Yield at issuance	Value of the bond yield to maturity at the date of issuance	Bloomberg	numeric
Maturity	Maturity date of the bond	Bloomberg	date
Issuance date	Date of first issuance of the bond	Bloomberg	date
Issued amount	Total amount raised by the issue of the bond (ml €)	Bloomberg	numeric
Credit rating	Credit rating assigned to the bond by the main rating agencies: S&P, Fitch and Moody's.	Bloomberg	categorical
Call option	Dummy variable indicating the presence of a call option for the bond	Bloomberg	binary
Currency	Currency in which the bond is denominated	Bloomberg	categorical
Yield curve spot rate	Yield curve values for maturities between 3 months and 30 years	ECB database	numeric
Panel B: *Company-specific Variables*			
Sector	4-digit code identifying the economic activity according to the NACE Rev. 2 classification	Bloomberg, MSCI	categorical
Equity ratio	Ratio of company's common equity over total assets (2023 balance sheet)	Bloomberg	numeric
Environmental rating	Score with a 0-10 range measuring company's exposure to environmental risks and its contribution toward environmental issues	MSCI	numeric
Panel C: *Green bond-specific Variables*			
Allocation Report	Indicates the availability of a post-issuance allocation report for a security	Bloomberg	binary
Impact Report	Indicates the availability of a post-issuance impact report for a security	Bloomberg	binary
Assurance Provider	Returns "yes" when the issuer's sustainable framework or other equivalent at-issuance documentation includes a statement to the effect that the issuer includes a framework assurance provider	Bloomberg	binary

Management of Proceeds	Returns "yes" when the issuer's sustainable framework or other equivalent at-issuance documentation includes a statement to the effect that the issuer has a management of proceeds process	Bloomberg	binary
Project Selection Process	Returns "yes" when the issuer's sustainable framework or other equivalent at-issuance documentation includes a statement to the effect that the issuer has a project selection process	Bloomberg	binary
Reporting Commitment	Returns "yes" when the issuer's sustainable framework or other equivalent at-issuance documentation includes a statement to the effect that the issuer has an instrument reporting commitment process	Bloomberg	binary
Pre-issuance impact framework	Indicates the availability of a pre-issuance impact framework for a security	Bloomberg	binary
Fully Allocated Indicator	Indicates if a given instrument's net proceeds have been entirely allocated to eligible projects	Bloomberg	binary
FactSet green flag	Returns "yes" when the bond is labelled green by FactSet	Factset	binary
CBI certification	Indicates whether the bond is certified according to standards of the Climate Bonds Initiative	CBI database	binary

Table A.2: Distribution of European corporate green bonds (N = 4,193) by green bonds-specific binary variables listed in panel C of Table A.1.

	yes	no
FactSet green flag	3649	544
CBI certification	62	4129
Allocation Report	1352	2841
Impact Report	1443	2750
Assurance Provider	4051	83
Management of Proceeds	4045	77
Project Selection Process	4060	62
Reporting Commitment	4047	75
Pre-issuance impact framework	3983	65
Fully Allocated Indicator	920	3273

Table A.3: Distribution of green bonds by the categorical variables *Call option* and *Currency* (N = 1,312).

Call option		Currency	
yes	770	EUR	950
no	542	SEK	99
		GBP	77
		USD	76
		CHF	56
		NOK	21
		Others	33

Table A.4: Summary statistics of numeric variables included in the regressions (see eq. 1) computed on the estimation set (1312 bonds). Yield spreads are evaluated as the difference between the bond yields at issuance and the yield curve spot rate at the date of issuance for a comparable maturity. *Tenor* is the difference in years between maturity and issue date. The *Credit rating* is constructed as a scale 0-21 where 0 corresponds to the worst and 21 to the higher credit quality. The *Equity ratio* is computed as the ratio of firms' common equity over total assets. MSCI Environmental rating is on a 0-10 scale where 10 represents the highest level of greenness.

	N	Mean	St. Dev.	Min	Median	Max
Yield spread	1312	1.88	1.37	−1.45	1.56	9.45
Finance	667	1.80	1.44	-1.45	1.46	9.45
Energy-intensive	63	1.79	0.81	-0.42	1.66	3.88
Fossil-fuel	18	2.33	2.54	0.49	1.38	9.05
Utilities	258	1.71	1.19	-0.49	1.35	7.96
Transport	20	1.95	1.09	0.61	1.69	4.24
Housing	148	2.23	1.14	0.33	1.93	6.55
Other	138	2.18	1.52	-1.06	1.80	7.74
EUR	950	1.67	1.09	-1.20	1.40	9.05
SEK	99	1.92	0.91	0.39	1.82	5.39
NOK	21	2.90	1.30	1.27	2.71	6.44
USD	76	3.72	1.34	1.28	3.62	7.96
CHF	56	0.05	0.64	-1.14	0.11	1.74
GBP	77	3.20	1.60	-0.43	2.92	8.72
Other	33	2.81	2.44	-1.45	2.95	9.45
Tenor (years)	1312	8.6	7.37	1.7	7	62
Issued amount	1312	955.34	3229.81	5	500	95020
Credit rating	1312	14.85	3.29	0	14	21
Equity ratio	1242	18.05	17.16	−2.99	10.32	84.62
Environmental rating	1032	6.74	1.77	0.62	6.69	10

Table A.5: Likelihood ratio F-tests for model comparison based on the Kenward-Roger approximation for the degrees of freedom (see Kenward and Roger (1997)). Model 1 represents the baseline regression of yield determinants, excluding the green indicator and company-specific covariates. Model 2 includes the Equity ratio from the balance sheet of companies. In Model 3 the Green Indicator is added among the covariates. In Model 4 a dummy variable identifying financial firms is added. Model 5 includes the CPRS classification. In Model 6, the Environmental rating is included. Degrees of freedom of the F-distribution are reported.

	test statistic	ndf	ddf	p-value
Model 1 vs Model 2	16.15	1	355.51	0.000
Model 2 vs Model 3	14.33	1	1181.15	0.000
Model 3 vs Model 4	57.23	1	351.58	0.000
Model 4 vs Model 5	2.90	5	362.12	0.014
Model 5 vs Model 6	9.27	1	257.88	0.003

A.2 Additional Figures

Figure A.1: Distribution of green bonds (N = 1,312) by country of risk of the issuer.

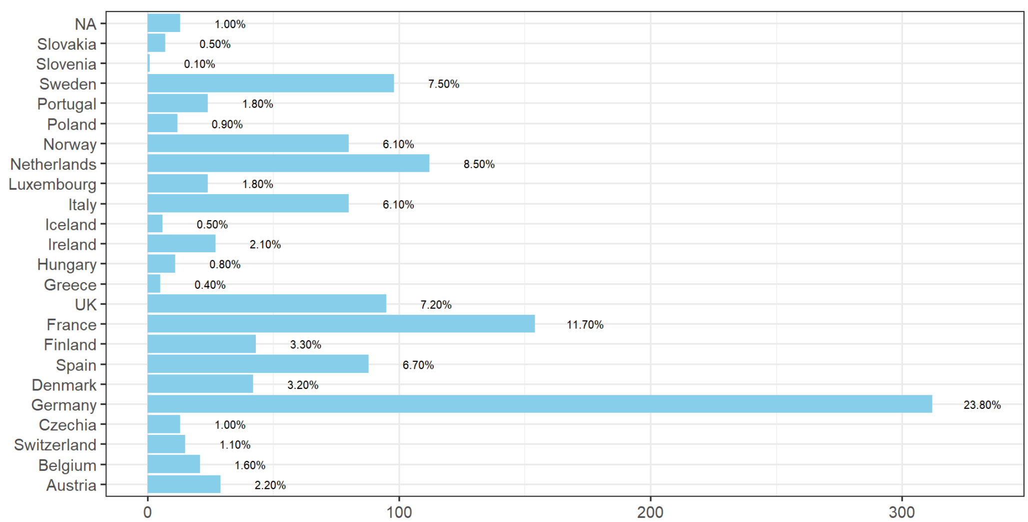

Figure A.2: Distribution of green bonds by companies' CPRS classification (Battiston et al., 2017).

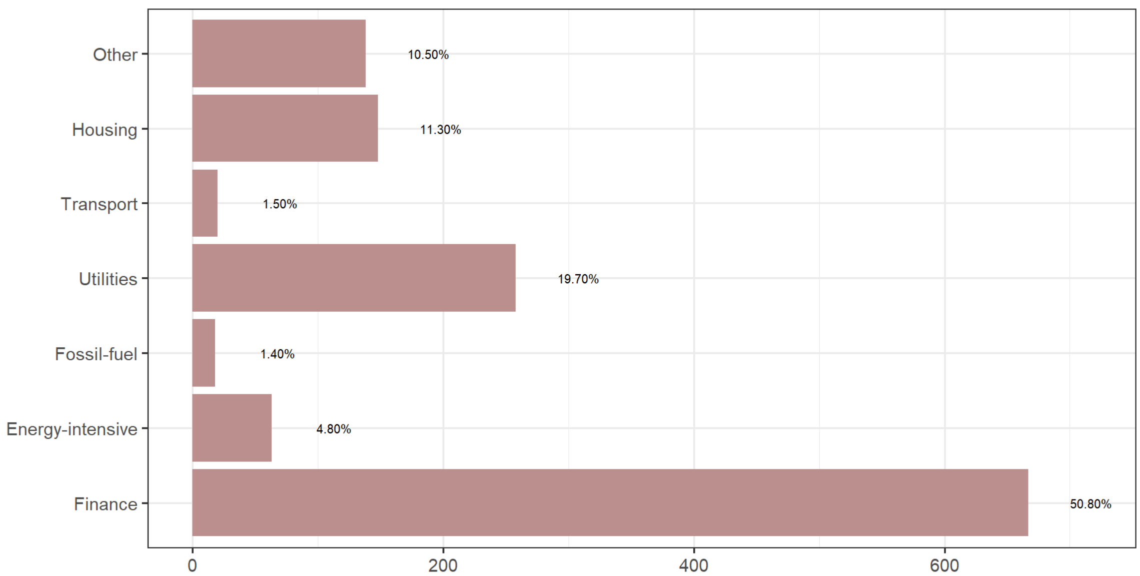

Figure A.3: Correlation matrix of numeric variables included in the regression. Correlation method: Pearson.