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CUI PRODEST? THE HETEROGENEOUS IMPACT OF GREEN BONDS ON COMPANIES' ESG SCORE

by Alessandro Moro* and Andrea Zaghini**

Abstract

With the aim of providing a comprehensive framework of analysis, this paper develops a signalling model in which green bonds enable companies to disclose the adoption of clean production processes. Given that investors exhibit environmental preferences, companies that rely on green technologies benefit from lower financing costs and are able to improve their environmental performance. Specifically, green bonds encourage more polluting companies to start transitioning towards cleaner production. Using a large global sample of companies and a difference-in-differences strategy, we successfully test the model's implications. The analysis also reveals that green bonds issued to finance mitigation activities are the most effective in improving companies' environmental performance. In line with the model's predictions, these bonds display the largest yield differential (greenium) compared with their conventional counterparts.

JEL Classification: G11, G12, G24, Q51, Q56.

Keywords: sustainable finance, ESG scores, green bonds, greenium, corporate bonds.

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1 Introduction[1]

Being a relatively new financial instrument, corporate green bonds have received increasing attention by the economic literature both at the empirical and theoretical level. However, not only contributions focus on different aspects providing results that at best are mixed, but also a conceptual framework for the analysis of the actual placement and the environmental consequences of the issuance of a green bond is entirely missing. The aim of this paper is to fill this gap. We nest four main strands of the literature: the signaling motivation of green bonds, i.e., revealing a credible commitment to adopt clean production practices (Fatica and Panzica, 2021; Flammer, 2021); the existence of the greenium, i.e., the convenience of issuing a green bond instead of a traditional one when financing climate-friendly projects (Zerbib, 2019; Caramichael and Rapp, 2024; Moro and Zaghini, 2025); the investors' environmental non-pecuniary motives, i.e., the reason for buying a green bond even at a yield inferior to that on a traditional bond (Pástor et al., 2021; Baker et al., 2022); the impact on the environment, i.e., the effect on the environmental performance of corporations after the green issuance (ElBannan and Löffler, 2024; Guesmi et al., 2025).

Starting from the last issue and focusing on companies' environmental performance as measured by the Environmental, Social, and Governance (ESG) score, our first research question can be stated as follows: Are the green bond placements able to improve the environmental performance of the issuer via an increase in the ESG score, and the E score in particular?

From a theoretical point of view, we develop a model in which companies can choose between a clean (green) and a polluting (brown) technology. Green technology is less productive, but it increases the reputation of companies. Companies are heterogeneous, as the weight of green reputation in the pay-off function is company-specific. Companies issue bonds to finance the acquisition of capital. Green bonds are those issued by companies that adopt green technology. In the model there are also investors who are endowed with environmental preferences such that, in equilibrium, the rental rate of green capital is lower than that of brown capital (greenium). We compare the equilibrium with and without green

[1]The views expressed in the paper are those of the authors and and do not involve the responsibility of the Bank of Italy. We thank Laura Bartiloro, Alberto Felettigh, Fabrizio Ferriani, Michele Loberto, Valerio Nispi Landi, Alfonso Rosolia, Andrea Silvestrini, Marco Taboga, and an anonymous referee of the Bank of Italy's working paper series for their insightful comments and suggestions.

bonds. The model predicts that the existence of green bonds encourages more companies to adopt the green technology with respect to the equilibrium without them. This happens because green bonds act as a signaling device allowing investors to identify companies adopting the green technology. In turn, these companies face lower financing costs than their brown counterparts given the existence of the greenium. Moreover, the companies that adopt the green technology only when green bonds are available are those that increase the most the stock of green capital with respect to the equilibrium without green bonds. Thus, from a transition perspective, green bonds seem to be particularly useful for polluting companies. These results are amplified by the existence of a larger greenium.

From an empirical point of view, we test the model implications, by estimating the impact of green bond issuance on companies' environmental performance. In other words, we use the changes in the environmental performance as a proxy of the evolution of the transition process. We collect information from LSEG Data Analytics and Standard&Poors Capital IQ on ESG scores and other morphological characteristics of a large sample of corporations located worldwide over the period 2012-2022. We merge these data with the information from Dealogic DCM Analytics on green and conventional bond placements in the primary market at the global level. The merging of the company-level dataset with the bond database allows us to determine the year and the amount of brown and green bond issuance of each company.

The identification strategy is based on a carefully designed staggered DID (difference-in-differences) scheme. The treatment group is made by the companies that issued at least one green bond; the control group is made by the companies that never issued green bonds. The pre- and post-treatment periods are defined, at the company level, as the years before and the two years after the issuance of a green bond. Consistently with the theoretical model, estimates show that the issuance of green bonds has a positive and significant effect on the ESG score of "brown" companies only, i.e. those with an environmental (E) score below the median level at the beginning of the time horizon. This improvement in the overall ESG score is entirely due to an increase in the E score, with the other two components (S and G) remaining unaffected. Moreover, we also find that green bonds are able to effectively reduce greenhouse gas emissions of polluting firms.

We also look at the bonds' use of proceeds as a possible further source of heterogeneity in the effectiveness of green bonds. It is worth reminding that green bonds are identical to traditional bonds, but for the proceeds of the issuance, that are committed to be employed for climate-friendly projects only, i.e. projects with an environmental scope. The earmarking of the funds raised from the placement represents a shift from traditional bond investing, where investors typically focus on broad company balance sheet characteristics and creditworthiness indicators, rather than the specific use of funds. Therefore, our second research question can be formulated as follows: Is the effectiveness of green bonds influenced by the use of their proceeds? In order to perform this analysis, we re-estimate the model with different treatment groups, according to the primary use of proceeds of the green bond issuance. Results show that green bonds issued to finance mitigation projects, especially in the field of clean transportation and construction, have the largest impact on companies' ESG score. Conversely, green bonds issued to finance adaptation initiatives do not have a significant effect on companies' ESG.

Since investors are aware of the green outreach of the projects to be funded, our third research question is the following: Do investors (differently) price the "use of proceeds" to which the issuing company committed in the green bond prospectus? By estimating bond-level regressions, we find that bonds issued to finance clean transportation and construction are the ones with the largest greenium. This results is again consistent with the theoretical model that predicts that the larger is the greenium attached to bonds, the larger is the investment in green technology.

We contribute to the existing literature in several respects. First, extant contributions suggest an overall positive effect of green bonds on issuing companies' ESG score (Flammer, 2021; Yeow and Ng, 2021; Battaglia et al., 2024; Guesmi et al., 2025) and a negative impact on their carbon intensity (Fatica and Panzica, 2021; ElBannan and Löffler, 2024). We instead show, both theoretically and empirically, that green bonds have a heterogeneous impact on companies' environmental performance. In particular, green bonds are able to induce polluting companies to adopt greener technologies. From this result a crucial policy implication follows: reducing investors' portfolio share of high emitters in favor of low emitters may not lead to an effective decarbonization, as stressed by Hartzmark and Shue (2023) and Angelini (2024), and confirmed in a macroeconomic setup by Bartocci et al. (2024).

Second, we create a bridge between the quoted (scant) literature on the effects of green bonds on companies' environmental performance and the (abundant) literature on the existence of the greenium.[2] According to our model, the existence of a greenium justifies the usefulness of green bonds, as they create incentives to induce companies to reconsider their production processes. At the same time, our empirical analysis shows that green bonds with a larger negative greenium are those most effective in improving companies' ESG scores.

Third, and connected with the previous points, our analysis is a first attempt to explore the heterogeneity in the use of green bond proceeds and the consequences for both the pricing of green bonds and the impact on corporate ESG scores.

The remainder of the paper is organized as follows. Section 2 illustrates our theoretical framework and derives some empirically testable implications. Section 3 describes the data employed in the empirical part and presents some stylized facts. Section 4 carries out our econometric exercises. Finally, Section 5 offers some concluding remarks and policy implications.

2 Model

In this section, we set up a baseline signaling model, inspired by the seminal contribution of Spence (1973). In the theoretical framework, green bonds act as a powerful signaling device, allowing investors, who exhibit environmental preferences, to identify companies adopting clean technologies, and thus reducing the financing costs of such companies. Although simple, the model is sufficiently general to incorporate standard features of climate models (trade-off between a clean and a polluting technology, investors with environmental preferences, green bonds as a signaling device) and it is susceptible of many possible interpretations and extensions. Hence, the proposed framework is useful in order to derive meaningful and empirically testable implications.

[2]Note that in the seminal contribution on corporate green bonds, Flammer (2021) did not find any premium on green bonds. On the contrary, the most recent contributions find that green bonds are placed at a negative premium with respect to similar traditional bonds. Two are the most likely reasons: i) the issuance of green bonds has substantially increased with respect to her sample, providing new evidence; ii) an increased awareness about the consequences of climate change has spread worldwide, especially after the COVID-19 pandemic that worked as an environmental "wake-up call".

2.1 Companies and technologies

The economy is populated by a mass one of companies. Companies use capital k as the only productive input in order to produce an homogeneous good y. Companies can choose two mutually exclusive technologies: a brown, b or a green, g technology. In both cases the production function is quadratic. Hence, the output produced by company i with technology j is:

$$y_{ij} = \left(\alpha_j - \frac{k_{ij}}{2}\right) k_{ij}. \tag{1}$$

In order to acquire capital k, companies issue bonds, that pay a return equal to r_j. We assume that the brown technology is more productive ($\alpha_b > \alpha_g$), but the green technology is able to provide an extra-profit to companies, via improving their reputation. We assume that reputation e_{ig} is a linear function of the green capital:

$$e_{ig} = \beta_g k_{ig}. \tag{2}$$

Each company values this extra-benefit with a weight ω_i, which is company-specific and drawn from a uniform distribution in the $(0, 1)$ interval. Hence, the green technology is costly for firms with a low environmental attitude, because it is less productive than the brown one and the reputation gain it entails has little value for such companies. Formally, the pay-off received by company i employing technology j can be formalized as:

$$\Pi_{ij} = \left[\left(\alpha_j - \frac{k_{ij}}{2}\right) k_{ij} - r_j k_{ij}\right] + \omega_i 1_j\left(g\right)\left(\beta_g k_{ig}\right), \tag{3}$$

where $1_j\left(g\right)$ is the indicator function that takes value one when company i chooses the green technology ($j = g$). The reputation gain $\beta_g k_{ig}$ is expressed in monetary terms and captures, in a reduced-form fashion, the extra-profits firms can earn from adopting a green technology. For instance, the extra-gain can derive from consumers' willingness to buy goods produced with a cleaner production process.[3] Another way of introducing firms' heterogeneity is

[3]Note that it is straightforward to endogenize the reputation gain by removing the good homogeneity assumption and assuming monopolistic competition among companies. Moreover, under the following two conditions the new framework would yield the same solution of the baseline model described in the text. First, the production function is linear in the capital stock k. Second, there is a linear demand for each good variety i and technology j: $p_{ij} = \alpha_j + 1_j\left(g\right)\omega_i\beta_g - (k_{ij}/2)$. In this set-up, companies adopting a green technology would have, *ceteris paribus*, a higher demand than their competitors employing a brown

that green firms might have a different productivity $\alpha_g + \omega_i \beta_g$ depending on the productive sector of their business activity. For instance, in some sectors, such as in the service sector, adopting green technology might be easier and more profitable than in other sectors, like manufacturing.

The timeline of events is the following: first, companies choose technology; second, they issue bonds to acquire capital; third, when production is completed, companies receive profits from production and extra-gains from reputation.

The maximization of the pay-off function (3) yields the capital demand of each company:

$$k_{ij} = \alpha_j + \omega_i 1_j (g) \beta_g - r_j. \tag{4}$$

Optimized profits can be written as:

$$\Pi_{ij} = \frac{k_{ij}^2}{2}. \tag{5}$$

2.2 Investors

In the model there is also a mass one of identical investors who have a preference for the financing of companies adopting green technologies. As in Pástor et al. (2021) and Baker et al. (2022), investing in green companies yields an extra-utility equal to $\delta > 0$ for each unit of capital invested.[4] Formally, the utility of the representative investor can be written as:

$$U = [1 + \nu (r_g + \delta) + (1 - \nu) r_b] k, \tag{6}$$

where ν is the share of capital invested in companies adopting the green technology.

We assume that companies' weight on green reputation and their choice about technology adoption are not directly observed by investors. In addition, companies' green reputation is determined after the production phase. Hence, only the existence of third-party certified green bonds can signal to investors, at the moment of their investment decisions, the en-

technology.

[4]The extra-utility investors earn by investing in green companies can be motivated by genuine environmental preferences or because green assets represent an hedge against climate risk (see Pástor et al., 2021). See instead Schmittmann and Gao (2022) for a model of asymmetric information with transition risk that generates a negative greenium even in the absence of investors' environmental preferences.

vironmental choice of companies with regard to the technology adopted in the production phase. In other words, only when green bonds are available, investors can maximise their utility (6) choosing the share ν. For simplicity, we also assume that the supply of capital is perfectly inelastic and equal to $\bar{k}$.

2.3 Equilibrium without green bonds

In the absence of green bonds, the rental rate of green and brown capital is the same, as investors are not able to discriminate between brown and green projects: $r_b = r_g = r$. In this case, there is a self-sorting equilibrium, in which companies with ω_i such that $\Pi_{ig} > \Pi_{ib}$ choose the green technology. This inequality is true if and only if:[5]

$$\omega_i > \frac{\alpha_b - \alpha_g}{\beta_g} \equiv \bar{\omega} \tag{7}$$

Given our assumption about the perfectly inelastic supply of capital, in equilibrium the rental rate of capital must satisfy:

$$\bar{\omega}\left(\alpha_b - r\right) + \int_{\bar{\omega}}^{1} \left(\alpha_g + \omega\beta_g - r\right) \mathrm{d}\omega = \bar{k}, \tag{8}$$

from which it is possible to derive the equilibrium value for the rental rate of capital:

$$r^* = \bar{\omega}\alpha_b + \left(1 - \bar{\omega}\right)\alpha_g + \frac{\left(1 - \bar{\omega}^2\right)}{2}\beta_g - \bar{k}. \tag{9}$$

2.4 Equilibrium with green bonds

Suppose there is a third-party institution, like a rating agency, that certifies bonds depending on the environmental nature of the technology adopted in the production process. Bonds issued to acquire capital for the green technology are certified as green, while the others are considered brown. Thus, the rating agency guarantees that green bonds are an effective and credible signal of issuers' environmental commitment (Flammer, 2021), preventing companies

[5]In the presence of climate/transition risk, such as a carbon tax τ that reduces the profitability of brown firms, a larger share of firms would adopt the green technology. E.g., considering a carbon tax per unit of brown output with a probability q of occurrence, equation (7) becomes $\bar{\omega} = \left[\alpha_b\left(1 - q\tau\right) - \alpha_g\right]/\beta_g$

adopting the brown technology to issue green bonds (greenwashing).[6] In this set up, investors are able to choose between the two types of bonds and maximize their utility (6) with respect to ν. As a result of this maximization, in equilibrium, the remuneration of brown bonds must satisfy:

$$r_b = r_g + \delta. \tag{10}$$

Indeed, this condition makes investors indifferent between investing in brown bonds, that exhibit a higher yield, and in green ones, that have a lower yield but entail an utility benefit. Hence, parameter δ captures the so-called greenium, i.e., the lower financing cost of green projects relative to their brown counterparts.

When green bonds are available, there is still a threshold value for ω_i such that $\Pi_{ig} > \Pi_{ib}$. Indeed, companies choosing the green technology are those that have:

$$\omega_i > \frac{(\alpha_b - \alpha_g) - (r_b - r_g)}{\beta_g} - \equiv \hat{\omega}. \tag{11}$$

Combining the last two expressions it is possible to show that:

$$\hat{\omega} = \bar{\omega} - \frac{\delta}{\beta_g} < \bar{\omega}. \tag{12}$$

In the equilibrium with green bonds, a larger fraction of companies choose the green technology with respect to the equilibrium without green bonds. This happens because green bonds allow companies adopting a clean technology to attract capital at cheaper financing conditions. The larger the greenium, the larger the number of companies choosing the green technology.

In equilibrium, keeping the endowment of capital fixed at $\bar{k}$ and preserving the assumption of inelastic capital supply, the rental rate of brown capital must satisfy:

$$\hat{\omega}\left(\alpha_b - r_b\right) + \int_{\hat{\omega}}^{1} \left(\alpha_g + \omega\beta_g - r_b + \delta\right) \mathrm{d}\omega = \bar{k}, \tag{13}$$

[6] Greenwashing can be formalized through models of hidden action, like Schmittmann and Gao (2022). Anyway, in these models, certification and compliance costs make green bonds less attractive for firms with a low environmental commitment. In our framework, in which we do not explicitly take into account such costs, in the absence of the rating agency, brown firms would find it convenient to issue green bonds, that have a lower yield, and the separating equilibrium would collapse in the pooling one.

from which it is possible to derive its equilibrium value:

$$r_b^* = r^* + \delta\left(1 - \frac{\hat{\omega} + \bar{\omega}}{2}\right) > r^*. \tag{14}$$

Analogously, the equilibrium value for the rental rate of green capital is:

$$r_g^* = r^* - \delta\left(\frac{\hat{\omega} + \bar{\omega}}{2}\right) < r^*. \tag{15}$$

2.5 Comparative statics

Denoting with $\Delta x = \hat{x} - \bar{x}$ the difference between the value of variable x in the equilibrium with green bonds ($\hat{x}$) and the same variable in the equilibrium without green bonds ($\bar{x}$), it is possible to assess the change in the capital stock for companies adopting the green technology when moving from a context without green bonds to one with green bonds. In addition, given that $k_{ig} = \beta_g^{-1} e_{ig}$, the change in the capital stock is also proportional to change in the companies' reputation. Analitically:

$$\Delta k_{ig} = \begin{cases} 0 & \omega_i \leq \hat{\omega} \\ \alpha_g + \omega_i \beta_g - r_g^* > 0 & \hat{\omega} < \omega_i \leq \bar{\omega} \\ r^* - r_g^* > 0 & \omega_i > \bar{\omega} \end{cases}, \tag{16}$$

in which $\alpha_g + \omega_i \beta_g - r_g^* \geq r^* - r_g^*$, as $\alpha_g + \omega_i \beta_g - r^* = \bar{k}_{ig} \geq 0$.[7]

Consequently, the companies that increase their stock of green capital the most (and thus improve their green reputation or their ESG score the most) are those that exhibit an intermediate value of the weight of green reputation. These companies find it convenient to invest in green technology only when green bonds are available. Thus, green bonds affect both the intensive and extensive margin of such companies. Conversely, companies with a very strong environmental attitude adopt the green technology even in the absence of green bonds, while the existence of green bonds induces them to increase to a lesser extent their stock in green capital as a result of the lower financing costs. Therefore, in this case, green bonds affect only the intensive margin. Finally, companies that do not care about their green

[7]More precisely, this happens for reasonable values of parameters α_g and β_g such that $\bar{k}_{ig} \geq 0 \ \forall i$ in the equilibrium without green bonds. This is a sufficient condition to guarantee that $\alpha_g + \omega_i \beta_g \geq r^*$.

reputation do not adopt any clean technology even if green bonds are available.

Analogously, it is possible to compute the change in the stock of capital in the equilibrium with green bonds relative to the one without green bonds for firms adopting the brown technology:

$$\Delta k_{ib} = \begin{cases} r^* - r_b^* < 0 & \omega_i \leq \hat{\omega} \\ r^* - \alpha_b < 0 & \hat{\omega} < \omega_i \leq \bar{\omega} \\ 0 & \omega_i > \bar{\omega} \end{cases}, \tag{17}$$

in which $r^* - \alpha_b \leq r^* - r_b^*$, as $\alpha_b - r_b^* = \hat{k}_b \geq 0$. As expected, the companies reducing the most the stock of brown capital are the ones that decide to adopt the green technology when green bonds are available (i.e. those with an intermediate value of ω_i). However, it is interesting to note that companies with a poor environmental concern (those with a low level of ω_i) also reduce the stock of their (brown) capital as the introduction of green bonds increases the rental rate of such capital.

Since the capital supply is fixed at $\bar{k}$, it is possible to show, from simple algebraic computations, that the aggregate increase in green capital exactly offsets the decrease in the brown capital:

$$\int_0^1 \Delta k_{ig}(\omega)\,\mathrm{d}\omega = -\int_0^1 \Delta k_{ib}(\omega)\,\mathrm{d}\omega = \bar{\omega}\left(\bar{k_b} - \hat{k_b}\right) + \frac{\delta}{\beta_g}\bar{k}_b > 0. \tag{18}$$

From equation (5) and the systems of equations (16) and (17) it turns out that the signaling equilibrium improves the profit of the companies always adopting the green technology. Firms always choosing the brown technology are instead worse off. Looking at companies that adopt the green technology only when green bonds are available, those with $\omega_i > \hat{\omega} + \left(r_b^* + r^* - 2r_g^*\right)/\beta_g)$ are better off in the equilibrium with green bonds than in the equilibrium without this financial instrument. Finally, investors improve their utility in the separating equilibrium ($\hat{U} = (1 + r_b^*)\,\bar{k}$) with respect to the pooling equilibrium ($\bar{U} = (1 + r^*)\,\bar{k}$).

2.6 Empirical implications

The theoretical model delivers some empirically testable implications. First, as long as green bonds reduce companies' financing costs as a result of investors environmental preferences

($\delta > 0$), the availability of this financial instrument should lead to a general improvement in companies' green reputation. According to the model, this happens because green bonds lead to an increase in the number of companies adopting green technologies (extensive margin) and to a higher level of capital invested in green production processes (intensive margin).

Second, green bonds issued by brown companies (i.e., those adopting a brown technology in the equilibrium without green bonds) should have a larger impact on companies' environmental performance than bonds issued by green companies (i.e., those already adopting a green technology in the equilibrium without green bonds). Indeed, the model suggests that the lower financing costs of green bonds provide an effective incentive for brown companies with a medium ω_i to change their technology and adopt a cleaner production process. The increase in the green capital due to the new adoption of green technology (extensive margin) is larger than the capital increase attributable to the companies already adopting the green technology (intensive margin). In turn, this means a greater improvement in the reputation of brown than green companies.

Third, the size of the greenium (δ) matters: the larger the negative yield differential between green and brown bonds, the higher the investment in green technologies and the relative improvement in green reputation. Thus, bonds with a larger greenium should improve companies' environmental performance to a greater extent.

3 Data

In order to empirically test the model implications, we merged data from several providers. In the first part of the dataset we collected information on bond placements in the primary market, sourced from three data providers: Dealogic DCM Analytics, LSEG Data Analytics and Bloomberg. Given that we are interested in assessing the reasons behind the heterogeneity in the cost of financing of green projects, we focus on the initial placement of the bond in the primary market, that exactly defines the financing cost conditions for the issuer.[8] We end up with a dataset of around 400,000 placements issued worldwide from January 2012 to December 2022, of which more than 8,000 are certified green bonds.

[8]While secondary market prices and volatility affect prospective issuance and they can be thought of as the current market assessment of the issuance (Goldstein and Yang, 2017), they do not change the face value of the already issued bonds and thus the cost for the issuer.

The gathered data provide a comprehensive coverage of the green bond market, capturing around 95 per cent of the green bond issuance as reported by the Climate Bonds Initiative database. For each new bond placed, we have the following information from Dealogic DCM Analytics: the pricing date; a green label that identifies green bonds; the rating of the bond and that of the issuer; the maturity (in years); the amount issued (in billion Euros); the currency in which the bond is denominated; the frequency of the coupon; the interest rate type (zero-coupon, fixed, and variable); the agreed use of proceeds for green bond. In addition, we also have dummies identifying collateralized, subordinate, and callable bonds. At the issuer level we have: the company rating; the nationality; the country of incorporation; the business sector description at the 2-digit SIC code level; the ultimate parent name, nationality and business sector. The annualized yield to maturity at issuance is instead sourced from LSEG Data Analytics and Bloomberg.

The second part of the dataset contains instead the ESG scores (used as a proxy of companies' green reputation) and some morphological characteristics of a sample of around 1,800 companies located worldwide and observed during the 2012-2022 period. In detail, the ESG scores and the sub-components are sourced from LSEG Data Analytics (Thomson Reuters ASSET4). The morphological features, including total (and current) assets and liabilities, total debt, market capitalization, return on equity (RoE), return on assets (RoA), are taken from Standard&Poors Capital IQ. The matching of the company-level dataset with the bond database, using several indicators of the bond issuer as the key variable, allows us to identify the year and the amount of green and non-green bond issuance of each company.

Focusing on the companies' sample, Fig. 1 shows the value of green bond issuance over the 2012-2022 period, together with the relative share of green bonds (hereinafter, green share). The two indicators exhibit similar dynamics. Both were almost null in the first three periods. In particular, in 2012 none of the companies in the sample issued a green bond.[9] Then, both green bond issuance and the green share started to grow steadily until 2020, when growth became exponential. So, our sample covers a time span that is long enough to cover the transition from a period in which green bonds did not exist (or were not used) to a new phase in which this financing instrument has became increasingly popular.

[9]The first green bond was issued in 2007 by the European Investment Bank (EIB). In November 2013 there was a turning point in the market with the first corporate green bond issued by Vasakronan, a Swedish property company. Only later on, at the end of 2016, was the first sovereign green bond issued by Poland.

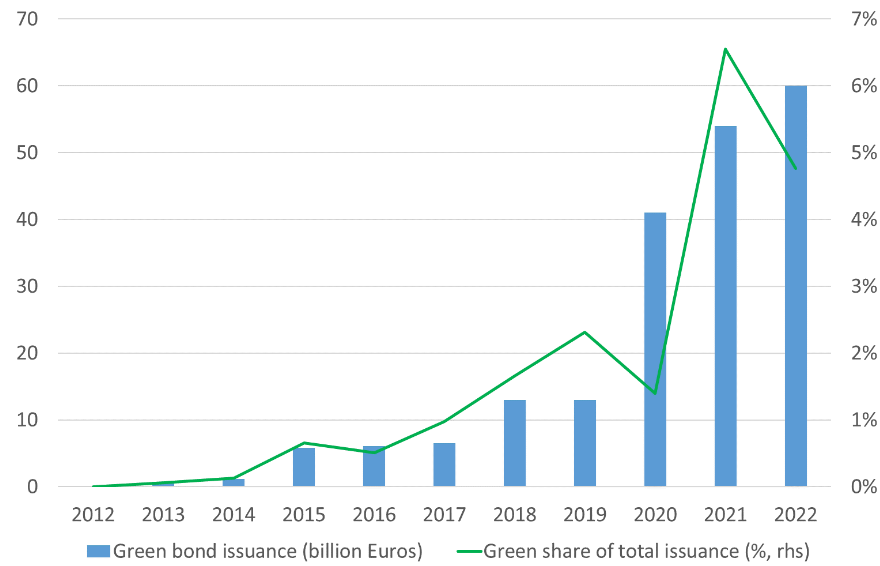

Figure 1: Green bond issuance and share of green bond issuance over time.

Looking at the distribution of ESG scores over time, from Fig. 2 it is possible to observe that the median value increased over time, signaling a general improvement in the ESG performance within the sample of companies. This is fully consistent with the predictions of our theoretical model, according to which the availability of green bonds should induce more companies to adopt green technologies — and increase the investment in green capital from companies already adopting clean production processes — thus improving companies' environmental performance. At the same time, the distribution of ESG scores becomes more concentrated, suggesting a catching up by more polluting companies. Again, this is consistent with our model, as the more polluting companies are encouraged to issue green bonds and adjust their productive processes by the lower financing costs of green bonds.

It is worth stressing that our sample includes companies from all the advanced countries and the major emerging economies (Fig. A.1). It is also representative of the main productive sectors (Fig. A.2). By looking at the share of green bond over total issuance by nationality and by sector (Fig. A.3 and Fig. A.4), it emerges that companies located in large emerging markets, like China and South Africa, or in some of the main European countries have the largest green shares; at the same time, companies involved in consumer products, construction, and transportation issue relatively more green bonds than those operating in

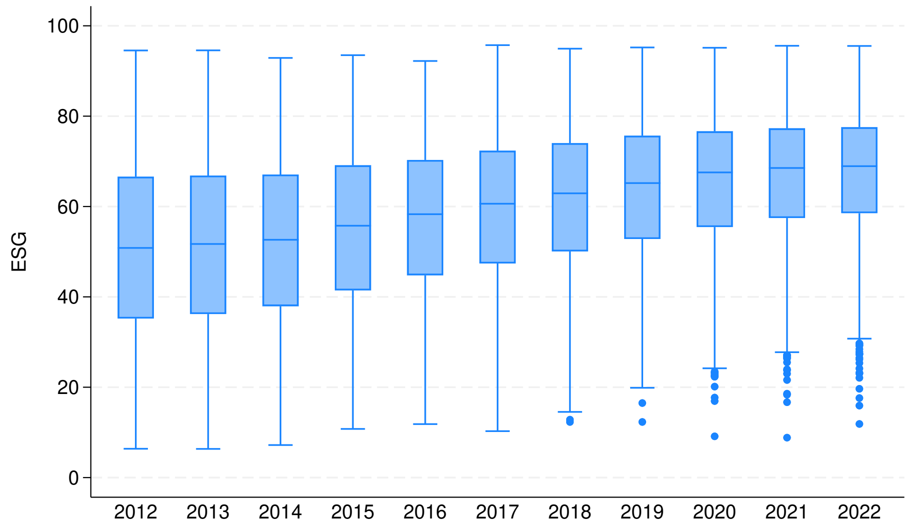

Figure 2: ESG distribution over time.

other productive sectors, especially chemical and metal industries and oil and gas sectors.

4 Econometric analysis

In this section, we first estimate the effect of green bond issuance on companies' environmental performance, depending on companies' environmental attitude at the time when green bonds were not available. We perform a bunch of robustness checks regarding both the definition of green versus brown companies as well as the measurement of companies' environmental performance. Second, we explore the heterogeneous impact of green bonds due to the different uses of the proceeds. Third, we discuss the implications of the parallel trend assumption typical of the DID approach. Finally, we perform bond level regressions in order to verify that the (green) bonds with the most significant impact on companies' ESG score are those with the largest negative greenium.

4.1 Green bond issuance and ESG scores

We adopt a staggered difference-in-difference approach in order to detect the impact of green bond issuance on companies' ESG performance. In particular, we estimate the following model:

$$ESG_{i,t} = \mu_i + \lambda_t + \gamma GB_i \times Post_{i,t} + \phi X_{i,t-1} + \varepsilon_{i,t}, \tag{19}$$

where $ESG_{i,t}$ is the ESG score (or its sub-components) of company i in year t; GB_i is the treatment variable, taking value one if company i issues at least one green bond, and zero, otherwise; $Post_{i,t}$ is a dummy variable that takes value one for each company in the year of a green bond issuance and in the subsequent two years; μ_i are company fixed effects; λ_t are time fixed effect. X_{it} includes some relevant control variables, lagged one period: the company size, measured by the natural logarithm of total assets; the return on assets (RoA); the leverage ratio, defined as the ratio of total debt over total assets; the ratio of current asset to current liabilities; the liquidity ratio, defined as the ratio of current assets over total assets; Tobin's Q, calculated as market capitalization to total assets ratio (Table A.1 in the Appendix reports the summary statistics of all the variables). Equation (19) is estimated with Ordinary Least Squares (OLS); robust standard errors are clustered at the company level.

Note that in this DID framework the outcome does not determine the treatment, since even in the case a company is planning in advance to issue a green bond and (possibly) improving the environmental performance, this rarely happens over more than one year. If that were the case, it would show in the parallel trend assumption checks.[10] On the other hand, there is not a mechanical link between the green bond placement and the ESG score, since green issuance is not included in the determinants of the E score (the environmental component of the Thomson Reuters ASSET4 ESG score by LSEG).

We estimate the model over the 2012-2022 period on the entire sample of 1,840 companies, as well as on the two sub-samples represented by brown companies only and green companies only. We identify these two groups using the median of the environmental score (E score, the first component of the ESG score) in 2012, the year in which corporate green bonds were not available. Thus, we identify brown (green) companies as those with an E score in 2012 below (above) the sample median in that year. We perform this split because, according

[10] In Section 4.3, we provide evidence that in the pre-treatment period the two ESG trends of treated and control issuers were similar. The check is run by conditioning, as traditionally done in the literature, on a large number of covariates to make the playing field as level as possible. In addition, we also employ a matching procedure à la Flammer (2021), that restrict the sample to companies for which the trend assumption is mechanically imposed.

Table 1: Effects of green bond issuance on the ESG score. Brown (green) companies are those with an E score below (above) the median in 2012. In column (4) we consider green companies excluding those in the top 10% of E scores in 2012.

	(1)	(2)	(3)	(4)
	All	Brown companies	Green companies	Green - top 10%
	ESG	ESG	ESG	ESG
GB * Post	-0.732	2.542**	0.320	1.547**
	(0.558)	(1.050)	(0.528)	(0.644)
Observations	20,240	10,120	10,120	8,096
Adjusted R-squared	0.834	0.788	0.775	0.746
Company Controls	YES	YES	YES	YES
Company FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

to our theoretical model, the availability of green bonds should be an effective incentive for brown companies caring for their reputation to adopt clean technologies and improve their environmental score.

Table 1 shows the estimates on the entire sample and on the two subgroups. Taking into account all observations, the effect of green bond issuance on ESG performance is not statistically significant. However, when restricting the sample to brown companies only, the effect turns out to be highly significant. The issuance of green bonds improves companies' ESG score by more than 2 points in the year of the issuance and in the subsequent two. The effect on green companies is positive, but not statistically significant. This result is likely due to the bounded nature of the ESG score (ranging from 0 to 100), which limits the marginal impact of additional green capital at the upper end of the scale. Indeed, by excluding from the sample of green companies those above the 90th percentile of the E score distribution in 2012 (see column 4), we uncover a significant effect, though smaller in magnitude than that observed for brown companies.

These results are not surprising when looked through the lenses of the theoretical framework. Indeed, one of the model implication is that companies that increase the most their investment in green capital and improve the most their ESG score, are those that invest in green technology only when green bonds are available. In the empirical setup, brown (green) companies are identified as those characterized by low (high) levels of green technology adoption when the corporate green bonds were not available, i.e, those for which the E score was below (above) the median in 2012. Therefore, "empirical" brown (green) companies can be mapped to the "theoretical" companies with a weight of green reputation ω_i below (above) the threshold $\bar{\omega}$ in the equilibrium without green bonds. According to our estimates, when green bonds became actually available, brown companies issuing green bonds improved their ESG score more than their green competitors, exactly as expected from our theoretical model (see equation 16).

These estimates are robust with respect to the definition of brown and green companies. Table A.2 in the Appendix shows the results of the estimation for three groups of companies identified through the tertiles of the E distribution in 2012. The effect of green bond issuance on the ESG score is significantly positive and declining for companies within both the the first and central tertiles of the E score distribution, but it not significant for the top tercile companies. Similarly, also when selecting brown and green companies using the median of the E score in 2012 within each productive sector, results are confirmed (see Table A.3).

In addition, results are also robust to the initial placement. While in the estimates presented in Table 1 the treatment effect is computed considering all the green bonds issued over the reference period, in Table A.4 we focus on the very first green bond placement for each company, the so called debut (green) bond. The estimate of the treatment effect is thus concentrated on 293 green bonds only. However, both the magnitude of the effect on the ESG score of brown companies and the missing statistical significance for the green companies are confirmed.

Table A.5 shows the results for the regressions estimating whether the effects of green bond issuance on the ESG score is sensible to the amount issued (relative to the overall company debt). More precisely, for each green bond, we distinguish whether the amount placed relative to the company's debt is higher or lower than the median of the historical distribution. While not statistically significant, results hint that when the ratio of green bonds issued over debt is above the median (high G-share), green bonds might have a greater impact on the ESG score of brown companies.

Focusing on the group of brown companies only, Table 2 reports the estimates of the

Table 2: Effects of green bond issuance on the ESG sub-components. Only brown companies.

	(1)	(2)	(3)
	E score	S score	G score
GB * Post	4.545**	1.702	1.054
	(1.791)	(1.211)	(1.424)
Observations	10,120	10,120	10,120
Adjusted R-squared	0.704	0.774	0.642
Company Controls	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

impact of green bond issuance on each of the three sub-components of the ESG score: the environmental score (E), the social score (S) and the government score (G). It is possible to observe that the placement of green bonds leads to a statistically significant improvement of the environmental score of the issuing company, while the effect is not significant for the other two ESG components. This is in line with the conjecture that the availability of green bonds, making the funding of green projects cheaper, makes companies more willing to adopt the green technology and thus improve their environmental score.

This result is confirmed also when directly looking at the greenhouse gas (GHG) emissions, expressed in CO2 equivalent terms and relative to companies' total assets (as in Fatica and Panzica, 2021). Table A.6 shows that, in the period after the green bonds issuance, brown companies were able to reduce their GHG emissions. The estimated coefficients are instead not significant for already green companies.

We also test other possible econometric specifications. Instead of splitting the sample, we run regressions on the entire sample of companies adding the interaction $GB_i \times Post_{i,t} \times BC_i$, where BC_i is a dummy equal to one for companies with an E score below the median in 2012 (i.e., brown companies). Results again show that brown companies improve their ESG score via an increase in the E sub-component, while green companies do not exhibit a statistically significant improvement in their environmental performance (Table A.7).

Table 3: Green bonds by use of proceeds

Use of proceeds	Frequency
Adaptation	165
Mitigation (of which):	812
Energy and pollution control	302
Clean transportation and construction	510
General purpose	214

A further check follows from the contributions by Callaway and Sant'Anna (2021) and Sun and Abraham (2021) that cast doubts on the statistical properties of the two-way fixed effect estimators in staggered difference-in-difference setups with multiple treatment periods, proposing alternative estimators. In order to prove the robustness of our results, we adopt the Sun and Abraham (2021) estimator, which includes the interactions between the treatment effects and the cohort of treatments: $GB_i \times Post_{i,t} \times 1\,(t = cohort_i)$. In particular, in our setting, the cohorts are defined for each year as the companies that issue their first green bond in that year. We aggregate cohorts in three groups: companies that issue their first green bond in the 2013-2016 period, in the 2017-2019 period, and in the 2020-2022 period. Results are reported in Table A.8 for the entire sample and for the two sub-groups of brown and green companies. Estimates show that only brown companies improve their environmental performance after the first green bond issuance, especially those that issue their first green bond after the outbreak of the COVID-19 pandemic.[11]

4.2 The role of the use of proceeds

Each green bond is intended to raise funds to finance a given company-specific green project. Thus, each green bond is associated with an agreed use of proceeds. We now investigate whether the heterogeneity in the uses of the proceeds has an effect on the post-issuance change in the company's ESG score.

First, we aggregate the declared use of proceeds into the two very broad, but standard categories of climate change adaptation and climate change mitigation. We also maintain a residual category, constituted by the remaining "General purpose" and for all green bonds for

[11]Similar results can be obtained considering the full set of cohorts (one for each year of issuance) instead of the three-group aggregation.

Table 4: Effects of green bond issuance by use of proceeds (Brown companies).

	(1) ESG	(2) ESG	(3) E score	(4) E score
Adaptation * Post	0.507	0.569	1.884	2.447
	(2.521)	(2.099)	(5.715)	(5.818)
Mitigation * Post	2.354**		4.602**	
	(1.160)		(2.015)	
(Energy + Pollution Control) * Post		1.267		1.717
		(1.472)		(2.504)
(Transportation + Construction) * Post		2.409*		8.364***
		(1.450)		(2.897)
General Purpose * Post	2.577*	1.613	4.772*	4.471*
	(1.556)	(1.338)	(2.579)	(2.440)
Observations	10,120	10,120	10,120	10,120
Adjusted R-squared	0.788	0.786	0.704	0.704
Company Controls	YES	YES	YES	YES
Company FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

which this information is not available. Then, we further distinguish, within the mitigation group, two more specif uses of proceeds: 1) green bonds issued to finance "Alternative and renewable energy" and "Pollution prevention and control" (we label this group "energy and pollution control", Energy + Pollution control); 2) green bonds issued to promote clean transportation and construction (we label this group "clean transportation and construction", Transportation + Construction). Table 3 shows the frequency of green bonds in our sample according to the proposed use of proceeds classification.

In order to test for a possible role of the use of proceeds in shaping the effect of green bond issuance on the ESG score, we estimate the following augmented model:

$$ESG_{i,t} = \mu_i + \lambda_t + \sum_k \gamma_k GB_{i,k} \times Post_{i,k,t} + \phi X_{i,t-1} + \varepsilon_{i,t}, \tag{20}$$

where $GB_{i,k}$ takes value one if company i issues at least one green bond with the k-th use of proceeds, and zero otherwise; $Post_{i,k,t}$ identifies, for each company, the year of a green bond issuance with the k-th use of proceeds and the following two years.

The results of the estimation on the sample of brown companies are reported in Table 4, displaying the effects on the ESG score in the first two columns and on the E score in the last two columns. In addition, in the first and third columns, we adopt the broader use of proceeds classification, while in the other columns we disentangle, within the mitigation group, the effects of clean energy and those of clean transportation and construction. Estimates show that green bonds issued to finance projects related to the mitigation of climate change are far more effective in enhancing companies' ESG and E scores than green bonds used to finance adaptation initiatives. In particular, green bonds issued to finance clean transportation and clean construction are the ones with the largest impact on the environmental performance of companies. We will further investigate this result and provide a plausible interpretation in the Section dedicated to bond differences in green premia.

4.3 Parallel trend hypothesis

To support a causal interpretation of the effects of green bond issuance on companies' ESG performance, it is important to verify the parallel trends assumption for both groups of treated and non-treated issuers in the pre-treatment periods. In order to check for the absence of differential pre-trends in ESG dynamics prior to issuance, we estimate the following specification:

$$ESG_{i,t} = \mu_i + \lambda_t + \sum_{s=-6}^{5} \gamma_s GB_i \times D_{i,t,t_0+s} + \phi X_{i,t-1} + \varepsilon_{i,t}, \quad (21)$$

where D_{i,t,t_0+s} is a dummy equal to one if t is the s-th year after the issuance of the first green bond in year t_0. We set a window of 6 years before the issuance of the first green bond and 5 years after the issuance of the first green bond. The year before the issuance of the first green bond is considered the reference period ($\gamma_{-1} = 0$). The parallel trend hypothesis is confirmed if $\gamma_s = 0$ for $s < 0$.

The estimates of the γ parameters are reported in Fig. 3 for brown and green companies. The ESG score of companies issuing green bonds has the same trend of companies never issuing green bonds in the periods before the first issuance. Indeed, the estimates are never statistically significant, thus supporting the parallel trend assumption. In the period after the issuance, and thus out of the scope of the test, we have that the ESG score of brown

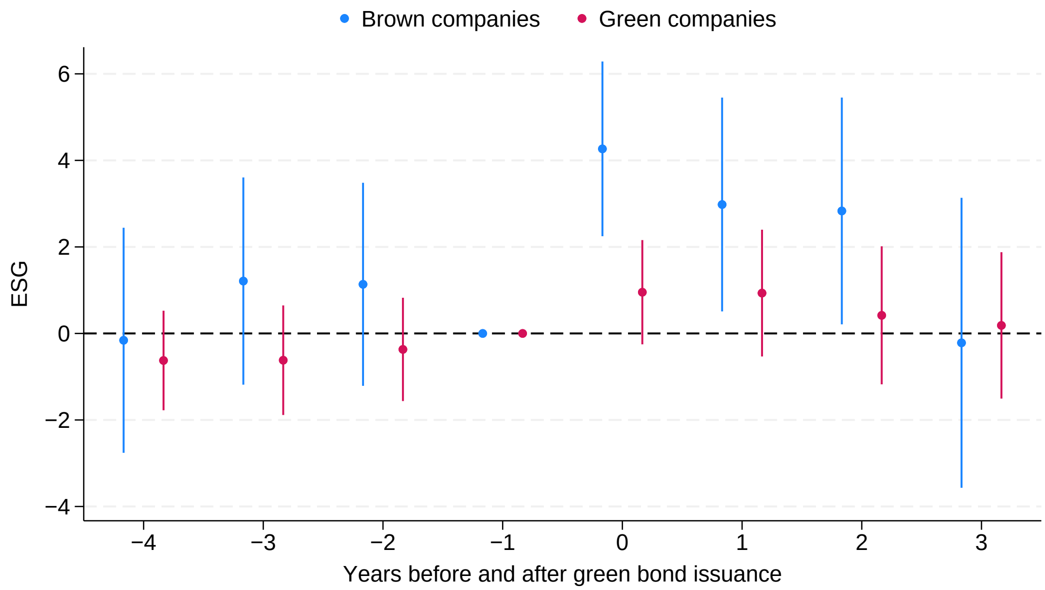

Figure 3: Parallel trend test for brown and green companies. Estimates of the impact of the first green bond placement on the ESG score before and after the issuance and 90 per cent confidence interval.

companies significantly improves in the first year of issuance and in the subsequent two years, relative to that of non-issuing companies. Instead, green companies do not benefit from the issuance of green bonds, as the dynamics of their ESG score is statistically similar to that of non-issuing companies in the periods after the first green bond issuance.

As an additional robustness exercise, to increase the comparability between treated and untreated companies prior to the issuance of green bonds, we employ a matching procedure similar to the one used in Flammer (2021). Using nearest neighbor propensity score matching, each green bond issuing firm in a given cohort of issuance (year t) is matched with a non-issuing peer exhibiting the same ESG score in the year prior to the issuance (year $t-1$), the same ESG variation between $t-2$ and $t-1$, and same balance sheet characteristics in $t-1$. Then, estimation is performed only on the matched firms. Results are reported in Table A.9. The magnitude and significance of the estimates are virtually unaffected even in this much smaller but more homogeneous sample, corroborating the hypothesis that parallel trends hold in our study.

4.4 Green premia

To assess whether green bonds that are more effective in improving companies' ESG performance also exhibit a larger negative greenium, we rely on the bond-level dataset. We restrict the sample to corporate bonds only, excluding bonds issued by governments, local authorities and multilateral development banks. We end up with a dataset of 325,000 bonds, 6,038 of which showing the green label. Using this dataset we estimate the following specification:

$$Yield_{b,c,n,t} = \alpha - \delta Green_b + \sigma Z_b + \xi_n + \psi_{c,t} + \nu_{b,c,n,t}, \tag{22}$$

where $Yield_{b,c,n,t}$ is the annualized yield to maturity at issuance on bond b, denominated in currency c, issued by an issuer resident in country n in month t. The variable $Green_b$ is a dummy that takes value one for green bonds, and zero otherwise. The vector Z_b contains bond and issuer characteristics: maturity (measured in years to maturity), amount issued in billion Euros, the frequency of coupon (one dummy for each frequency), the interest rate type (zero-coupon, fixed, variable), a dummy for collateralized bonds, a dummy for subordinate bonds, a dummy for callable bonds, the rating of the bond, the rating of the issuer,[12] issuer's sector-specific fixed effects. With ξ_n we denote nationality fixed effects, while $\psi_{c,t}$ indicates time varying fixed effects taking into account the currency of denomination. Equation (22) is estimated with OLS; robust standard errors are clustered at the issuer level.

The assumption underlying the econometric model is that conditioning on a rich set of bond, issuer and sector characteristics, in addition to macroeconomic and financial factors, that vary over time and across currency of denomination, the remaining difference between a green and a conventional bond defines the greenium δ.

We also analyze the heterogeneity in green premia based on the use of proceeds estimating the following specification:

$$Yield_{b,c,n,t} = \alpha - \sum_k \delta_k Green_{b,k} + \sigma Z_b + \xi_n + \psi_{c,t} + \nu_{b,c,n,t}, \tag{23}$$

in which $Green_{b,k}$ takes value one if bond b is green and has the k-th use of proceeds (adaptation, mitigation, etc).

[12]The rating of the bond (issuer) is first linearized between 1 (CC/Ca) and 20 (AAA/Aaa), so that, when the same bond (issuer) receives more than one assessment from Moody's, Fitch and Standard&Poors, they can be averaged. Then, the average is transformed into a set of dummy variables.

Table 5: Estimates of green premia. All corporate bonds and only matched bonds.

	(1)	(2)	(3)	(4)	(5)	(6)
		All bonds			Only matched bonds	
	Yield	Yield	Yield	Yield	Yield	Yield
Green	-0.107**			-0.0712*		
	(0.042)			(0.043)		
Green * Adaptation		-0.105	-0.105		-0.0834	-0.0841
		(0.085)	(0.085)		(0.086)	(0.086)
Green * Mitigation		-0.159***			-0.110**	
		(0.048)			(0.049)	
Green * (Ener. + Poll. Contr.)			-0.0839			-0.0302
			(0.073)			(0.073)
Green * (Tran. + Constr.)			-0.225***			-0.180***
			(0.055)			(0.059)
Green * General Purpose		-0.00687	-0.00622		0.00467	0.00540
		(0.084)	(0.084)		(0.082)	(0.082)
Observations	325,000	325,000	325,000	54,341	54,341	54,341
Adjusted R-squared	0.507	0.507	0.507	0.490	0.490	0.490
Bond controls	YES	YES	YES	YES	YES	YES
Nationality FE	YES	YES	YES	YES	YES	YES
Currency x Month FE	YES	YES	YES	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

The first column in Table 5 reports the results of the estimation of specification (22), showing an overall negative greenium of around 11 basis points. Specification (23) is estimated in the second and third columns of Table 5, for the broader (adaptation, mitigation, other) and finer (adaptation, energy and pollution prevention, clean transport and construction, other) classification of the use of proceeds. It turns out that green bonds issued for mitigation purposes, in particular to finance clean transportation and construction, have a larger (negative) greenium, relative to bonds issued for the adaptation to climate change.

We can now provide an explanation for the result found in Section 4.2 about a stronger effectiveness of some use of proceeds in improving the company ESG score. According to our theoretical model, a larger greenium should lead to a more sizeable investment in green technologies and a larger reputational improvement. Since the greenium on bonds issued for mitigation purposes (particularly, those for the financing of clean transportation and construction) is larger, the ESG improvement for the issuing companies was expected to be stronger. One possible interpretation why the mitigation greenium is larger than the adaptation one is that investors are more willing to finance "macro" green projects that can directly tackle CO2 emissions, than "micro" green projects focused on the single-company adaptation challenges. This in turn makes the greenium on such bonds larger and provides an incentive to companies in those businesses sectors to adopt cleaner technologies and place green bonds.

In the last three columns of Table 5 we estimate the same specifications but adopting a two-stage approach, in order to increase the comparability between green and brown bonds. First, we use the propensity score matching approach to match each green bond to a set of similar brown bonds based on common characteristics: maturity, amount issued, frequency of coupon, interest rate type (zero-coupon, fixed, variable), bond type (collateralized, subordinate or callable bonds), rating of the bond, rating of the issuer, sector of the issuer. Then, we perform the estimation of the model considering only green bonds and the matched brown counterparts. In particular, the matching procedure associates each green bond to 8 brown bonds. It is possible to observe in the fourth column that the greenium remains negative and around 7 basis points, even considering this more homogeneous comparison. The last two columns confirm that bonds issued for mitigation purposes, especially those for clean transportation and construction, are the ones with the largest greenium.

5 Concluding remarks and policy implications

Our analysis shows, both theoretically and empirically, that green bonds are a useful financial instrument in promoting the transition to a low carbon economy. In particular, they have a positive and statistically significant effect on the environmental performance of more polluting companies, while their impact on already environment friendly companies is not significant. According to our theoretical framework, the effectiveness of green bonds depends on the environmental preferences of investors and the existence of a so-called greenium, i.e. a lower return on green bonds relative to otherwise similar conventional bonds.

The empirical analysis also indicates that green bonds issued to finance projects under the broad umbrella of mitigation policies, especially in the field of clean transportation and construction, are the most effective in improving companies' environmental performance. Indeed, these bonds are the ones with the largest (negative) greenium.

Overall, these results suggest that investors with non-pecuniary environmental concerns should channel their funds not only to already compliant companies but also, and even more so, to companies transitioning from a "brown" state. Indeed, significantly shifting the portfolio composition away from high emitters and towards low emitters may not lead to a fully-fledged decarbonization or an effective transition risk mitigation (Hartzmark and Shue, 2023; Angelini, 2024; Bartocci et al., 2024).

Regarding the use of proceeds, our analysis suggests that widening investors' attention to other possible scopes, beyond the clean transportation and construction, could increase the effectiveness of other types of green bonds and sustain their role in the transition process of the productive system.

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Appendix

Additional figures and tables

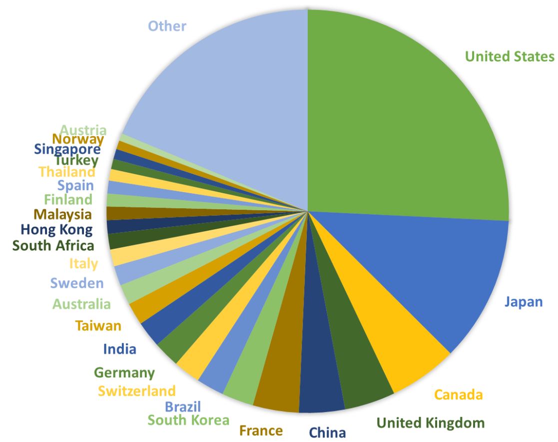

Figure A.1: Distribution of companies by nationality.

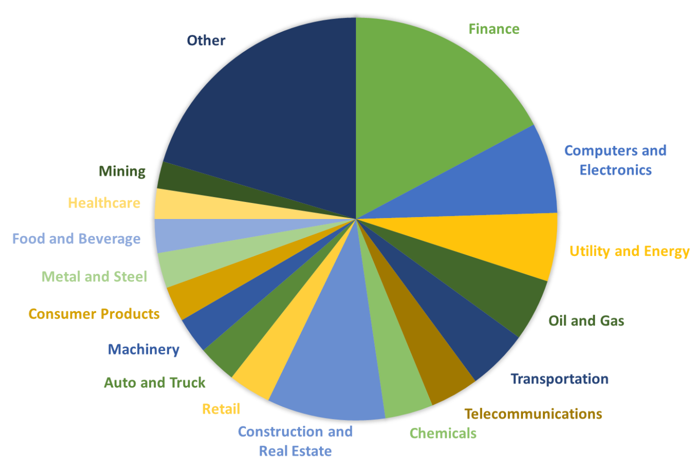

Figure A.2: Distribution of companies by productive sector.

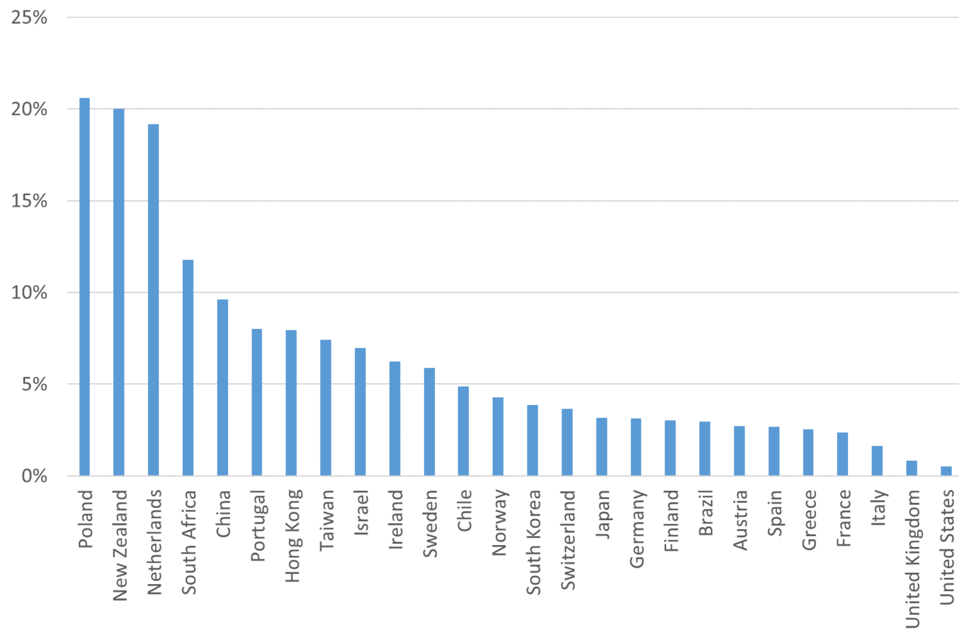

Figure A.3: Share of green bond issuance by companies' nationality.

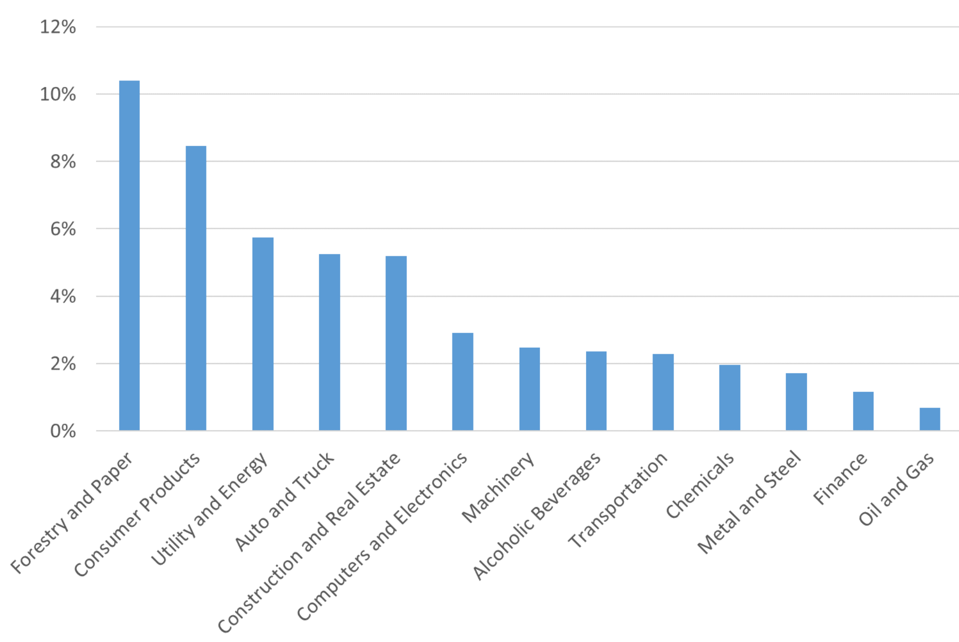

Figure A.4: Share of green bond issuance by companies' sector.

Table A.1: Summary statistics of the company-level regressors.

	(1) N	(2) mean	(3) sd	(4) min	(5) max
ESG score	20,240	59.13	17.83	6.350	95.72
E score	20,240	57.50	24.62	1.741	95.77
S score	20,240	60.09	21.55	0.670	98.78
G score	20,240	59.58	20.64	0.470	99.43
Size	20,240	9.553	1.526	6.338	13.86
RoA	20,240	4.216	3.913	-4.314	19.74
Leverage ratio	20,240	29.00	17.07	0.925	87.64
Cur. A-L ratio	20,240	146.3	118.5	6.862	823.0
Liquidity ratio	20,240	33.41	20.70	1.825	94.32
Tobin's Q	20,240	88.18	97.18	2.258	556.4
GB * Post	20,240	0.0442	0.206	0	1

Table A.2: Effects of green bond issuance on the ESG by tertile of E score in 2012.

	(1) 1st tertile ESG	(2) 2nd tertile ESG	(3) 3rd tertile ESG
GB * Post	4.457***	1.818**	0.252
	(1.519)	(0.806)	(0.557)
Observations	6,754	6,743	6,743
Adjusted R-squared	0.777	0.765	0.756
Company Controls	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A.3: Effects of green bond issuance on the ESG score. Brown (green) companies are those with an E score below (above) the sector-specific median in 2012.

	(1)	(2)
	Brown companies	Green companies
	ESG	ESG
GB * Post	2.818**	0.150
	(1.096)	(0.520)
Observations	10,142	10,098
Adjusted R-squared	0.799	0.779
Firm Controls	YES	YES
Firm FE	YES	YES
Year FE	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A.4: Effects of the first green bond issuance on the ESG.

	(1)	(2)	(3)
	All	Brown companies	Green companies
	ESG	ESG	ESG
GB * Post	-0.0675	2.848***	0.437
	(0.516)	(0.994)	(0.480)
Observations	20,240	10,120	10,120
Adjusted R-squared	0.834	0.788	0.775
Company Controls	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A.5: Effects of high and low levels of green bond issuance on the ESG. High and low green bond issuance is defined considering the median of the distribution of green issuance and overall companies' debt ratio.

	(1) All ESG	(2) Brown companies ESG	(3) Green companies ESG
GB * Post * low GB issuance	-0.723	2.380**	0.492
	(0.570)	(1.035)	(0.560)
GB * Post * high GB issuance	-0.754	2.883**	-0.130
	(0.728)	(1.431)	(0.681)
Observations	20,240	10,120	10,120
Adjusted R-squared	0.834	0.788	0.775
Company Controls	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A.6: Effects of green bond issuance on GHG emissions (expressed in CO2 equivalent terms and relative to companies' total assets). Brown (green) companies are those with an E score below (above) the median in 2012.

	(1) All GHG emissions	(2) Brown companies GHG emissions	(3) Green companies GHG emissions
GB * Post	-61.54	-85.56**	-69.85
	(43.572)	(38.381)	(57.070)
Observations	16,313	6,677	9,636
Adjusted R-squared	0.846	0.875	0.832
Company Controls	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A.7: Effects of green bond issuance on the ESG and its sub-components. Specification with the interaction between treatment effect and brown companies dummy.

	(1)	(2)	(3)	(4)
VARIABLES	ESG	E score	S score	G score
GB * Post	-3.278***	-6.385***	-2.132***	-2.082**
	(0.561)	(0.715)	(0.734)	(0.972)
GB * Post * Brown company	9.116***	16.36***	6.637***	4.531***
	(1.180)	(1.950)	(1.387)	(1.692)
Observations	20,240	20,240	20,240	20,240
Adjusted R-squared	0.835	0.806	0.816	0.660
Company Controls	YES	YES	YES	YES
Company FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A.8: Effects of green bond issuance on the ESG score. Brown (green) companies are those with an E score below (above) the median in 2012. Sun and Abraham (2021) estimator.

	(1) All ESG	(2) Brown companies ESG	(3) Green companies ESG
GB * Post * cohort 2013-16	1.803**	0.884	1.265
	(0.871)	(1.379)	(1.020)
GB * Post * cohort 2017-19	-0.245	2.755**	0.244
	(0.771)	(1.269)	(0.787)
GB * Post * cohort 2020-22	-0.489	3.323**	0.306
	(0.856)	(1.608)	(0.773)
Observations	20,240	10,120	10,120
Adjusted R-squared	0.834	0.788	0.775
Company Controls	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A.9: Effects of the first green bond issuance on the ESG after matching each green bond issuing firm with a non-issuing peer with similar pre-issuance characteristics.

	(1) All ESG	(2) Brown companies ESG	(3) Green companies ESG
GB * Post	0.692	2.690***	0.459
	(0.493)	(0.997)	(0.466)
Observations	5,995	2,112	3,883
Adjusted R-squared	0.817	0.784	0.777
Company Controls	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES

Notes: Cluster-robust standard errors at issuer level in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1