European Commission

JRC TECHNICAL REPORT

# Green bonds as a tool against climate change?


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2020

*JRC Working Papers in Economics and Finance, 2020/10*


Joint Research Centre

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https://ec.europa.eu/jrc

JRC121894

PDF ISBN 978-92-76-22105-0 ISSN 2467-2203 doi:10.2760/24092

Luxembourg: Publications Office of the European Union, 2020


How to cite this report: Fatica, S. and Panzica, R., *Green bond as a tool against climate change?* Luxembourg: Publications Office of the European Union, 2020, ISBN 978-92-76-22105-0, doi:10.2760/24092, JRC121894

**Abstract**

While green bonds are becoming increasingly popular in the corporate finance practice, little is known about their implications and effectiveness in terms of issuers' environmental engagement. Using matched bond-issuer data, we test whether green bond issues are associated to a reduction in total and direct (scope 1) emissions of non-financial companies. We find that, compared to conventional bond issuers with similar financial characteristics and environmental ratings, green issuers display a decrease in the carbon intensity of their assets after borrowing on the green segment. The decrease in emissions is more pronounced, significant and long-lasting when we exclude green bonds with refinancing purposes, which is consistent with an increase in the volume of climate friendly activities due to new projects. We also find a larger reduction in emissions in case of green bonds that have external review, as well as those issued after the Paris Agreement.

Keywords: climate change; green bonds; impact investing; corporate sustainability; environment

JEL classification: G12, Q50, Q51

## Acknowledgement

We thank participants at the 2nd JRC Summer School on Sustainable Finance for valuable comments and feedback. Responsibility for remaining errors lies with the authors. The views expressed herein are those of the authors and do not necessarily reflect the views of the European Commission.

# 1 Introduction

Green bonds are debt instruments that differ from conventional fixed income securities only in that the issuer pledges to use the proceeds to finance projects that are meant to have positive environmental or climate effects. Since its debut in 2007, the green bond market has been growing steadfastly. According to the Climate Bond Initiative (2020), new issues have reached 230 billion euros (257 bn USD) globally in 2019, up from 142 billion in 2018 and 28 billion euros in 2014. While the overall size of the green segment is still tiny in comparison to the funds raised with conventional bonds, there is massive potential for further market growth as environmental issues are raising high on the policy agenda. For instance, Europe alone is estimated to need about 180 billion euros of additional investment a year to achieve the targets set for 2030 in the context of the 2015 Paris Agreement on climate change, including a 40% cut in greenhouse gas emissions. The growing interest of public policy towards green bonds has indeed already materialised into a number of initiatives to encourage market participants, on both the demand and the supply side. For instance, direct subsidies or grant schemes, such as the Sustainable Bond Grant in Singapore, are in place to support eligible issuers in covering the additional costs associated with external review for the green securities. Likewise, several jurisdictions worldwide, including China and Honk Kong, have issued regulations in order to enhance transparency and disclosure on the green bond market, which is instrumental in aligning investors' incentives. A major development at the international level is the design of uniform green bond standards by the European Commission, in the context of a broader initiative to promote sustainable finance. Like for existing market-based voluntary standards, the proposed EU standards adopt a project-based approach grounded on the bond proceeds being used for environmentally beneficial projects (EU Technical Expert Group on Sustainable Finance, 2019). By laying down detailed criteria, such as mandatory reporting on the allocation of proceeds and on the environmental impact, as well as verification, the standard ultimately aims to improve the effectiveness, comparability and credibility of the European green bond market.

Against this backdrop, little is known about the implications and effectiveness of green bonds. The emerging literature on the topic focuses primarily on pricing in the market for municipal (and sovereign) securities (Baker et al., 2018; Karpf and Mandel, 2018). With few exceptions, empirical findings point to the existence of a negative, albeit often small, yield differential in favour of green securities compared to similar regular bonds (Gianfrate and Peri, 2019), on primary and secondary markets alike. High demand from investor motivated by non-pecuniary motives, specifically pro-environmental preferences, has been identified has a determining factor for the yield difference to occur (Zerbib, 2019). Such preferences might accordingly translate into market outcomes and affect equilibrium prices, beyond expectations regarding return and risk. Fatica, Panzica and Rancan (2019) find that, among corporate issuers, the negative premium materializes only in favour of non-financial green issuers. They attribute the lack of a premium for financial institutions to the fact that the greenness of the bond, and thus the nature of the underlying project it finances, might be particularly difficult to signal for these issuers, by the very same nature of their business. For financial institutions, resorting to the green debt market often involves engaging in green lending, instead of investing directly in green assets. A second strand of the literature focuses on the effects of green bond issues on company outcomes. Tang and Zhang (2020) and Flammer (2019) find that corporate green bond issuances are followed by positive stock market reactions, and help attract an investor clientele that values the long term and the environment. Importantly, these effects would not be exclusively driven by the potentially lower cost of capital associated to green debt.

In the light of the benefit brought about by green securities, a major concern among practitioners and investors relates to the so-called 'greenwashing', whereby companies purport to engage in green investment in order to attract impact-oriented investors while in practice engaging in investment that has little environmental value (Grene, 2015). Issuers would be lured into window-dressing to reap the benefit of lower financing costs, which would need to be balanced anyways against the additional costs associated to the green label, as well as of the positive stock market effects for shareholders. The concern for greenwashing is also motivated by the absence of legal enforcement mechanisms to ensure compliance with the use of proceeds laid out in the green bond prospectus. Instead, as discussed in section 2, the green bond market relies on private governance regimes, such as voluntary certification standards put forward by several agencies and associations to ensure issuers of green bonds are using the financing proceeds for environmentally friendly purposes. If greenwashing prevails, green bonds are unlikely to have any real impacts that are beneficial to the environment. By contrast, if green bonds are actually issued to finance environmentally friendly projects, we should ultimately observe an improvement in the environmental performance of the companies raising funds on the green segment. A second important issue concerns additionality in green investment. In so far as they are issued to refinance existing green projects that were previously financed with conventional bonds, green bonds do not generate additional capital for environmental protection and climate action. As such, they would not necessarily be associated to increased volumes of environmentally friendly activities (Bongaerts and Schoenmaker, 2020).

In this paper, we shed light on these issues by investigating the implications of green bond issues for firms' environmental outcomes. The analysis of the impacts of green bonds in terms of issuers' environmental performance and engagement is still practically unexplored, due to important data limitations. To uncover any real effects associated to green bond issuances, one would ideally need detailed information on the investment projects for which the bond proceeds are earmarked, as well as their ultimate environmental impacts. However, such detailed information is seldom disclosed on a regular basis. In particular, impact reporting is not mandatory in any guidelines, although considered as a best practice, as it strengthens market accountability (International Capital Market Association, 2018). Therefore, we must consider indirect evidence, taking the issuance of a green bond as the relevant event that potentially affects companies' environmental outcomes. Specifically, we test whether green bond issues are associated to a reduction in firm-level carbon emission intensities. We first motivate our choice to focus on emissions instead of a wider range of environmental indicators by documenting that the majority of green bonds are issued to finance investment projects geared towards climate change mitigation. Next, in our econometrics exercise, we find evidence that, compared to conventional bond issuers with similar financial characteristics and environmental ratings, green issuers display a decrease in carbon emissions (per unit of assets) after borrowing on the green segment. In that, our results are consistent with the evidence presented in Flammer (2019). However, we extend and enrich her analysis in a number of ways. First, we consider both total and direct (or scope 1) emissions, reducing concerns of results being driven by measurement error affecting broader emission aggregates. Second, we purge our analysis from the potential confounding factors of corporate financial policies by considering separately green bonds that are not issued for refinancing purposes. While the evidence for the full sample is mixed, remarkably we find a more pronounced and significant decrease in emissions when we exclude green bonds issued for refinancing existing projects. This is consistent with an increase in the volume of climate friendly activities due to new projects. While we cannot claim causality, also because green bonds account for a limited share of companies' total borrowing and, thus, investment capacity, our findings suggest that green bonds act as a credible signal of firms' climate-related engagement. As such, our evidence is not consistent with the 'greenwashing' argument. Moreover, the stronger reduction in emissions that we find when we exclude green bonds issued for refinancing purposes is suggestive of 'additionality' in investment, in the sense of green securities financing new green investment. As further corroborating evidence to the signalling argument, we also find a larger reduction in emissions for green bonds that have external review, as well as for those issued after the Paris Agreement. Cost considerations – in the case of external review – and the need to accelerate the low-carbon transition given the Paris pledge might be the determining factors behind such stronger commitment towards the environment.

The rest of the paper proceeds as follows. Section 2 documents how green bond proceeds are used. Section 3 describes the data and the empirical model, while the results are presented in Section 4. Finally, section 5 concludes.

## 2 Green bonds and reporting on the allocation of proceeds

Disclosure of relevant information to the market has been identified as one of the reasons for the increasing popularity of green bonds among investors (Financial Times, 2019). Specifically, transparency on the allocation of proceeds is a characteristic feature of green securities, since they are tied to the 'green nature' of the investment projects rather than explicitly to their ultimate environmental impact. Accordingly, the leading market guidelines require disclosure on the management of proceeds, at least annually after issuance (International Capital Market Association, 2018). As a common, less stringent market practice, information on the use of proceeds is provided at the issuance stage in the bond prospectus, alongside the bond's financial features, whose disclosure essential in orienting investors' choices, and, therefore, mandatory. Further detailed requirements, for instance on the accounting methodology for proceeds, need to be fulfilled for the bond to qualify for external certification (Climate Bonds Initiative, 2018). As expected, market development has been both accompanied and favoured by an increasing propensity to report on the part issuers, particularly in the most recent years.

Using the qualitative information disclosed by the issuers and collected by financial market data providers, we are able to compare reporting practices on the use of proceeds for a large pool of green bonds and issuers. Specifically, we use a sample of 1,105 green bonds issued worldwide by the corporate sector over the period 2007-2019. Our data source is Dealogic DCM, one of the main providers of bond primary market information (see Section 3.1).[1] We retrieve the information on the use of proceeds through the 'tranche note', i.e. the qualitative information that accompanies each bond tranche.[2] Specifically, we hand-collect information on the type of projects that the green bonds are financing, and map it to broad categories linked to different environmental objectives, notably climate change mitigation and adaptation, circular economy and waste prevention and recycling, pollution prevention and control. We are especially interested in climate change mitigation, which is the focus of our analysis.[3]

Figure 1 plots the distribution of green bond financed projects across environmental objectives. Minimal project-level information is available for around 90% of bonds, in terms of both the number contracts and the amounts raised. Roughly, half of all bonds – or 56% of those disclosing information on the use of proceeds – are issued to finance projects intended to mitigate climate change. These are mostly projects relating to renewable energy and energy-efficient technologies. In addition to the allocation to the broadly defined projects, some issuers disclose more detailed information, for instance on the specific technology types (e.g. wind and solar energy generation), or on how proceeds are distributed across the different countries or regions where the company has operations. A non-negligible share of reporting green bonds (29% in terms of contracts, almost 37% in terms of amount) are issued to finance multiple projects that are associated to different environmental objectives. The sheer majority of these 'mixed' bonds – adding up to one-fourth of the total number of contracts - are destined to finance activities for climate change mitigation. In terms of amount, proceeds from 'mixed' bonds account for 34% of total funds, although we cannot quantify the funds earmarked for climate-related objectives since we do not have information on the exact shares allocated to the different investment projects. Overall, 74% of all bonds contracts are issued for projects with the purpose of climate change mitigation, partly or fully. This amounts to up to 80% of raised funds.

Importantly, the tranche note provides additional relevant information that allows us to place green bond issuances in the broader context of corporate financial policy. Specifically, based on their stated financial features, we identify green bonds issued for refinancing purposes and non-refinancing green bonds. Refinancing green bonds are indeed issued to refinance existing green projects that were previously presumably financed with regular bonds, rather than new projects. Since we are interested in the real impacts of green securities, this distinction is not trivial. We

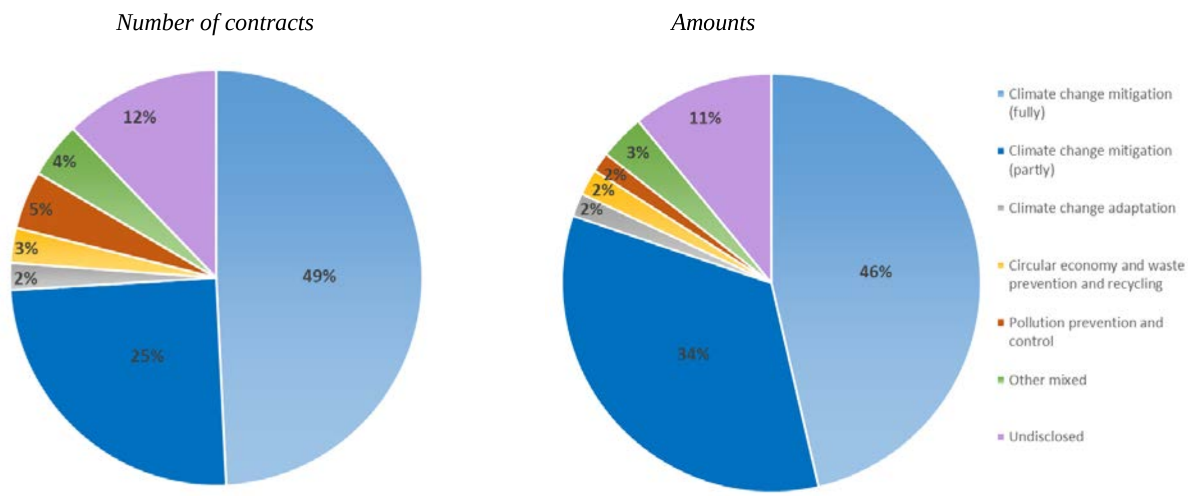
[1] Information on green bonds is available also from other data providers, among which Bloomberg is one of the most commonly used. Bloomberg data on green bonds comprise a comparable number of securities. However, Dealogic DCM provides a more comprehensive reporting on the main bond characteristics.

[2] Specifically, we analyze the fields 'bonds use of proceeds' and 'category'. The latter contains information on the detailed investment projects to which the funds are allocated. We additionally classify as 'undisclosed' the bonds for which there is no description available in the 'category' field.

[3] Categories making up the broad objective of climate change mitigation include investment in renewable or climate-neutral energy; energy efficiency; clean or climate-neutral mobility; use of renewable materials; increasing carbon capture and storage use; de-carbonization of energy systems; clean and efficient renewable or carbon-neutral fuels.

document that around 16% of the contracts in place are issued for refinancing purposes, roughly the same percentage when the amount raised are considered.

**Figure 1 Breakdown of green bonds by projects' environmental objectives**




# 3 Data and empirical model

This section describes the data and the econometric approach that we use to evaluate the environmental performance of green bond issuers measured in terms of carbon intensity.

## 3.1 Data

To build our dataset, we start from data on green and conventional bond issues from Dealogic DCM. Dealogic, one of the main data providers on bond primary markets worldwide, gives detailed information on bond characteristics at the tranche level, alongside some minimal information on the bond issuer, i.e. name, country and industry. The database is widely used for analyses on the international bond market (see, e.g., Hale and Spiegel, 2012). We select all bond tranches issued worldwide by non-financial corporations up to 2019.[4] Next, we match bond data with company financial and environmental data, retrieved from Datastream Asset4. In particular, we obtain financial data on profits, market capitalization, total assets, debt and revenue. As for environmental data, we collect companies' ESG ratings, a composite measure of sustainability performance along the three dimensions of environmental, social and governance actions. Naturally, in our analysis we focus on the environmental component of the index, which is calculated by the data provider based

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[4] Specifically, we exclude from the analysis sectors with SIC 2-digit codes of 60 and above. While very active on the green bond market, banks, insurers and other financial institutions are directly responsible for a very small fraction of greenhouse gas emissions. In fact, banks' contribution to the low-carbon transition seems to materialize mostly through reduced lending to more polluting sectors (Fatica, Panzica and Rancan, 2019). However, these activities are currently not reflected in the different scopes for emission reporting.

on information on resource use, emissions and green innovation, gathered from different sources. As the outcome of interest, we also collect data on company carbon emissions. Specifically, we use two measures of emissions: i) total Greenhouse Gas (GHG), if available, else total carbon dioxide (CO2) emissions – both comprising direct and indirect emissions; ii) direct (or Scope 1) emissions.[5] In all instances, emission are expressed in terms of CO2 equivalent. Because they are based only on company reporting, Scope 1 emissions are available for a smaller number of firms compared to total emissions. For the latter, we complement reported values with estimates, whenever the former are not available.[6] As our outcome variable, we use the emission intensity of assets, calculated as the ratio of emissions over the book value of total assets. The variable is expressed in tons of CO2 equivalent per thousand/Euro. Accounting for missing values of any of the relevant variables, we end up with 92 corporate green bond issuers and a pool of 919 conventional bond issuers.

## 3.2 The model

Let $i$ index companies, and t years. Following Flammer (2019), we assume that our outcome of interest in terms of emission intensity ($y_{it}$) can be modelled as:

$$y_{it} = \alpha_i + \alpha_{jt} + \alpha_{ct} + \beta \times Green\ Issuer_{it} + \gamma \times \boldsymbol{x}_{it} + \varepsilon_{it} \qquad (1)$$

where $\boldsymbol{x}_{it}$ is a vector of control variables at the company level; $\alpha_i$ are company fixed effects, $\alpha_{jt}$ and $\alpha_{ct}$ are industry-year and country-year fixed effects, respectively, that are allowed to vary over time, while $\varepsilon_{it}$ is the error term. Company fixed effects control for unobservable factors affecting emissions that are firm-specific and time-invariant. The other fixed effects control for country-specific and industry-specific shocks, that are allowed to vary over time. In model (1), the *level* of emissions is assumed to be different for green bond issuers after the issuance. This effect is captured by the coefficient $\beta$, where $Green\ Issuer_{it}$ is a dummy that equals one if a has issued a green bond by year t and zero otherwise.

We estimate model (1) in first differences since we are interested on the effect of green bonds on the *growth* of emission intensity. Moreover, the first-difference approach accounts for the high persistence in the variables. Thus, we let $\Delta$ be a first-

[5] Carbon emissions from a company's operations and economic activity are typically grouped into three different categories. Scope 1 (or direct) emissions from production, as those emitted from sources that are owned or controlled by the reporting entity. Scope 2 (or indirect) emissions from consumption of purchased electricity, heat, or steam, that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity. Finally, scope 3 emissions are those generated from the production of purchased materials, product use, waste disposal, outsourced activities, etc. Reporting propensity and practices vary significantly across emission categories.
[6] We use the following variables in Datastream Asset4: ENERDP024 and ENERDP023. If firms do not report total GHG/CO2 information we replace the missing data with the *estimated* total GHG/CO2 (variable ENERDP123) if available. Datastream Asset4 does not provide *estimates* of scope 1 and scope 2 emissions.

difference operator so that, for example, $\Delta y_{it} = y_{it} - y_{it-1}$. Our estimating equation is, then:

$$\Delta y_{it} = \alpha_j + \alpha_c + \beta \times Green\ Bond_{it} + \gamma \times \Delta \boldsymbol{x}_{it} + \Delta \varepsilon_{it}. \qquad (2)$$

In equation (2), $Green\ Bond_{it}$ is a dummy variable that takes the value of one in the year in which a green bond is issued, and zero otherwise. $\alpha_j$ and $\alpha_c$ are industry and country fixed effects, which control for time-invariant differences across industries and countries. Such specification is consistent with time-varying fixed effects that evolve linearly with time in the specification in levels in model (1). Issuer fixed effects drop out due to differencing. The coefficient β measures the effect of the green bond issue on the growth of emission intensity controlling for changes in other firm characteristics that may act as confounding factors. Our estimates will thus be driven by the way emissions change for companies that issue a green bond relative to companies that issue a conventional bond in the same period. To ensure proper identification of the effect of interest, we select conventional issuers that are economically and financially comparable to the green borrowers using a matching procedure (see next section).

Unless otherwise specified, we include a vector of control variables $\Delta \boldsymbol{x}_{it}$ that can affect our measure of environmental performance. In particular, we use revenues (in logarithms) as a measure of the value of sales, which naturally correlate with emissions. We also include asset turnover, defined as the ratio between revenue and total assets, as a measure of the efficiency in the use of assets in generating sales. Finally, we control for different profitability levels using the return on assets (ROA), the ratio of operating income before depreciation to the book value of total assets. To mitigate the impact of outliers, all variables are winsorized at the 1$^{st}$ and 99$^{th}$ percentiles of their empirical distributions. We provide also unconditional estimates of the effects of green bond issue by dropping the vector of controls from model (2). In all cases, standard errors are robust to heteroscedasticity, and clustered at the industry level to allow for correlation of unknown form in residuals within industries across time.

### 3.3 Matching

A major empirical challenge in evaluating the environmental performance of green bond issuers is the presence of confounding factors that potentially affect both the choice to borrow on the green market segment and emissions. To deal with the endogeneity of green financing choices, we use comparable issuers of conventional bonds as a counterfactual. In other words, we select conventional bond issuers that are as similar as possible to green bond issuers in their economic and financial characteristics, except for the fact that they have not borrowed on the green bond market. Specifically, we adopt a matching approach that proceeds in two steps. First, for each green bond issuer, we select all companies that have issued at least one conventional bond in the same industry, country and time period. We exclude from the potential control group conventional issuer that have borrowed also on the green market. Conditioning the inclusion in the potential control group on country, industry and time ensures that green and conventional bond issuers operate in the same business environment, and thus are faced with the same economic and regulatory conditions. In the second step, within the restricted pool of conventional issuers, we pick those that are most similar to the green bond issuers based on economic and financial characteristics in the year before the green bond has been issued. Specifically, we match green to conventional bond issuers based on their environmental rating - the E score component of the ESG metric - and a number of financial characteristics. We use size, defined as the natural logarithm of the book value of total assets, leverage (debt-to-asset ratio), and Tobin Q, calculated as the ratio of the market value of total assets to the book value of total assets, as a measure of the valuation of the company. Using the environmental rating as a matching characteristic ensures that treated and control firms have a similar broad environmental engagement prior to the green bond issuance. This rules out that green bond issuers structurally adopt environment-friendlier policies than conventional issuers. The use of Tobin Q as a measure for firm value addresses concerns that green issuers have better growth and investment opportunities. Finally, accounting for size and indebtedness (leverage) further addresses demand-side issues on the debt market, notably the possibility that green borrowers may have better or higher propensity to access to capital markets than conventional bond issuers. All in all, the matching procedure enables us to come up with a plausible counterfactual before the choice of the type of bond to be issued – green or conventional – has been made.

Formally, we perform the matching using a coarsened exact matching methodology (Iacus, King and Porro, 2012). Compared to other standard matching methods, such as the propensity score, coarsened exact matching has the important advantage of reducing the imbalance in the empirical distribution of the confounders between the treated and control group, thereby minimizing concerns of biased statistical inferences and model dependence (King and Nielsen, 2019).[7] By pruning observations so that the remaining data are better balanced between the two groups of bond issuers, this approach indeed ensures that the multivariate empirical distributions of the covariates in the two groups are more similar. The risk of model dependence is reduced, since green issuers that have no reasonable matches among the set of available conventional issuers are discarded. As a measure of the overall ex ante imbalance we use the L1 statistic, introduced in Iacus, King and Porro (2012).[8]

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[7] In this approach, each variable is recoded so that substantively indistinguishable values are grouped and assigned the same numerical value. Then, exact matching is applied to the coarsened data to determine the matches and to prune unmatched units. Finally, the coarsened data are discarded and the original (uncoarsened) values of the matched data are retained.

[8] The L1 metric is based on the difference between the multidimensional histogram of all pretreatment covariates in the treated group and the same in the control group. Perfect global balance (up to coarsening) is indicated by L1= 0, and larger values indicate larger imbalance between the groups, with a maximum of L1= 1, which indicates complete separation.

**Table 1. Covariate imbalance in matched and unmatched data**

The table reports covariate imbalances before and after coarsened exact matching (CEM). The L1 distance measures the covariate imbalance between green and conventional bond issuers based on financial characteristics and environmental ratings before a green bond issuance. L1 is bounded between zero and one and a lower value indicates a lower imbalance. Differences in the mean, minimum, 25% quantile (p25), median (p50), 75% quantile (p75), and maximum also reported.

| | $L_j1$ | Δmean | Δmin | Δp25 | Δp50 | Δp75 | Δmax |
|---|---|---|---|---|---|---|---|
| Panel A: Coarsened exact matched data | | | | | | | |
| *Multivariate L1 distance: 0.79* | | | | | | | |
| E score | 0.077 | 0.672 | -5.000 | 0.470 | 0.330 | -0.540 | -0.710 |
| Size | 0.083 | 0.079 | 0.024 | 0.107 | 0.117 | -0.022 | 0.104 |
| Leverage | 0.121 | 0.001 | -0.025 | 0.013 | 0.006 | -0.006 | -0.014 |
| Tobin Q | 0.097 | 0.002 | 0.004 | 0.000 | 0.000 | 0.007 | 0.014 |
| Panel B: Unmatched data | | | | | | | |
| *Multivariate L1 distance: 0.99* | | | | | | | |
| E score | 0.329 | 15.837 | 4.110 | 23.840 | 19.430 | 11.240 | 1.750 |
| Size | 0.300 | 0.846 | 2.100 | 0.864 | 0.807 | 0.620 | 0.000 |
| Leverage | 0.172 | -0.002 | 0.089 | -0.013 | 0.012 | 0.002 | -0.292 |
| Tobin Q | 0.195 | -0.010 | 0.000 | -0.003 | -0.006 | -0.007 | -0.286 |

In **Table 1** we report the L1 statistics summarizing the difference between the multivariate empirical distribution of the covariates observed before the bond issue for the green bond issuers and the matched control group of conventional bond issuers, before and after the coarsened exact matching. Remarkably, the fact that unmatched data are extremely imbalanced points to a significant risk of biased inference in the full sample. Matching successfully reduces the multivariate covariate imbalance measure by roughly 20%. The reduction is apparent also for the imbalance in each variable separately, reported in the first column ($L_j1$). Differences in means between the two groups of issuers are also reduced, and so are the sheer majority of the differences in the empirical quantiles of the distributions of the two groups.

## 4 Results

In this section we discuss the results from estimating model (2) on our sample of green bond issuers using the change in total and direct CO2 emissions, normalized by the book value of total assets, as a measure of environmental performance. The baseline estimates are then followed by a number of extensions. In all cases, we use alternatively the full matched sample and a smaller sample obtained by excluding firms that have issued green bonds with refinancing purposes. In this way, by focusing on new projects, we obtain an indirect test for additionality in green investment.

## 4.1 Baseline results

**Table 2** reports the baseline estimates. In columns (1) and (2) we use the change in total CO2 intensity as our dependent variable, while columns (3) and (4) employ the direct (or scope 1) emission intensity. Due to more limited reporting, when we consider direct emissions we end up with a smaller sample, the number of data points being roughly halved compared to the sample for total emissions. Panel A of **Table 2** shows the results for the full sample of matched issuers. For both total and direct emission intensity, we estimate a negative and statistically significant coefficient for the green bond dummy. This implies that the issue of a green bond is associated with a reduction in CO2 emissions. The unconditional results in columns (1) and (3) remain virtually unchanged when we include firm-level controls (columns (2) and (4)). In panel B of **Table 2** we focus on the sub-sample that excludes green bonds issues devoted to refinancing existing projects. In line with our expectations, we find that the coefficients of the green bond dummy are larger (in absolute value) than those in the full matched sample, indicating, ceteris paribus, a stronger effect on the volume of climate-friendly activities. They are also statistically significant at the highest level across all specifications. In evaluating and comparing the economic magnitude of the estimated effects, let us focus on scope 1 emissions. The coefficient of interest, around -0.025, translates into a reduction of 4% in direct emission intensity, since the relevant average carbon intensity in the sample is 0.61 tons/thousands of Euros of assets. When we consider the sub-sample that excludes refinancing green bonds, the magnitude of the reduction in direct emission intensity doubles with respect to the corresponding estimate in the full matched sample, reaching a decrease of roughly 9% at the sample average for direct emissions.

Naturally, in our framework, the reduction of emissions cannot be directly and solely attributed to the projects financed by the green bonds, given also the small amount of funds raised in the green segment compared to overall companies' financing needs (Flammer, 2019). Hence, while it would not be appropriate to claim causality, our results are nonetheless consistent with green bond issues signalling a credible commitment towards climate-friendly company behaviour. Stated from a different perspective, the fact that we find a significant improvement in the climate-related performance of companies after a green bond issue runs against the 'greenwashing' argument. In the case of greenwashing, we would not find a steeper de-carbonization pattern of green borrowers compared to conventional bond issuers. Moreover, the stronger results obtained when we exclude green bonds issued for refinancing purposes provide further corroborating evidence to the signalling argument, and point to significant additionality in new green projects.

**Table 2. Baseline results**

The table reports the baseline results of regressing carbon intensity on a green bond issuance indicator, as in model (2). Robust standard errors, clustered at issuer level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

*Panel A: Including green bonds issued for refinancing purposes*

| | Total emissions | | Direct emissions | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| green_bond | -0.0821** | -0.0832** | -0.0234* | -0.0252** |
| | (0.037) | (0.035) | (0.013) | (0.012) |
| Observations | 1,506 | 1,506 | 827 | 827 |
| R-squared | 0.0186 | 0.0361 | 0.0295 | 0.0380 |
| Country FE | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Firm-level controls | No | Yes | No | Yes |

*Panel B: Excluding green bonds issued for refinancing purposes*

| | Total emissions | | Direct emissions | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| green_bond | -0.1277*** | -0.1250*** | -0.0598*** | -0.0549*** |
| | (0.037) | (0.036) | (0.003) | (0.007) |
| Observations | 1,314 | 1,314 | 740 | 740 |
| R-squared | 0.0192 | 0.0369 | 0.0393 | 0.0484 |
| Country FE | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Firm-level controls | No | Yes | No | Yes |

### 4.1.1 Robustness checks

We perform several checks to assess the robustness of our baseline findings. **Table 3** shows the results for the two samples comprising all green bonds (Panel A) and excluding green securities issued for refinancing purposes (Panel B).[9] First, we use a more stringent structure of the fixed effects by interacting the country and industry dummies with year dummies. This specification allows us to control for a more complex form of aggregate shocks that may affect emissions. In particular, the interactive country-time and industry-time fixed effects control for country-specific and industry-specific shocks, respectively, that are allowed to vary over time. The results are reported in columns (1) and (4) for total and direct emissions, respectively. The coefficient estimates for the full sample are larger (in absolute value) than those in the baseline specification, and still highly significant. Likewise, excluding green bonds issued for refinancing purposes leads to a more marked effect

[9] We report only the results without company-level controls. The estimates from the full model, available upon request, are quantitatively and qualitatively similar.

in the case of total emissions, whereas for direct emission the results are virtually unchanged compared to the baseline (Panel B).

**Table 3. Robustness checks**

The table reports the results of regressing carbon intensity on a green bond issuance indicator, as in model (2). Columns (1) and (3) use emissions over total assets as the dependent variable and interactive country-time and industry-time fixed effects. In columns (2) and (5) the dependent variable is the ratio between emissions and revenues. In columns (3) and (6) the dependent variable is the level of carbon emissions (in logs), and size is used as a firm-level control. Robust standard errors, clustered at issuer level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

*Panel A: Including green bonds issued for refinancing purposes*

| | Total emissions | | | Direct emissions | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| green_bond | -0.1318** | -0.1684* | -0.0999*** | -0.0445*** | -0.0084 | -0.2071** |
| | (0.055) | (0.083) | (0.033) | (0.012) | (0.020) | (0.093) |
| Observations | 1,264 | 1,506 | 1,506 | 618 | 827 | 827 |
| R-squared | 0.3160 | 0.0342 | 0.0644 | 0.7204 | 0.0494 | 0.0496 |
| Country-time FE | Yes | No | No | Yes | No | No |
| Industry-time FE | Yes | No | No | Yes | No | No |
| Country FE | No | Yes | Yes | No | Yes | Yes |
| Industry FE | No | Yes | Yes | No | Yes | Yes |
| Firm-level controls | No | No | No | No | No | No |

*Panel B: Excluding green bonds issued for refinancing purposes*

| | Total emissions | | | Direct emissions | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| green_bond | -0.1796** | -0.2679** | -0.0889** | -0.0628*** | -0.0533*** | -0.0926*** |
| | (0.062) | (0.094) | (0.039) | (0.004) | (0.016) | (0.010) |
| Observations | 1,121 | 1,314 | 1,314 | 559 | 740 | 740 |
| R-squared | 0.3284 | 0.0357 | 0.0991 | 0.7220 | 0.0620 | 0.1124 |
| Country-time FE | Yes | No | No | Yes | No | No |
| Industry-time FE | Yes | No | No | Yes | No | No |
| Country FE | No | Yes | Yes | No | Yes | Yes |
| Industry FE | No | Yes | Yes | No | Yes | Yes |
| Firm-level controls | No | No | No | No | No | No |

As a second robustness check, we consider a different definition of emission intensity as our dependent variable. Specifically, we use the ratio between emissions and revenues, as a measure of the carbon efficiency of production. Since revenues and emissions are highly correlated, in this way we rule out that our baseline findings pick up a decrease in activity rather than a reduction in emissions. We report the results for total and direct emissions in columns (2) and (5), respectively. When we consider the full sample of bonds (Panel A), we find a mildly significant decrease for total emissions, while the effect on direct emissions is not estimated with precision. By contrast, moving to Panel B, which excludes green bonds issued for refinancing purposes, shows again that green bonds are associated to a highly significant reduction in emission intensity, expressed in terms of revenue.

Finally, since so far our analysis has focused on emission intensities, albeit differently defined, it may well be that the denominator has driven our results. This is also a major drawback of using revenues as the normalizing aggregate, given their cyclicality and potential volatility. To rule out this concern, we replace our dependent variable with the level of emissions measured in tons of CO2 equivalent, in logs. The estimates, reported in columns (3) and (6) in Table 3, give reassuring indications that our baseline results are indeed capturing decarbonization, rather than the evolution of other firm aggregates, such as assets or turnover. Both panels show that green bond issuance is associated to a reduction in emissions, both total and direct. The effects are also highly statistically significant.

## 4.2 The role of external review

Green bond issuers may go through independent parties' external review of their securities and investment processes, as a way to reassure the markets that the proceeds are indeed used to finance the green projects outlined in the bond prospectus. While the approaches and scope of external review may vary across market players, undoubtedly such practice reduces information asymmetries between issuers and investors.[10] At the same time, naturally, this benefit comes at a cost for the issuers. Costs are both direct, to pay for the services of the external reviewer, and managerial and operational, to ensure compliance with the requirements of the chosen standard. Likewise, non-compliance with the verification standards also entails a reputational cost for the company, as anecdotal evidence shows. Hence, it is plausible to assume that external review provides a stronger signal of the environmental commitment of the green issuers than the simple self-attributed green label. Indeed, Baker et al. (2018) and Fatica, Panzica and Rancan (2019) find that pricing in the primary market for municipal and corporate bonds, respectively,

[10] External review commonly involves a wide range of services from environmental consultancy to audits on use of proceeds. For our purposes, we are interested in three different types of external review: second party opinion, verification and certification. These instances involve compliance with different criteria. In particular, a second party opinion is usually provided based on the assessment of the company green bond framework against market expectations and industry best practices. Verification concerns compliance with a designated set of criteria, such as internal or external standards or claims made by the issuer. Finally, certification can be obtained if there is consistency with a recognized external standard or label, which, in turn, is based on the definition of specific criteria.

is affected by external review. Since external review acts as a credible signal for bonds that actually have environmental or climate-related benefits, verified and certified bonds are more appealing to green-minded investors than self-labelled green securities. Thus, they ultimately benefit from an additional negative yield compared not only to conventional bonds but also to self-labeled green securities.

**Table 4. The role of external review**

The table reports the results of regressing carbon intensity on a green bond issuance indicator, as in model (2). External review is a dummy variable that equals one for bonds with external verification or certification. Robust standard errors, clustered at issuer level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

*Panel A: Including green bonds issued for refinancing purposes*

| | Total emissions | | Direct emissions | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| green_bond | -0.0987** | -0.1011** | -0.0137 | -0.0192 |
| | (0.044) | (0.041) | (0.015) | (0.015) |
| green_bond*external review | -0.0401** | -0.0379** | -0.0376* | -0.0339* |
| | (0.016) | (0.017) | (0.018) | (0.018) |
| Observations | 1,506 | 1,506 | 827 | 827 |
| R-squared | 0.0187 | 0.0363 | 0.0295 | 0.0381 |
| Country FE | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Firm-level controls | No | Yes | No | Yes |

*Panel B: Excluding green bonds issued for refinancing purposes*

| | Total emissions | | Direct emissions | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| green_bond | -0.1502** | -0.1463** | -0.0501*** | -0.0432*** |
| | (0.053) | (0.053) | (0.004) | (0.004) |
| green_bond*external review | -0.0629*** | -0.0637*** | -0.0727*** | -0.0703*** |
| | (0.003) | (0.007) | (0.005) | (0.007) |
| Observations | 1,314 | 1,314 | 740 | 740 |
| R-squared | 0.0194 | 0.0371 | 0.0394 | 0.0484 |
| Country FE | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Firm-level controls | No | Yes | No | Yes |

To test if the stronger signal carries over to climate performance, we estimate model (2) adding an interaction dummy for green bonds that are verified or certified. The coefficient of the dummy would give an indication of the additional effect of external review. We report our results in **Table 4**. Panel A shows the results for the full matched sample, for both total and direct $CO_2$ emission intensity. The review dummy is negative and statistically significant at 5% level in columns (1) and (2), indicating indeed that external review signals a stronger commitment towards climate-friendly investment, which results in lower total emission intensity. The additional effect of external review for direct emissions is comparable, albeit statistically significant at 10% level. Restricting the analysis to green bonds that are not issued for refinancing purposes yields more marked evidence of the important signalling effects of external review. Across all specifications in Panel B of **Table 4**, external review is associated to additional negative impacts on emissions, both total and direct. The estimates are always highly statistically significant (1% level). Moreover, the baseline effects associated to self-labelled green bonds are also estimated with high precision. All in all, the results are consistent with the argument that external review act a stronger signal of the genuine commitment of green bond issuers to engage in additional investment to respond to climate change.

### 4.3 The Paris Agreement: a turning point?

In December 2015 the United Nations Framework Convention on Climate Change (UNFCCC) established the Paris Climate Agreement, considered as a landmark in global efforts to tackle climate change. The agreement sets the ambitious target of limiting the rise in global warming to well below 2°C compared to pre-industrial levels by the end of the century (Art. 2.1(a)), which would require massive reductions in $CO_2$ emissions in the next decades. At the same time, the Agreement recognizes the role of financing de-carbonization by putting forward a commitment to "making finance flows consistent with a pathway towards low Greenhouse Gas emissions and climate-resilient development" (Art. 2.1(c)). Naturally, by raising awareness on climate issues from the general public but also economic and financial actors, such unprecedented commitments might in general have made businesses more environmentally-conscious and therefore more willing to align their behavior with climate objectives. Importantly, reaching climate policy objectives entails a transition process towards a more efficient allocation of resources, whereby some fixed and financial assets may become stranded, that is, undergo a significant devaluation (Edenhofer et al., 2020). Inevitably, this would crucially affect asset owners – households and firms alike. By the same token, the low-carbon transition has impacts on financial markets, which may have started to adjust accordingly, notably by pricing in climate risk. Delis et al. (2018) find indeed that after the Paris Agreement stock markets have penalized companies with large fossil fuel reserves, which are considered stranded assets. More generally, Capasso, Gianfrate and Spinelli (2020) show that companies with high carbon footprint are perceived by the market as more likely to default, ceteris paribus, particularly after the Paris Agreement. This supports the view that climate change exposure is not only increasingly priced, but also affects the overall creditworthiness of companies on bond and loan markets. In line with this evidence, Palea and Drogo (2020) document that carbon risk translates into a higher cost of debt, while, importantly, transparency and disclosure may act as mitigating factors.

Against this backdrop, arguably firms might have higher incentives in financing the investment in climate friendly projects with green bonds after the Paris Agreement. Thus, we adapt our set up to check whether the Paris Agreement has had an impact on the reduction of CO2 emissions associated to the issue of green bonds. We test this hypothesis in two alternative ways. First, we restrict our sample to bonds issued after 2015. In this model, the green bond dummy captures the effect of the issue with respect to the issue of a conventional bond in the period after the Paris Agreement. Second, we use a modified specification of the baseline regression model where we add a dummy for the post-2015 period, both in levels and in interaction with the green bond dummy. We are particularly interested in the coefficient on the interaction variable, because it captures the difference-in-differences estimate in emission intensity between green and conventional bond issuers across the two periods spanning the agreement on the Paris protocol.

**Table 5** reports the results for the unconditional regression model without frim-level controls.[11] Odd-numbered columns display the estimates in the post-2015 subsamples. Across all specifications, the estimates are qualitatively and quantitatively similar to those obtained for the full sample period (**Table 2**). This suggests that there is no differential effect of the Paris protocol in the post-agreement period. Even-numbered columns in **Table 5** show the estimates for the difference-in-differences test. The coefficient on the interaction variable is negative but is not estimated with high precision in the full matched sample (Panel A). Once we exclude green bonds that are issued for refinancing purposes, we find a negative and strongly significantly coefficient for the interaction dummy (Panel B). This suggests that the firms have significantly reduced both total and direct emissions upon issuing a green bond after the Paris Agreement when compared with conventional issuers in the pre-2015 period.

[11] Results are virtually unchanged when we use the conditional model including firm-level covariates.

**Table 5. Effect of the Paris Agreement**

The table reports the results of regressing carbon intensity on a green bond issuance indicator, as in model (2). Post Paris Agreement is a dummy variable that equals one for the period after 2015. Robust standard errors, clustered at issuer level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

*Panel A: Including green bonds issued for refinancing purposes*

| | Total emissions | | Direct emissions | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Post Paris Agreement | | 0.0287** | | 0.0261*** |
| | | (0.011) | | (0.006) |
| green_bond | -0.0824* | -0.0771** | -0.0231** | -0.0338 |
| | (0.040) | (0.033) | (0.011) | (0.025) |
| green_bond* Post Paris Agreement | | -0.0724* | | -0.0060 |
| | | (0.037) | | (0.010) |
| Observations | 1,301 | 1,506 | 673 | 827 |
| R-squared | 0.0189 | 0.0209 | 0.0227 | 0.0312 |
| Country FE | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Firm-level controls | No | No | No | No |

*Panel B: Excluding green bonds issued for refinancing purposes*

| | Total emissions | | Direct emissions | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Post Paris Agreement | | 0.0325*** | | 0.0253*** |
| | | (0.011) | | (0.006) |
| green_bond | -0.1271*** | -0.1210*** | -0.0467*** | -0.0848*** |
| | (0.042) | (0.036) | (0.012) | (0.003) |
| green_bond*Post Paris Agreement | | -0.1161** | | -0.0371*** |
| | | (0.040) | | (0.009) |
| Observations | 1,132 | 1,314 | 608 | 740 |
| R-squared | 0.0186 | 0.0218 | 0.0219 | 0.0408 |
| Country FE | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Firm-level controls | No | No | No | No |

## 4.4 Anticipation and dynamic effects

Finally, we check for anticipation and dynamic effects in the reduction of emission intensities after green bond issues. In particular, we estimate the following model:

$$\Delta y_{it} = \alpha_j + \alpha_c + \sum_{t=T_i-2}^{T_i+2} \beta_k \, 1\{K_{it} = k\} + \gamma \times \Delta \boldsymbol{x}_{it} + \Delta\varepsilon_{it}, \quad (3)$$

where $\alpha_j$ and $\alpha_c$ are industry and country fixed effects, $\Delta \boldsymbol{x}_{it}$ is the set of firm characteristics, as described above, that we use in the conditional specification, $T_i$ is the year when the firm issues a green bond, and $K_{it} = t - T_i$ are dummies for the relative time of the event defined as the issue of the green bond. The set of coefficients $\beta_k$ are the main coefficients of interests. For $k < 0$, they capture pre-trends or lead effects; for $k > 0$ they capture the dynamic correlation between green bond issue and emission intensity. They measure the change in emissions of green bond issuers relative to the pre-issuance reference year, over and above the change observed for the control group comprising matched conventional issuers that do not resort to the green segment.

We report the results in **Table 6**. We find evidence of some pre-trends and dynamic effects limited to direct emission intensity (Panel A). Pre-trends in the year before the issue of a green bond – which we label as year zero - are not substantial relative to the cumulative reduction in emissions taking place up to the second year after the issue. Panel B of **Table 6** reports the corresponding estimates in the sub-sample that excludes green bonds issued for refinancing purposes. The results point again to positive pre-trends for direct and, to a lesser extent, also for total emissions, at least in the unconditional specification. At the same time, there is strong evidence of a long-lasting reduction in emissions after the green bond issuance. The negative effects are highly statistically significant and sizable across all specifications, reaching a cumulative effect of -0.16 for both total and direct emissions. In the latter case, the magnitude of the change increases over time (in absolute value).

## Table 6. Anticipation and dynamic effects

The table reports the results of regressing carbon intensity on a green bond issuance indicator, as in model (3). Robust standard errors, clustered at issuer level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

*Panel A: Including green bonds issued for refinancing purposes*

| | Total emissions | | Direct emissions | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $T_{-2}$ | 0.0068 | 0.0054 | 0.0127 | 0.0139 |
| | (0.009) | (0.010) | (0.013) | (0.014) |
| $T_{-1}$ | 0.0114 | 0.0099 | 0.0332** | 0.0357** |
| | (0.007) | (0.006) | (0.015) | (0.016) |
| T | -0.0810** | -0.0828** | -0.0197 | -0.0217* |
| | (0.037) | (0.035) | (0.015) | (0.012) |
| $T_1$ | -0.0003 | -0.0115 | 0.0027 | -0.0077 |
| | (0.002) | (0.009) | (0.004) | (0.011) |
| $T_2$ | -0.0043 | -0.0033 | -0.0563* | -0.0546* |
| | (0.006) | (0.006) | (0.031) | (0.030) |
| Observations | 1,506 | 1,506 | 827 | 827 |
| R-squared | 0.0186 | 0.0361 | 0.0303 | 0.0389 |
| Country FE | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Firm-level controls | No | Yes | No | Yes |

*Panel B: Excluding green bonds issued for refinancing purposes*

| | Total emissions | | Direct emissions | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $T_{-2}$ | 0.0108 | 0.0049 | 0.0178 | 0.0136 |
| | (0.017) | (0.019) | (0.024) | (0.028) |
| $T_{-1}$ | 0.0171** | 0.0104 | 0.0447** | 0.0442** |
| | (0.007) | (0.008) | (0.019) | (0.020) |
| T | -0.1273*** | -0.1254*** | -0.0587*** | -0.0539*** |
| | (0.038) | (0.037) | (0.003) | (0.006) |
| $T_1$ | -0.0190** | -0.0211*** | -0.0205*** | -0.0194*** |
| | (0.007) | (0.007) | (0.004) | (0.004) |
| $T_2$ | -0.0183*** | -0.0164*** | -0.0955*** | -0.0930*** |
| | (0.005) | (0.005) | (0.030) | (0.027) |
| Observations | 1,314 | 1,314 | 740 | 740 |
| R-squared | 0.0193 | 0.0370 | 0.0406 | 0.0496 |
| Country FE | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Firm-level controls | No | Yes | No | Yes |

## 5 Conclusions

In this paper we investigate the association between green bond issuances and companies' environmental performance. Using information reported in the bond prospectuses, we first document that the sheer majority of corporate green bonds are issued to finance project with climate mitigation purposes. We further distinguish between green bonds issued for refinancing purposes and non-refinancing green bonds. Then, we test whether green bond issues are associated to a reduction in carbon intensity at the firm level. While results are mixed when pooling all bonds together, once we focus on non-refinancing bonds, we find strong evidence that this is the case. Compared to conventional bond issuers with similar financial characteristics and environmental ratings, non-refinancing firms borrowing on the green segment show a decrease in the carbon intensity of their assets, up to two years after the bond issuance. This holds for both total and direct (scope 1) emissions, and is consistent with an increase in the volume of environmentally friendly activities due to new projects. We also find a larger reduction in emissions in case of green bonds that have external review, as well as those issued after the Paris Agreement. In case of external review, the stronger commitment towards the environment may be attributed to cost considerations. More compelling perception of the need to accelerate the low-carbon transition in order to reduce climate risk might be the motivation behind the differential effect after the Paris Agreement.

Our results should be interpreted having an important caveat in mind. In our framework, the reduction of emissions cannot be directly and solely attributed to the projects financed by the green bonds, given also the small amount of funds raised in the green segment compared to overall companies' financing needs. Hence, it would not be appropriate to claim causality. However, our results strongly corroborate the view that green bond issues signal a credible commitment towards climate-friendly company behaviour. Otherwise said, our evidence is clearly not consistent with the 'greenwashing' argument. If greenwashing prevails, green bonds are unlikely to have any real impacts that are beneficial to the environment. Moreover, the stronger results that we obtain once we exclude securities issued for refinancing purposes provide further supporting evidence of the link between green financial choices and an increase in green fixed capital. As such, our findings point to the relevance of green bonds in the broader context of firms' climate commitment.

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KJ-AE-20-013-EN-N

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doi:10.2760/24092

ISBN 978-92-76-22105-0