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Center for Financial Studies | Goethe University | Theodor-W.-Adorno-Platz 3 | 60323 Frankfurt am Main | Germany
| Phone +49 69 798 30050 | info-cfs@hof.uni-frankfurt.de | www.gfk-cfs.de

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Is the Government always greener?

Caterina Di Tommaso[◊], Salvatore Perdichizzi[∞], Samuel Vigne[σ], Andrea Zaghini*

Abstract

This research focuses on the cost of financing green projects on the primary bond market and tests for a potential price differential between green bonds issued by government entities and those issued by supranational and private sector issuers. Our findings indicate that government entities benefit from more favorable pricing conditions worldwide. This advantage is growing over time and particularly pronounced for sovereigns and municipal authorities. Our analysis also reveals that country-specific factors, such as strong political commitment to address climate change, low income level and high degree of indebtedness are significant predictors of the pricing spread across bonds.

JEL classification: G15, G32, H63, C21.

Keywords: Green bonds, Sovereign debt, Yield spread, Greenium.

* Bank of Italy, DG Economics and Research, Via Nazionale 91, 00184 Rome, Italy. E-mail: andrea.zaghini@bancaditalia.it and CFS, Goethe University Frankfurt, House of Finance, 60629 Frankfurt am Main, Germany.

[◊]University of Bari; [∞]University of Bologna; [σ]LUISS Business School

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1 Introduction

Green bonds are a specific type of fixed-income securities issued by a variety of entities (private sector, public sector, and supranational agencies) that are currently playing an important role in the fight against climate change. They provide a way for issuers and investors to support environmentally friendly projects and to contribute to the transition to a low-carbon economy. In addition, they are the best candidate to satisfy the appetite of investors attending to environmental concerns (BlackRock 2020). The cornerstone of a green bond is the compulsory utilization of the proceeds for eligible green projects only. The latter are listed in the *Green Bond Principles* published by the International Capital Market Association (ICMA) and include initiatives related to renewable energy, energy efficiency, pollution prevention and control, and other environmentally beneficial projects (ICMA 2021).

It took time for the green bond market to develop after the initial "Climate Awareness Bond" issued in 2007 by the European Investment Bank. While constantly growing up to 2021, there are two phases of acceleration for the green bond market. The first in 2016, after the ratification of the Paris climate agreement reached the 21st UN Climate change conference (COP21), and the second just before the outburst of the Covid-19 pandemic, when several sovereigns and supranational institutions started their green issuance and new institutional actors entered the fight to climate change. According to Climate Bonds' Market Intelligence data, since 2016 the market increased at an impressive annual growth rate of over 50%, it breached the threshold of USD 1 trillion at the end of 2020 and doubled to USD 2 trillion in the second half of 2022. The cumulative number of issuers around the world since 2016 stands at 2,460, with 382 green bond debuts in 2022 only (CBI 2021).

One of the most popular investigation concerning green bonds is whether they provide a direct incentive to corporations and institutions that wish to invest in climate friendly projects. One of the potential direct incentives is in the form of a borrowing cost advantage for green bonds versus conventional

bonds: a lower yield spread at issuance, also known as "greenium". This is a non trivial question given that issuing a green bond may be costly. Indeed, committing the bond proceeds to green projects only restricts companies' investment policies. Moreover, to qualify as a "certified" green bond, issuers have to look for a third-party assessment to establish that the proceeds are funding projects in line with the *Green Bond Principles*. The procedure gives rise to additional administrative and compliance costs (Flammer 2021).

While broadly in favour of a negative premium for green bonds, the evidence gathered so far is not unanimous. Results depend on the set of bonds analyzed, the econometric methodology employed, the period under review, and the nature of the issuer: whether it is a non-financial corporation, a bank, a supranational institution, or a government entity (Zerbib 2019, Tang and Zhang 2020, Baker et al. 2022, Bolton et al. 2022).

Even though our research is related to greenium literature, given the extant uncertainty about the size of the greenium in general and the sovereign greenium in particular, our choice is to focus on green bonds only and on a slightly different premium: the difference between the yield of government and corporate green bonds. We label this difference as government green spread (GGS). Studying the price differences across green bonds can provide valuable insights into the market demand for environmentally friendly investment opportunities and wider trends in sustainable finance. Indeed, the pricing of green bonds can help issuers, investors and policymakers to understand the level of market acceptance of these securities, and whether there is room for investment opportunities that have both financial returns and a positive environmental impact.

In addition, by looking at the yield at origination of the bonds on the primary market, we can assess how the cost of financing green projects varies across sectors.

Our contribution is incidentally related also to the literature on the relation between sovereign and corporate risk. On the one hand, we are among

the few studies directly analyzing the difference in bond yields at issuance (Bevilaqua et al. 2020, Gopinath et al. 2023). On the other hand, we are the first, to the best of our knowledge, to focus on the particular market segment of green bonds. While we might expect the cost at issuance to be higher for corporations than government entities, given the traditional view that corporate risk include country risk (Durbin and Ng 2005, Borensztein et al. 2013, Almeida et al. 2017, Jappelli et al. 2022), when dealing with green bonds the issue may not be so straightforward. The spread between government green and corporate green bonds (GGS) may not be comparable with that arising from non-green ordinary bonds for at least two reasons. First, since the return on a green bond can be thought as the return of a similar non-green bonds plus the greenium (which usually is negative), the GGS ends up to depend on the difference between the government and corporate green premia. However, as already mentioned, the market assessment of the greenium varies across sectors and over time. Secondly, the issuers of green bonds are different from those of ordinary bonds. While the green government issuers are a proper subset of all government issuers, the set of corporate green issuers may not be a subset at all. Indeed, there are many corporations placing green bonds only. Finally, note that while the tenet that corporate risk include country risk leads us to expect a higher yield for corporate bonds than sovereign bonds, it is less evident when we compare corporations to a broader government aggregate, in which the role of the sovereign is marginal, or even completely absent, in several periods, as in our sample.

Our main working hypothesis is that the decision-making process concerning the issuance of a green bond is different across government entities and private sector corporations. Private firms have a micro perspective: they issue green bonds to raise capital for environmentally beneficial projects that still have a private return. Governments instead are able to take into account the negative externalities stemming from climate change and thus better able

to provide large-scale (macro) projects aimed at reaching carbon neutrality, limiting global warming and curbing CO2 emissions. Thus, how much investors are willing to renounce in term of return also depends on the green outreach of the project they are financing.[1]

An empirical preliminary analysis confirms the goodness of our choice of focusing on green bonds only. When all bonds (green and non-green) are taken into account, government issuance shows a lower yield as predicted by the literature on the "country risk". However, green bonds face a further discount that varies over time, making them inherently different from all other bonds and making their cross-sector pricing mechanism worth analysing.

We can thus state our main research questions as: Is the government able to finance green projects at a discount with respect to other issuers? Are all government institutions treated in the same way on the global (green) bond market? Are there country specific characteristics that can directly influence the pricing mechanism?

To preview our results, we find that, *ceteris paribus*, the government aggregate formed by government sponsored entities (GSEs), municipal authorities (including the county/distric level), provincial authorities and central authorities (sovereigns) always faces a lower funding cost for green projects than private sector corporations and supranational entities. The spread between government green bonds and all other green bonds is estimated in the range 55-68 basis points. The spread seems to be increasing over time and larger for green bonds issued by sovereigns and municipal authorities. When looking to specific country characteristics, we find that the cost of green issuance is negatively correlated with the level of economic development and positively with the debt level. However, even when taking into account the

[1] In addition, note that government issuance can play a role in promoting the development of the green bond market and improving the transparency of these securities. By creating favorable regulations and policies, governments can not only encourage the issuance of green bonds, but also make them more accessible to a wider range of investors (OECD 2021).

above-mentioned characteristics, the government faces lower green financing costs than other issuers.

The rest of the paper is structured as follows. Section 2 places the contribution of the paper in the current literature. Section 3 introduces the econometric methodology. Section 4 deals with the dataset. Section 5 discusses the baseline estimations. Section 6 provides further insights based on specific country characteristics. Section 7 proposes some robustness checks. Section 8 concludes.

2 Related literature

As already mentioned, one of the most recurring topics in the current green finance literature is the search for the existence of a green bond premium, also known as greenium: the yield difference between a green bond and another otherwise identical non-green bond. Green bonds are debt instruments, whose proceeds are committed to the financing of low-carbon, climate-friendly projects. Moreover, they seem to best satisfy the appetite of investors with pro-environmental preferences (Krueger et al. 2020, Bolton and Kacperczyk 2021, Giglio et al. 2021, Pastor et al. 2022).

While abundant and increasing, the literature is still inconclusive about existence, size and magnitude of the greenium for both for corporate (Zerbib 2019, Tang and Zhang 2020, Flammer 2021, Baker et al. 2022) and sovereign issues (Kapraun et al. 2021, Doronzo et al. 2021, Bolton et al. 2020).

Concerning corporate issuance, Zerbib (2019) focuses on a set of 110 green bonds priced on global markets between 2013 and 2017. The author reports a statistically significant negative premium with respect to conventional non-green bonds, even though very limited in magnitude (around 2 basis point). In line with this finding are the results by Baker et al. (2022) that place the premium in a range of 5-9 basis points. Somewhat larger is the premium estimated by Fatica et al. (2021) for the green issuance by non-financial cor-

porations (22 basis points). At the same time, they find that green bonds issued by financial corporations do not enjoy any negative yield differential and that the greenium of supranational institutions stands at 80 basis points. Tang and Zhang (2020) report that stock markets seem to respond positively to the announcement of green bond issuance, whereas Flammer (2021) documents a significant increase in firms' environmental performance after the issuance, that in turn indicates that green bonds are effective in improving companies' environmental footprint. However, both contributions do not find any price difference between green bonds and conventional bonds issued by the same firm.

As concerns the sovereign greenium, most studies rely on matched bonds with similar characteristics. Sakai et al. (2022) study the secondary market for sovereign German twin bonds (i.e. bonds that are almost identical but for the green label) and find evidence for a greenium that ranges between 2 and 5 basis points. Grzegorczyk and Wolff (2022) expand the sample of matches to ten twin bonds issued by seven EU countries and find a statistically significant greenium up to 15 basis points. Doronzo et al. (2021) compare the yields on bonds issued by Belgium, France, Ireland, and the Netherlands. They find that the performance of sovereign green bonds is not as good as the conventional bonds: from primary market data emerges that sovereign green bonds have a slightly positive greenium at 3.8 basis points (i.e., the green yield is higher than the non-green yield). This evidence is confirmed by Bolton et al. (2022) for a set of 63 matched bonds issued by sovereigns and supra-national institutions. Using data on a larger sample of bonds Kapraun et al. (2021) show that the existence and significance of the greenium vary substantially across currencies and issuer types. In particular, it stands at 18.5 basis points for bonds issued by official entities (governments and supranational institutions) on the primary market and at 4.5 on secondary market trades.

Even though for the sake of brevity just a partial account could be pro-

vided of the abundant research, this literature review reveals that there is still not unanimity on the pricing of green bonds and there are several issues that need to be further explored by researchers in order to provide valuable insights for policymakers, issuers and investors in the green bond market. To address one of these key gaps, our analysis focuses on the different pricing of green bonds, more precisely the difference between those issued by government entities and those issued by other issuers from the non-public sector at large. As already mentioned, we investigate the possibility that the different use of proceeds from the green issuance by public sector and private sector issuers may influence also the cost of financing in the primary bond market.

The relation between sovereign and corporate debt has been extensively investigated by a different strand the literature (Durbin and Ng 2005, Borensztein et al. 2013, Almeida et al. 2017, Jappelli et al. 2022). Given that a deterioration in the sovereign risk usually presses governments to take fiscal actions which hurt the domestic economy and thus the private sector (increasing current and future taxes, cutting subsidies to firms, reducing public expenditures), we would expect corporate bond returns to be higher than sovereign bond returns. In other words, since sovereign credit risk is a component of corporate credit risk, the risk compensation required by investors would be at least as high for corporate borrowers as for their sovereigns. While there are additional reasons to prefer a sovereign bond to a corporate bond due fact that the former are usually safer, more widely acceptable as collateral, and more liquid on secondary market trades, there are also reasons to prefer corporate bonds to sovereign bonds. First of all because sovereign debt has no bankruptcy mechanism: there is no supranational legal authority to enforce payments to creditors. Thus, it is much harder to enforce (Asonuma and Trebesch 2016). The literature has also suggested that there might be further circumstances. For instance, Durbin and Ng (2005) compared the spreads on bonds issued by firms from emerging market economies with those on bonds issued by the firms home governments to assess the existence

of a possible sovereign ceiling that forbids corporate yields to be lower than sovereign yields. They find several cases where a firm's bond trades at a lower spread than that of the government, indicating that investors do not always apply the sovereign ceiling. This happens especially for firms having substantial export earnings and thus being less affected by domestic shocks. Bevilaqua et al. (2020) document that corporate borrowers are able to issue debt that is priced at lower rates than sovereign debt during periods of unusually high sovereign yields. In addition, while they report a positive spread between corporate and sovereign debt at issuance and a significant co-movement over time, they also find evidence that the relation seems to have broken down after the global financial crisis. In a recent contribution, Gopinath et al. (2023) compare high-yield US corporate bonds to high-yield emerging market sovereign bonds over the period 2002-2021. They find that investor experiences in these two asset classes were surprisingly aligned showing comparable average unconditional yields and excess returns.

We distinguish from this literature by looking at the yield spread between bonds placed by a broader government aggregate and corporate bonds, and by narrowing the analysis to the green bond segment only. In addition, by focusing on the yield at issuance, we are among the few contributions directly investigating the development of the cost of debt financing in the global bond market (Bevilaqua et al. 2020, Gopinath et al. 2023).

3 Econometric Methodology

We focus on the development of the bonds' yield at issuance since we are interested in the actual cost of financing for the issuing institutions. While secondary market prices and volatility affect prospective issuance – they can be thought of as the current market assessments of those issuance (Goldstein and Yang 2017) – they do not change the face value of the already issued bonds and thus the cost for the issuer. Instead, the single originating trade

on the primary market exactly defines the company's commitment and the actual financing cost.

Our econometric set-up relies on a standard bond pricing model, where the bond yield at launch is linked to the two direct sources of risk of bond features and issuer characteristics and the indirect influence of the market development at the moment of issuance. Analytically:

$$Yield_i = \alpha_0 + \sum_k \beta_k V_{i,k}^{bond} + \sum_l \beta_l V_{i,l}^{issuer} + \sum_m \beta_m V_{i,m}^{market} + FE_i + \varepsilon_i \quad (1)$$

where V^{bond} are the K variables tracking bond i features, V^{issuer} are the L variables characterizing the issuing corporation of bond i, and V^{market} are the M variables concerning the market sentiment at the date of issuance of bond i. Finally, FE_i are additional fixed effects constructed as sets of dummy variables to take into account idiosyncratic shocks.

The model has a cross-section structure where all exogenous variables are taken at time t, the exact issuance day. Its estimation can be thought of as equivalent to a standard pooled OLS panel estimation. The cross-section approach allows a much larger selection of bonds and issuing institutions than a time series analysis. Furthermore, many bonds, especially from smaller issuers, are not constantly priced and traded in the secondary market and thus can not be employed in a time series approach. Even when secondary market quotes exist, prices are most of the times not coupled with actual trades. By focusing on the primary market, we then avoid the market distortion (the so-called "stale price problem") due to the scarce liquidity of many bonds in secondary trades (Diaz and Skinner 2001, Zaghini 2019, Nozawa and Qiu 2021).

The working hypothesis of equation (1) is that once the model is saturated by a large set of control variables and fixed effects able to take into account all possible sources of systematic difference between bonds and issuers, the

constant approximates the unavoidable cost of bond financing. In addition, by substituting the constant with a set of time dummies it is possible to follow the evolution of the cost of financing over time.

A multi-period difference regression model can be devised by selecting a given characteristic (of either the bond or the issuer) and interacting it with the set of time dummies. Not only can the cost of financing be followed over time, but also the differential effect on the set of bonds showing the selected characteristic can be singled out period by period. Analytically:

$$\begin{aligned} Yield_i &= \sum_j \alpha_j Time_{i,j} + \sum_j \delta_j feature_i * Time_{i,j} + \sum_k \beta_k V_{i,k}^{bond} + \\ &\sum_l \beta_l V_{i,l}^{issuer} + \sum_m \beta_m V_{i,m}^{market} + FE_i + \varepsilon_i \end{aligned} \quad (2)$$

where $Time_{i,j}$ are the j time periods that substitute for the constant and $feature_i$ is the dummy variable tracking the characteristic of interest. The coefficients α_j estimate the evolution over time of the cost of financing on the bond market and the coefficients δ_j the additional spread (negative or positive) that is associated with the selected characteristic.

The goal of our analysis is to investigate whether the domestic public sector (government for short) faces better pricing conditions when issuing a green bond than other domestic, international, and supra-national issuers. We rely on a broad definition of government which includes: municipal authorities, provincial authorities, government sponsored entities (GSEs), and the sovereign (central authorities) as classified by Dealogic DCM Analytic. The remaining issuers are instead labeled as: Banks, Real Estate Companies, Other Financial, Multilateral Development Banks and Entities (MDBs), and Non-financial Corporations (NFCs). We construct a dummy variable that takes the value 1 when bond i is issued by the government aggregate and 0 otherwise. From equation (2) we have that when the δ_j coefficient estimate

is negative (positive) the government faces better (worse) price conditions on green bond issuances than other issuers in period j.

In order, to saturate the model we rely on a broad set of controls and dummy variables. As already explained, they take into account the possible sources of systematic difference among bonds and issuers. The selection of the regressors is based on the traditional drivers of the risk premium (Elton et al. 2001, Collin-Dufresn et al. 2001, Campbell and Taksler 2003). In particular, as regards the bond features $\left(V_k^{bond}\right)$, the variables taken into account are: the time to maturity at origination, the amount issued, the currency of denomination, the coupon frequency and the type of deal (fixed, floating or zero-coupon). We also rely on dummy variables tracking the bond rating and whether the bond is collateralized, subordinated or callable.

The issuers characteristics in the set V_l^{issuer} include a measure of the creditworthiness of the corporation, the general industry sector and the business nationality. As for the creditworthiness, we rely on the rating provided by the three most important rating agencies: Moody's, Fitch and Standard&Poors. Given the likely non linear relation between the probability of default and the rating, we use a set of dummy variables, one for each rating grade.[2]

In the set V_m^{market} of variables tracking the financial stress, there are several market indices at the daily frequency: (i) the VIX and VSTOXX indexes, that are measures of the equity market volatility in the US and euro area, respectively; (ii) the CISS bond indexes by Hollo et al. (2012) , that measure the systemic stress in the financial markets of US, UK, euro area and China; (iii) the CDX North American index and the iTraxx Europe index, that capture market-wide variation in CDS spreads due to changes in fundamental credit risk, liquidity, and CDS market-specific shock Acharya et

[2]Note that we employ two different sets of ratings: one for the issuing institution and one for the bond. While the issuer rating assesses the overall creditworthiness of the issuer, the bond rating looks at the probability of default of a single security. This difference is particularly relevant for private corporations since the characteristics of each single bond vary much more than Government bonds.

al. (2014). In addition, also at the daily frequency, we include: (i) the index of macro news for the US and the euro-area provided by Citi; (ii) the index of economic policy uncertainty (EPU) by Baker et al (2022) for the US and the UK; (iii) the nominal effective exchange rate of the euro computed by the ECB with respect to the 19 main trading partners of the euro area. To account for global factors, we rely on the monthly index of global commodity prices from the IMF Global Commodity Dataset, which covers both oil and other commodities.

The time partition we employ to follow the evolution of the bonds' yield over time is centered on two main events: the worldwide commitment of reducing CO2 emission agreed at the COP21 in Paris and the involvement of new (institutional) actors in the fight against climate change just before the Covid-19 pandemic. In particular, we use two dates to anchor our periods: the signature of the Paris agreement (4 November, 2016), and the appointment of Christine Lagarde as President of the ECB (18 October, 2019).

The Paris Agreement represents a milestone in the fight against climate change for at least two main reasons. First, it sets a clear objective in terms of limiting the increase in the world temperature at 1.5° Celsius above pre-industrial levels and aims at the goal of "net zero emissions" between 2050 and 2100. In addition, while it is a legally binding international treaty adopted by 196 Parties, it is based on nationally determined contributions (NDCs), that embody efforts by each country to reduce national emissions and adapt to the impacts of climate change.

The appointment of Christine Lagarde, a recognized champion in the fight against climate change, as President of the ECB is instead an important moment for the broader involvement of national and supra-national institutions in tackling climate change issues. Already when she was Managing Director at the IMF she pushed for a larger involvement of financial sector and supra-national institutions in the funding of mitigation and adaptation costs. When President of the ECB, she started a campaign backing the need for

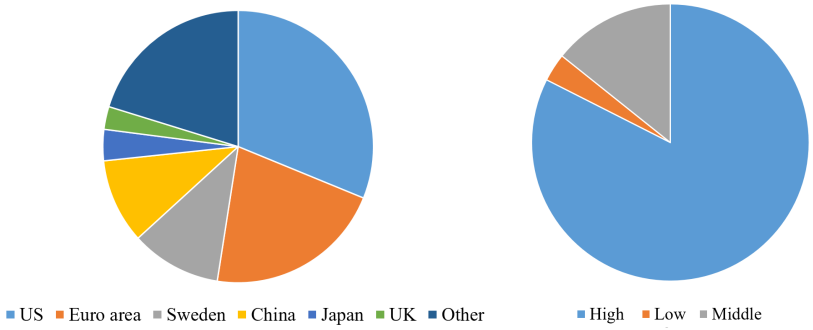
central banks to devote greater attention to understanding the impact of climate change at large, not only for its implications for inflation dynamics Lagarde (2020, 2021). As a matter of fact, in July 2021 the review of the ECB monetary policy strategy included an ambitious climate change action plan. Over the same period, the FED started assessing the implications of climate change on the macro-economy and the financial stability (Rudebusch et al. 2019) and the Bank of England launched a framework to green the Corporate Bond Purchase Scheme (Bank of England 2021). Worldwide, several sovereigns entered the green bond market with their first placements ever (Ecuador, Egypt, Germany, Hungary, Italy, Sweden and Thailand among others). Even though the US did not issue a sovereign green bond, the new administration rejoined the Paris agreement. At the supranational level the IMF proposed a new trust (Resilience and Sustainability Trust - RST) designed to provide affordable long-term financing to support countries undertaking macro-critical reforms to reduce risks to prospective balance of payment stability concerning climate change (IMF 2021).

While bearing in mind the two events, we decided to maintain the period from the end of the Paris meeting to its official start as a separate period, since it was not certain that it would have ever been ratified. Thus, we detail four periods of different length: 1) *Brown period* from the start of the sample on 1 January, 2014 to the conclusion of the COP21 meeting in Paris on 12 December, 2015; 2) *Paris period* from 13 December, 2015 to 4 November, 2016 when the Paris agreement entered into force ; 3) *Green period* from 5 November, 2016 to the Lagarde appointment as ECB President 18 October 2019; 4) *Institutional period* from 19 October, 2019 to the end of the sample (30 June, 2021).

4 Data description

Our dataset is an extensive collection of information from three main sources: Refinitiv Eikon, Bloomberg and Dealogic DCM Analytics. We have a universe of 6,763 green bonds issued worldwide between January 2014 and June 2021. It narrows down to a working sample of 5,905 bonds when taking into account all the needed information about bond characteristics, issuer features, and market prices.

Figure 1. Bond distribution by nationality (LHS) and income (RHS)



This Figure shows the percentage distribution of bonds by nationality on the left panel and by country income on the right panel.
Source: DCM Analytics by Dealogic.

Figure 1 illustrates that the United States and the group of the 19 euro-area countries are the top issuers of green bonds with a share of 31.2% and 21.3%, respectively (LHS panel). Also Sweden and China are robust issuers with world shares above 10%, whereas less abundant is the green issuance of bonds by Japan and UK (3.7% and 2.7%, respectively). Following the World Bank ranking of countries according to GDP, the RHS panel shows that the green bond issuance of middle-income countries (MICs) and especially low-income countries (LIC) is rather poor with a mere 14.3% and 3.3% world share, respectively.

The development over time of the green issuance by the industry sector

is reported in Table 1. One of the most interesting features is the late issuance of sovereigns, which entered the market as late as December 2016, when Poland issued the first ever sovereign green bond. As for the government aggregate formed by government sponsored entities (GSEs), municipal authorities, provincial authorities, and sovereigns, while facing a decline in terms of bond placed from the peak recorded in the Green period, it maintained a strong share in terms of value issued in the latest Institutional period at 23.4%.[3]

Table 1. Bond distribution by sector and period

	Brown	Paris	Green	Institutional	Total
Banks	51	52	340	511	954
Other Financials	2	4	86	66	158
Real Estate Companies	35	21	307	462	825
NFCs	205	68	752	879	1,904
MDBs	143	73	245	169	630
Government	99	46	962	327	1,434
- Government Sponsored Entities	*25*	*17*	*138*	*162*	*342*
- Local Authorities	*37*	*7*	*301*	*94*	*439*
- Provincial Authorities	*37*	*22*	*496*	*29*	*584*
- Sovereigns	-	-	*27*	*42*	*69*
TOTAL	535	264	2,692	2,414	5,905
Government share (bonds)	18.5	17.4	35.7	13.5	24.3
Government share (volume)	23.2	13.7	24.7	23.4	23.3

This Table reports the bond distribution by sector and period. NFCs stands for non-financial corporations; MDBs stands for multilateral development banks. Brown ranges from 1 January, 2014 to 12 December, 2015; Paris from 13 December, 2015 to 4 November, 2016; Green from 5 November, 2016 to 18 October, 2019; Institutional from 19 October, 2019 to 30 June, 2021. Source: DCM Analytics by Dealogic.

To further broaden the scope of our investigation, we obtained data on the Climate Change Performance (CCP) Index at the country level from GermanWatch.[4] The CCP Index aims to capture transparency in interna-

[3] In the Appendix we list all the entities belonging to the Government aggregate and report their green issuance.

[4] GermanWatch is an independent development, environmental, and human rights Non-governmental organization that has been collecting data on climate related issues since 2005, to enhance transparency of global climate politics and emissions. In particular, as an independent monitoring institution, it has gained a leading role in informing on the

tional climate politics and enables comparison of climate protection efforts and progress made by individual countries. It can be thought of as an instrument to assess governments actions and make them accountable for their climate change policies. In particular, the CCP Index evaluates 59 countries, which together generate more than 90% of global greenhouse gas emissions. Using standardized criteria, the CCP Index looks at four categories, with 14 indicators: Greenhouse Gas Emissions (40% of the overall score), Renewable Energy (20%), Energy Use (20%), and Climate Policy (20%). For instance, the Greenhouse Gas Emissions sub-Index is based on indicators taking into account past trends, current levels, future targets and the consistency with the Paris agreement on maintaining the increase in the world temperature below 1.5° Celsius.

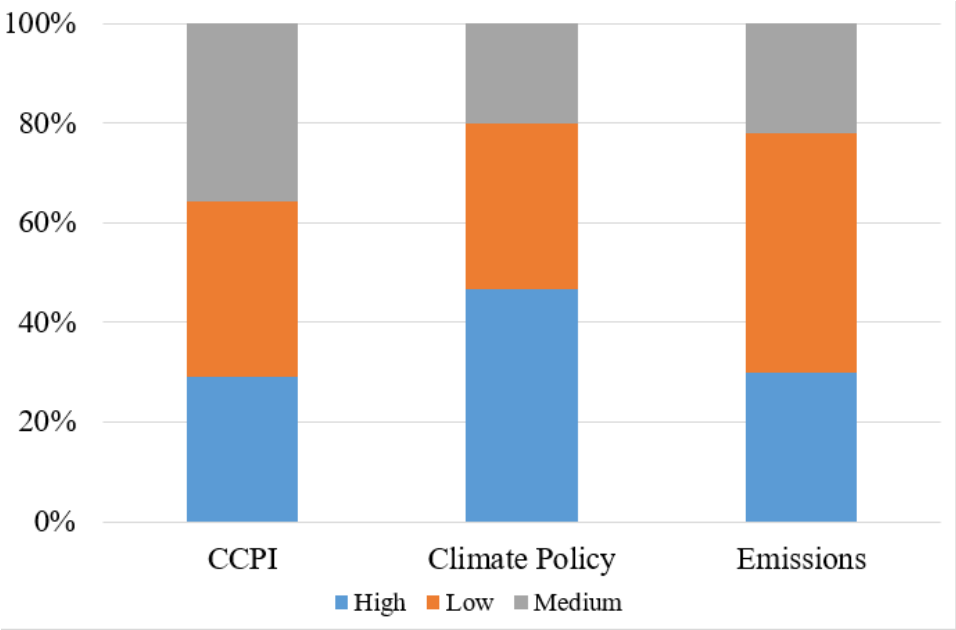
The data for the sub-Index Climate Policy is instead based on the performance rating provided by climate and energy policy experts from non-governmental organizations, universities and think tanks within the countries that are evaluated. In a questionnaire, they give a rating on a scale from one ("weak") to five ("strong") on the most important measures of their government. Both the national and international efforts and impulses of climate policies are scored. It assesses the political commitment of a country to fight climate change.

Figure 2 shows the distribution of the bonds in the sample according to the climate country assessment as measured by the CCP Index (CCPI), the Greenhouse Gas Emissions sub-Index (Emissions), and the Climate Policy sub-Index (Climate Policy). High, medium, and low represent the first, second, and third tercile of each index distribution. Given the different kinds of focus, it is not surprising to see that the relative weight within the bond

Paris Agreement implementation phase. Several countries around the world rely on GermanWatch indexes to assess the evolution of their climate policies (Canada, Chile, India, Malaysia, Portugal among others).

distribution is sufficiently different among the three indexes.

Figure 2. Bond distribution by climate performance



This Figure shows the percentage distribution of bonds by climate score: CCPI is the Climate Change Performance Index; Climate Policy is the Climate Change Policy Index; Emissions is Climate Change Emission Index. Low is the first tercile of the distribution, Middle is the second tercile of the distribution, High is the third tercile of the distribution.
Source: DCM Analytics by Dealogic and GermanWatch.

Table 2 presents the summary statistics of the overall sample (Panel A), by distinguishing bonds according to the issuer: government and other issuers. Additionally, the full sample period spanning from January 1, 2014 to June 30, 2021, is further divided into the four sub-periods described in the previous Section: *Brown period* (January 1, 2014 to December 12, 2015), *Paris period* (December 13, 2015 to November 13, 2016), *Green period* (November 14, 2016 to October 14, 2017), and *Institutional period* (October 15, 2017 to June 30, 2021). This subdivision allows for a more in-depth analysis of the trends and patterns within the green bond market over time.

The table includes the mean, standard deviation, difference in means, T-statistics, and p-values for the main variables included in equation (2) such as the yield at issuance (percentage points), the issued value (millions of euros), the bond maturity (days), the bond and the issuer ratings from the three top rating agencies (Fitch, Moody's and Standard&Poors) transformed into a scale of values from 1 (C) to 20 (AAA).

Table 2. Summary statistics

	Government green bonds			Other issuers green bonds			Difference in means	T-stat	P-value
	# of Bonds	Mean	SD	# of Bonds	Mean	SD			
Panel A: Full Sample (January,1 2014 to June,30 2021)									
Rate yield	1434	2.1136	1.3977	4471	2.7206	2.4703	0.6070	11.6236	0.0000
Value	1434	189.6699	601.2915	4471	199.9059	300.9293	10.2360	0.6202	0.5352
Maturity	1434	3827.8612	2556.6781	4471	3301.5010	4710.6844	-526.3602	-5.3942	0.0000
Bond rating	1434	18.3806	2.2284	4471	15.3733	3.8604	-3.0073	-30.6825	0.0000
Issuer rating	1434	17.5101	3.1699	4471	15.5896	3.6641	-1.9204	-13.1346	0.0000
Panel B: Brown period (January,1 2014 to December,12 2015									
Rate yield	99	2.2194	1.7608	436	3.5686	2.7585	1.3493	6.1099	0.0000
Value	99	168.7668	317.1699	436	126.5661	207.1682	-42.2007	-1.2641	0.2087
Maturity	99	3572.7273	2136.9045	436	2477.0688	1718.1301	-1095.6585	-4.7639	0.0000
Bond rating	99	18.9222	1.4396	436	16.7189	4.2108	-2.2033	-6.8082	0.0000
Issuer rating	99	15.9516	3.7610	436	17.5744	3.4708	1.6228	3.0782	0.0028
Panel C: Paris period (December,13 2015 to November,3 2016									
Rate yield	46	1.6638	0.7943	218	3.2872	2.5870	1.6234	7.7029	0.0000
Value	46	200.1015	261.1879	218	266.1558	415.1631	66.0542	1.3853	0.1691
Maturity	46	3747.3261	2133.5381	218	2530.0321	3095.1319	-1217.2940	-3.2202	0.0018
Bond rating	46	19.0889	1.2399	218	16.7647	3.5942	-2.3242	-6.7490	0.0000
Issuer rating	46	19.2174	1.8080	218	17.0593	3.6236	-2.1581	-4.4109	0.0000
Panel D: Green period November,4 2016 to October,18 2019)									
Rate yield	962	2.4370	1.2763	1730	3.1087	2.6039	0.6718	8.9665	0.0000
Value	962	117.4849	447.4367	1730	199.6267	325.3448	82.1419	5.0056	0.0000
Maturity	962	3940.6871	2570.8872	1730	3421.3064	4311.4708	-519.3808	-3.9133	0.0001
Bond rating	962	18.2688	2.3172	1730	16.0348	3.6561	-2.2340	-16.0804	0.0000
Issuer rating	962	17.3246	3.3078	1730	15.9880	3.4817	-1.3366	-6.1952	0.0000
Panel E: Institutional period (October, 19 2019 to June,30 2021)									
Rate yield	327	1.1936	1.2558	2087	2.1626	2.1337	0.9689	11.5776	0.0000
Value	327	406.8918	946.8912	2087	208.5386	278.8944	-198.3532	-3.7625	0.0002
Maturity	327	3584.5107	2670.3114	2087	3455.0081	5503.7994	-129.5026	-0.6795	0.4970
Bond rating	327	18.4488	2.2297	2087	14.3857	3.7487	-4.0631	-23.6858	0.0000
Issuer rating	327	18.0642	2.6371	2087	14.6751	3.5631	-3.3891	-16.2700	0.0000

This Table reports the summary statistics of the main variables employed in the regressions by secot and period: Rate yield is the yield at issuance of the bond in percentage points; Value is the amount placed in USD millions; Maturity is the maturity at issuance in days; Bond rating is the rating of the bond expressed as an average of the ratings assigned by the three top rating agencies (Moody's, Fitch and Standard&Poors) linearized between 1 (C) and 20 (AAA); Issuer rating is the average rating of the issuer. Mean is the sample average, SD is the sample standard deviation.
Source: DCM Analytics by Dealogic.

The table indicates that green bonds issued by other issuers tend to have

a higher yield rate, a lower maturity, a lower bond rating, and a lower issuer rating compared to those issued by the government. The p-values of the T-test are all below 0.001, indicating that the differences in means are statistically significant. However, there is no statistically significant difference between the government and the other issuers when considering the amount issued (p-value 0.5352). Furthermore, also the evidence from the sub-samples shows that government green bonds have consistently lower yield rates, higher maturities, higher bond ratings, and higher issuer ratings compared to green bonds issued by other entities. This suggests that government green bonds may be perceived as a more appealing investment option, possibly due to the specific bond and issuer characteristics reported in Table 2.

5 The cost of green projects

5.1 Are government bonds different?

In order to validate our approach of focusing on green bonds only to look for a possibly enhanced role of the government in financing green projects, we propose a preliminary analysis based on all the bonds issued over the period spanning from January 2014 to June 2021.

The first column of Table 3 shows that indeed government bonds have a smaller yield. The estimate of the government dummy introduced in equation (1) is negative and statistically significant at 58 basis points. Over a large sample of more than 200,000 global bonds, we thus confirm the results of the literature suggesting that when assessing the corporate risk, investors take into account also the country risk stemming from the government creditworthiness (Durbin and Ng 2005, Borensztein et al. 2013, Almeida et al. 2017, Jappelli et al. 2022).

At the same time, the second column suggests that government green bonds are priced differently. The interaction of the government dummy with the dummy tracking the green bonds is also negative and significant. The

spread with respect to conventional bonds stands at 55 basis points and can be interpreted as an estimate of the government greenium (Kapraun et al. 2021, Doronzo et al. 2021, Bolton et al. 2020).

Table 3. Public sector vs private sector bonds (full sample)

	(1)	(2)	(3)	(4)
Government	-0.5753 ***	-0.5288 ***		
	(0.0089)	(0.0092)		
Government*Green		-0.5473 ***		
		(0.0186)		
Brown*Government			-0.6699 ***	-0.6413 ***
			(0.0137)	(0.0138)
Paris*Government			-0.7146 ***	-0.6812 ***
			(0.0161)	(0.0162)
Green*Government			-0.4389 ***	-0.3578 ***
			(0.0112)	(0.0114)
Institutional*Government			-0.6524 ***	-0.6186 ***
			(0.0134)	(0.0138)
Brown*Government*Green				-0.0007
				(0.0843)
Paris*Government*Green				-0.4277 ***
				(0.0750)
Green*Government*Green				-0.7976 ***
				(0.0225)
Institutional*Government*Green				-0.2225 ***
				(0.0303)
Bond and Issuer controls	YES	YES	YES	YES
Financial stress controls	YES	YES	YES	YES
Currency*Time dummies	YES	YES	YES	YES
No. observations	200,311	200,311	200,311	200,311
R^2	0.9104	0.9107	0.9106	0.9111

This Table reports the estimated coefficients from regressions (1) and (2) where the dependent variable is the yield at issuance on both green and non-green bonds. Government is a dummy variable taking 1 when the bond is issued by one of the following governmental entities: GSE (government sponsored entities), local authorities, provincial authorities and sovereigns. Green is a dummy taking 1 when the bond has a green label. Brown is a dummy variable taking 1 when the bond is issued from 1 January, 2014 to 12 December, 2015; Paris takes 1 from 13 December, 2015 to 4 November, 2016; Green takes 1 from 5 November, 2016 to 18 October, 2019; Institutional takes 1 from 19 October, 2019 to 30 June, 2021. Robust standard errors are reported in parentheses. Symbols *, **, *** stand for statistically significance at 10%, 5%, 1%, respectively.

Also when following the time development, the government yield spread estimated according to equation (2) is negative and statistically significant in any of the four sub-periods (column 3). It ranges from 44 to 71 basis points and it does not show an evident time pattern.

In the fourth column we disentangle the effect of green bonds within the group of government bonds over time by relying on the triple interaction of time, government and green dummies. With the exception of the first brown period, the set of green bonds performs better than the conventional government bonds. Thus our evidence suggest that for the government aggregate the difference in the pricing of green bonds started only after the end of the COP21 meeting in Paris.

By construction, the control sample of the government bonds in the regressions in Table 3 is made by bonds issued by corporations and supranational institutions, regardless of being green or non-green. Thus, in order to device a fully fledged comparison of the cost of financing green projects, we have to rely on the subset of green bonds only. As already mentioned, the spread between Government green and corporate green bonds may be different from the same spread from conventional bonds for several reasons. For instance, the issuers of green bonds may be different from those of ordinary bonds in both the public and private sector, and the corporate greenium (which is a component of the green yield) may be different from the sovereign greenium, both in absolute value and over time.

In the next sections we focus on the global market of green bonds only, and by taking into account all the possible sources of difference across bonds, we assess whether the government shows a price advantage also when financing green projects.

5.2 Are government green bonds different?

When looking at the cost at issuance of green bonds only, it appears that the government is able to finance green projects at a discount with respect to all other sectors, in this sense, it is greener than other issuers.

Column 1 from Table 4 shows that when a dummy variable tracking the aggregate government is introduced in equation (1), the coefficient turns out to be negative and statistically significant at 59 basis points. In other words,

there is clear evidence of a (negative) government green spread (GGS) in the global segment of green bonds. The estimated value of the GGS is also economically relevant. Given that the unconditional mean of the yield at issuance on the universe of green bonds stands at 2.57% (see Table 2), the estimated discount amounts to 23% of the cost of funding.

Table 4. Green bonds: baseline regressions

	(1)	(2)	(3)
Paris Period	-0.1184	-0.1128	-0.1060
	(0.3425)	(0.3417)	(0.3436)
Green Period	0.1412	0.1500	0.1611
	(0.4134)	(0.4120)	(0.4162)
Institutional Period	-0.1452	-0.1188	-0.1169
	(0.4290)	(0.4277)	(0.4318)
Government Aggregate	-0.5890 ***		
	(0.0440)		
GSEs		-0.5497 ***	
		(0.0609)	
Local Authorities		-0.6757 ***	
		(0.0674)	
Provincial Authorities		-0.5475 ***	
		(0.0687)	
Sovereigns		-0.6708 ***	
		(0.1191)	
Brown*Government			-0.4754 ***
			(0.1649)
Paris*Government			-0.5470 ***
			(0.1886)
Green*Government			-0.5875 ***
			(0.0581)
Institutional*Government			-0.6235 ***
			(0.0574)
Bond and Issuer controls	YES	YES	YES
Financial stress controls	YES	YES	YES
Currency*Time dummies	YES	YES	YES
No. observations	5,905	5,905	5,905
R^2	0.898	0.899	0.898

This Table reports the estimated coefficients α_j and δ_j from equation (2). Brown period is a dummy variable taking 1 when bond i is issued from 1 January, 2014 to 12 December, 2015 and zero otherwise; Paris period from 13 December, 2015 to 4 November, 2016; Green period from 5 November, 2016 to 18 October, 2019; Institutional period from 19 October, 2019 to 30 June, 2021. Government is a dummy variable taking 1 when bond i is issued by one of the following governmental entities and zero otherwise: GSE (government sponsored entities), local authorities, provincial authorities and the sovereign. The dependent variable is the Yield at issuance. Robust standard errors are reported in parentheses. Symbols *, **, *** stand for statistically significance at 10%, 5%, 1%, respectively.

Are the distinct authorities belonging to the government aggregate behaving in the same way? Column 2 suggests that the phenomenon is common to all of them. The estimated coefficient for the GGS on each group is again negative and statistically significant. They also cluster in a bimodal distribution, with provincial authorities and GSEs at 55 basis points and sovereigns and municipal authorities at 67 basis points.

In order to check the evolution of the GGS over time, we estimate equation (2) when $feature_i$ is the government dummy (column 3). The first evidence is that the premium is confirmed in each of the four periods. In addition, it also seems that the GGS is increasing over time: from 48 basis points in the Brown period to 62 in the most recent Institutional period.[5]

A further investigation is proposed in Table 5 . Given the curious bimodal estimation of the coefficients of the different entities within the government aggregate, we check whether that pattern is a constant feature over time. Each column reports, in addition to the estimated coefficients of the interaction of the time dummies and the government dummy (top panel), the triple interaction of time, government and a dummy tracking a single group within the government aggregate. The former coefficients estimate the spread (positive or negative) witnessed by the aggregate government (now made out of the three groups that are not investigated in that column) with respect to all other green issuers. The latter coefficients estimate whether the selected group of governmental entities faces an additional spread (positive or negative) with respect to the other entities included in the government aggregate. For instance, column 1 in the top panel shows that the aggregate of governmental entities made by municipal authorities, sovereigns, and GSEs benefited from a spread ranging between 49 and 63 basis points over time. At the same time, the lower panel shows that in none of the periods did provincial authorities benefit from any additional spread, given that all the

[5]However, only the difference between the Brown period and the Institutional period is statistically significant (p-value<0.10).

coefficients of the lower panel are not statistically significant.

Table 5. Government entities comparison

	Provincial authorities	Local authorities	GSEs	Sovereigns
Brown*Government	-0.5568 ***	-0.4434 ***	-0.4445 ***	-0.4743 ***
	(0.1746)	(0.1732)	(0.2206)	(0.1649)
Paris*Government	-0.4917 ***	-0.5391 ***	-0.7015 ***	-0.5454 ***
	(0.1570)	(0.1907)	(0.2909)	(0.1855)
Green*Government	-0.6303 ***	-0.5351 ***	-0.6228 ***	-0.5931 ***
	(0.0628)	(0.0604)	(0.0671)	(0.0612)
Institutional*Government	-0.6280 ***	-0.6545 ***	-0.6246 ***	-0.5966 ***
	(0.0606)	(0.0619)	(0.0704)	(0.0611)
Brown*Government*Group	0.2368	-0.1200	-0.1018	-
	(0.3049)	(0.3174)	(0.2411)	
Paris*Government*Group	-0.1768	-0.1056	0.3236	-
	(0.2523)	(0.1738)	(0.3116)	
Green*Government*Group	0.0952	-0.2053 ***	0.1456	0.1300
	(0.0741)	(0.0725)	(0.1003)	(0.1773)
Institutional*Government*Group	-0.0002	0.1188	0.0099	-0.2347 *
	(0.0990)	(0.1045)	(0.0902)	(0.1351)
Bond and Issuer controls	YES	YES	YES	YES
Financial stress controls	YES	YES	YES	YES
Currency*Time dummies	YES	YES	YES	YES
No. observations	5,905	5,905	5,905	5,905
R^2	0.898	0.898	0.898	0.898

This Table reports in the top panel the estimated coefficients on the interaction of time dummies and the Government dummy; in the lower panel the triple interaction of time dummies, the Government dummy and a dummy tracking a given group within the Government aggregate (provincial authorties, local authorities, GSEs and the sovereign). Variables' definition are reported in Table 3. The dependent variable is the Yield at issuance. Robust standard errors are reported in parentheses. Symbols *, **, *** stand for statistically significance at 10%, 5%, 1%, respectively.

Also for the GSEs, there is not evidence of any additional spread over time (column 3). On the contrary, there is statistical evidence of a negative (additional) spread for the municipal authorities in the Green period and for the sovereigns in the Institutional period. In the Green period, the financing of green projects tailored to the local needs were the most appealing on the bond market. With respect to the other entities and authorities included in the government aggregate, they benefited from a further discount of 21 basis points (column 2). This might be due to the circumstance that, following the initial enthusiasm of the Paris agreement ratification, municipal authorities were able to implement green projects more swiftly than other

institutions. In addition, the concreteness and the tangible climate-friendly intensity of the local interest projects made them more appealing as suitable green investments and were rewarded by market investors.

A re-balancing of the destination of green bond proceeds towards more general-interest purposes took place in the last Institutional period. Indeed, the sovereign green bond issuance, that is usually associated to a macro green perspective (the financing of green projects that have a more general impact and more actively contribute to the abatement of CO2 emissions) increased since 2020 and in concomitance with the Covid-19 pandemic (Cheng et al. 2022, Baldi and Ferri 2022). Many countries, especially members of the European Union (EU), committed themselves to using increased fiscal spending to accelerate the green transition. Not only did several EU member states issued their inaugural sovereign green bonds during the Covid pandemic (Sweden, German, Hungary, Italy, and Spain), but the EU as a whole announced the aim of financing part of the pandemic response via green bonds (e.g., 30% of the Next-Generation-EU funds). The increasing role of sovereigns in the set up and financing of green projects has been rewarded by an additional market discount of 23 basis points with respect to the other governmental entities (column 4). This implies that in the Institutional period, the overall GGS spread with respect to non-governmental green issuers reached 83 basis points.

All in all, we found evidence that governmental entities benefited on the green bond market of a substantial premium. Moreover, the premium seems to be stronger in the most recent period characterized by a larger involvement of institutional players in the fight against climate change and an increased use of green bond proceeds for macro purposes. In the next Section, we investigate how some country-specific characteristics interact with the pricing of government green bonds.

6 Country specific characteristics

Are green issuers headquartered in countries with good climate scores rewarded by lower financing costs? Does the government still get better pricing with respect to other green issuers? In order to answer these questions, we rely on the GermanWatch indexes (Burk et al. 2022). In particular, countries are ranked according to three indexes: the general CCP Index, the Climate Policy sub-Index, and the Emissions sub-Index. Issuers from countries with the best ranking (top tercile) are tracked by an ad-hoc dummy variable. Following the notation of equation (2) we have that $feature_i$ takes the value 1 when bond i is issued by a firm/institution headquartered in a country with a good climate score (top tercile) and 0 otherwise (middle and lower terciles). In Table 6, the top panel reports in columns 1 to 3 the estimations of the selected climate index coefficients over time ($feature_i * Time_i$), whereas the lower panel reports the estimations of the triple interaction of time, climate Index and the government aggregate.

Regardless of the climate measure employed, there is evidence that in the most virtuous countries, the green issuance might be more costly than elsewhere. The top panel coefficients are statistically significant in several periods. This somewhat puzzling evidence may be explained by two circumstances. First, top values of the CCP Index, Climate Policy sub-Index, and Emissions sub-Index, while being attributed to countries with a good climate policy framework and a timely implementation of measures, may reflect stronger regulations and possibly higher carbon taxes. Firms issuing green bonds from those countries might thus be less competitive than international peers (IEA 2020, Bento et al. 2021). Secondly, early green placements might have been penalized because the firms issuing green bonds were those facing the most important challenges about adjusting the business model of production towards a reduction of CO2 and thus were less profitable. However, the top panel shows that in the most recent periods, this market disadvantage is disappearing, remaining statistically significant for the Climate Policy

sub-Index only.

Table 6. Climate change scores

	CCPI	Emissions	Climate Policy
Brown*Feature Top	1.1317 ***	0.9641 **	0.6666
	(0.4302)	(0.3896)	(0.4723)
Paris*Feature Top	0.4690 **	0.1266	0.2631
	(0.2349)	(0.2419)	(0.2515)
Green*Feature Top	0.3522 **	0.0513	0.5618 ***
	(0.1701)	(0.1699)	(01225)
Institutional*Feature Top	0.1224	-0.1408	0.2076 *
	(0.1590)	(0.1625)	(0.1186)
Brown*Feature Top*Government	-1.0578	-1.0098	-0.9727
	(0.8216)	(0.7878)	(0.6652)
Paris*Feature Top*Government	-0.0826	-0.0315	-0.4471 *
	(0.2154)	(0.2203)	(0.2691)
Green*Feature Top*Government	-0.4267 ***	-0.4006 **	-0.4883 ***
	(0.1556)	(0.1633)	(0.1441)
Institutional*Feature Top*Government	-0.5126 ***	-0.4472 ***	-0.6319 ***
	(0.1570)	(0.1599)	(0.1344)
Bond and Issuer controls	YES	YES	YES
Financial stress controls	YES	YES	YES
Currency*Time dummies	YES	YES	YES
No. observations	5,686	5,686	5,686
R^2	0.788	0.788	0.789

This Table reports in the top panel the estimated coefficients on the interaction of time dummies and the dummy Feature Top tracking the bonds for which the nationality of the issuer shows the feature under analysis (reported by column) in the top tercile; in the lower panel the triple interaction of time dummies, the dummy Feature Top and the Government dummy. The investigated features are: the Climate Change Performance Index (CCPI), the Greenhouse Gas Emission Index (Emissions), the Climate Policy Index (Climate Policy) sourced from GermanWatch. Variables' definition are reported in Table 3. The dependent variable is the Yield at issuance. Robust standard errors are reported in parentheses. Symbols *, **, *** stand for statistically significance at 10%, 5%, 1%, respectively.

Concerning the government, there is a significant cost advantage in green issuance, at least in the last two periods. The magnitude of the spread ranges between 40 and 63 basis points, in line with baseline estimations of the GGS in the previous Section. Thus, also in countries performing better in terms of climate actions, the government is associated to better funding conditions

for green projects.[6]

Table 7. Indebtedness and economic development

	Debt ratio	Income	Non-OECD
Brown*Feature Top	0.2426	0.9221 ***	0.7837 **
	(0.3874)	(0.3630)	(0.3626)
Paris*Feature Top	0.1845	1.0106 ***	0.3497 *
	(0.2753)	(0.3918)	(0.1877)
Green*Feature Top	0.1292	0.9963 ***	0.9434 ***
	(0.1897)	(0.2697)	(0.2409)
Institutional*Feature Top	0.6005 ***	0.6482 ***	0.5662 **
	(01990)	(0.2474)	(0.2468)
Brown*Feature Top*Government	-0.4199 **	0.3525	0.7648
	(0.1901)	(0.6334)	(1.1618)
Paris*Feature Top*Government	-0.6604 *	-1.0378	-0.5122 **
	(0.3528)	(1.1210)	(0.2601)
Green*Feature Top*Government	-0.5400 ***	-0.7212 **	-0.7351 **
	(0.1634)	(0.3169)	(0.3118)
Institutional*Feature Top*Government	-0.7787 ***	-0.7555 *	-0.6317 **
	(0.1780)	(0.4577)	(0.3524)
Bond and Issuer controls	YES	YES	YES
Financial stress controls	YES	YES	YES
Currency*Time dummies	YES	YES	YES
No. observations	5,905	5,861	5,905
R^2	0.792	0.810	0.794

This Table reports in the top panel the estimated coefficients on the interaction of time dummies and the dummy Feature Top tracking the bonds for which the nationality of the issuer shows the feature under analysis (reported by column) in the top tercile; in the lower panel the triple interaction of time dummies, the dummy Feature Top and the Government dummy. The investigated features are: the public debt GDP ratio (Debt ratio) sourced from the IMF; the economic development (Income) sourced from the World Bank. Column Non-OECD reports the estimated coefficients when the Feature Top is the non-belonging to the OECD group. Variables' definition are reported in Table 3. The dependent variable is the Yield at issuance. Robust standard errors are reported in parentheses. Symbols *, **, *** stand for statistically

A different set of questions is answered in Table 7: Are country characteristics as higher indebtedness and lower income correlated with the green

[6] Capelle-Blancard et al. (2019), comparing the return on sovereign bonds in 20 OECD countries, find that ESG performance significantly and negatively relates to sovereign bond yields. However, when considering the impact of the different ESG dimensions, they find that governance has a stronger impact than social performance and that environmental performance appears to have no significant impact.

bond pricing and the GGS?

While there is not evidence of a disadvantage in placing green bonds in highly indebted countries up to the Green period, column 1 reports that having a top tercile debt ratio is instead penalizing in the last period (top panel). The coefficient is estimated at 60 basis points, suggesting a large effect also from an economic point of view. This evidence squares well with the research on bond markets dynamics during the Covid pandemic, that suggests a more severe tightening of market conditions in countries fiscally constrained by high debt (Augustin et al. 2022, Cevik and Öztürkkal 2021, Nozawa and Qiu 2021). The advantage of the government in issuing green bonds is again large in all periods, ranging from 42 to 78 basis points.

Column 2 points instead to a strong price disadvantage of green issuers from low income countries. Firms and institutions from the lowest tercile of Real GDP (all the countries classified as low income and medium income by the World Bank) show a positive spread ranging from 92 to 101 basis points in the first three time periods (top panel). While still high, the spread declined to 65 basis points in the most recent Institutional period. This evidence points to a significant geographical fragmentation to the detriment of poor countries. However, focusing on the government's performance, the estimates reported in the lower panel suggest a much better market pricing with a relative advantage of 72 to 75 basis points in the last two periods. Thus, even in the difficult market conditions of low and medium- income countries, the government shows a sizable premium with respect to the other green issuers. The results are broadly confirmed when looking at those countries that do not belong to the OECD group (column 3).

7 Robustness

We propose several robustness checks along two lines. We first vary the public sector group and the private sector group of issuers, we then introduce

additional control variables concerning the sovereign creditworthiness.

Table 8. Robustness concerning the bond sample

	(1)	(2)	(3)	(4)
Paris Period	-0.1263	-0.1161	-0.0755	-0.0852
	(0.3437)	(0.3448)	(0.3724)	(0.3719)
Green Period	0.1470	0.1667	0.3413	0.3288
	(04166)	(0.4196)	(0.4691)	(0.4709)
Institutional Period	-0.1424	-0.1239	-0.0262	-0.0246
	(0.4325)	(0.4354)	(0.4880)	(0.4900)
Government Aggregate	-0.5808 ***		-0.6907 ***	
	(0.0470)		(0.0500)	
Brown*Government		-0.4722 ***		-0.8267 ***
		(0.1652)		(0.2060)
Paris*Government		-0.5464 ***		-0.6673 ***
		(0.1856)		(0.1594)
Green*Government		-0.5941 ***		-0.6618 ***
		(0.0617)		(0.0661)
Institutional*Government		-0.5903 ***		-0.7128 ***
		(0.0615)		(0.0625)
Bond and Issuer controls	YES	YES	YES	YES
Financial stress controls	YES	YES	YES	YES
Currency*Time dummies	YES	YES	YES	YES
No. observations	5,836	5,836	5,275	5,275
R^2	0.898	0.898	0.892	0.898

This Table reports the estimated coefficients α_j and δ_j from equation (2). Brown period is a dummy variable taking 1 when bond i is issued from 1 January, 2014 to 12 December, 2015 and zero otherwise; Paris period from 13 December, 2015 to 4 November, 2016; Green period from 5 November, 2016 to 18 October, 2019; Institutional period from 19 October, 2019 to 30 June, 2021. In column 1 and 2 Government is a dummy variable taking 1 when bond i is issued by one of the following governmental entities and zero otherwise: GSE (government sponsored entities), local authorities and provincial authorities; in column 3 and 4 also the sovereign is added. In column 3 and 4 multilateral development banks are dropped. The dependent variable is the Yield at issuance. Robust standard errors are reported in parentheses. Symbols *, **, *** stand for statistically significance at 10%, 5%, 1%, respectively.

Table 8 shows that the GGS does not change much when we take the sovereign out the public sector group, both over the whole time sample (column 1) and in each time period (column 2). The absence of the sovereign might be noted just in the last period: the GGS seems to level off instead of keeping increasing. This circumstance is consistent with the estimates from Table 5 that highlighted a better performance of sovereign green bonds in that period.

When excluding the multilateral development banks (MDBs) from the private sector group of issuers, we have an increase of the GGS estimate to 69 basis points over the whole time horizon (column 3). The difference with

respect to the baseline (Table 4, column 3) is particularly striking in the Brown period, increasing by 36 basis points to a spread of 83 basis points. This evidence is consistent with the findings of Fatica et al. (2021) that MDBs show a larger greenium than other green issuers. In addition, since MDBs were among the first institution issuing green bonds, it is not surprising to see a better performance in the Brown period.

Table 9. Robustness concerning the sovereign creditworthiness

	(1)	(2)	(3)	(4)	(5)	(6)
Paris Period	0.0869	0.0824	-0.1107	-0.0991	-0.0600	-0.0533
	(0.4793)	(0.4826)	(0.3428)	(0.3439)	(0.3521)	(0.3530)
Green Period	0.2972	0.2999	0.1630	0.1863	0.2536	0.2731
	(05181)	(0.5231)	(0.4133)	(0.4163)	(0.4345)	(0.4372)
Institutional Period	-0.0491	-0.0462	-0.1188	-0.0861	-0.0062	0.0226
	(0.5281)	(0.5343)	(0.4288)	(0.4317)	(0.4521)	(0.4551)
Sovereign Creditworthiness	0.1943	0.1955	0.1373	0.1390		
	(0.2344)	(0.2385)	(0.0831)	(0.0836)		
Government Aggregate	-0.5883 ***		-0.5878 ***		-0.5961 ***	
	(0.0445)		(0.0440)		(0.0445)	
Brown*Government		-0.6059 ***		-0.4810 ***		-0.5116 ***
		(0.1944)		(0.1651)		(0.1713)
Paris*Government		-0.5382 ***		-0.5159 ***		-0.5104 ***
		(0.1986)		(0.1841)		(0.1899)
Green*Government		-0.5886 ***		-0.5855 ***		-0.5934 ***
		(0.0590)		(0.0582)		(0.0590)
Institutional*Government		-0.5991 ***		-0.6247 ***		-0.6292 ***
		(0.0569)		(0.0575)		(0.0576)
Bond and Issuer controls	YES	YES	YES	YES	YES	YES
Financial stress controls	YES	YES	YES	YES	YES	YES
Currency*Time dummies	YES	YES	YES	YES	YES	YES
No. observations	5,346	5,346	5,902	5,902	5,905	5,905
R^2	0.903	0.903	0.899	0.898	0.899	0.898

This Table reports the estimated coefficients α_j and δ_j from equation (2). Brown period is a dummy variable taking 1 when bond i is issued from 1 January, 2014 to 12 December, 2015 and zero otherwise; Paris period from 13 December, 2015 to 4 November, 2016; Green period from 5 November, 2016 to 18 October, 2019; Institutional period from 19 October, 2019 to 30 June, 2021. Government Aggregate is a dummy taking 1 when bond i is issued by one of the following entities and zero otherwise: GSE (government sponsored entities), local authorities, provincial authorities and sovereigns. Sovereign creditworthiness is: the sovereign CDS in columns 1-2; the sovereign rating linearized between 1 (C) and 20 (AAA) in columns 3-4; the sovereign rating as a set of dummy variables (one for each notch) in columns 5-6.The dependent variable is the Yield at issuance. Robust standard errors are reported in parentheses. Symbols *, **, *** stand for statistically significance at 10%, 5%, 1%, respectively.

The second set of robustness checks concerns the role of the sovereign creditworthiness in driving the estimation results. In Table 9 column 1 and 2 we introduce the sovereign CDS as an additional control variable, in column 3 and 4 we add the sovereign rating as a variable ranging from 1 (C) to

20 (AAA) and in column 5 and 6 the sovereign rating as a set of dummy variables, one for each rating notch.

Not only is the sovereign creditworthiness never statistically significant, but also the overall GGS and the time dynamics remain almost entirely unaffected.

8 Conclusions

In this study, we provide empirical evidence on the pricing of green bonds in the global financial market. Specifically, we focus on the borrowing cost associated with green projects. We distinguish from most of the current literature since we look at the differences in the yield across green bonds. We differentiate between green bonds issued by the public sector and green bonds issued by the private sector (including supranational entities such as multilateral development banks). In particular, we define the government aggregate as made by the central authority (sovereign), municipal authorities, provincial authorities, and government sponsored entities (GSEs).

By considering motivations, costs, and constraints of issuing green bonds, such as the commitment to funding green projects and the additional administrative and compliance requirements, we rely on the working hypothesis that the decision-making process that leads to the issuance of a green bond is different across issuers. While governments have an encompassing view on the negative externalities stemming from climate change (macro approach), private entities take into account green projects only if they have also a positive business return (micro approach).

We find that the government always faces a lower funding cost than private sector corporations and supranational institutions: the spread between government green bonds and all other green bonds being estimated in the range 55-68 basis points. Furthermore, we find that in the most recent period, when the attention on climate change involved also additional authorities

such as central banks and the EU, and witnessed a buoyant green bond market entrance of sovereigns all around the world (Ecuador, Egypt, Germany, Hungary, Italy, Sweden and Thailand among others), the market advantage of government increased, especially for sovereigns.

The consistently lower funding costs of governmental entities than private sector corporations and supranational institutions underscores the pivotal role of the government in financing large-scale projects aimed at carbon neutrality and curbing CO2 emissions and suggests the possibility to leverage this funding advantage. On the one hand, domestic and supranational policymakers could seize this advantage by creating favorable regulatory frameworks and policies that encourage the government to issue green bonds. By doing so, the government can finance crucial climate related projects more efficiently, thereby accelerating the transition to a greener economy. On the other hand, policymakers should also tailor policies for the private sector, given the significant yield spread observed between government and other issuers' green bonds. This might include: providing financial incentives, offering regulatory guidance, facilitating partnerships between public and private entities to promote sustainable investments. By supporting these issuers, policymakers can increase the size of the market, diversify the green bond issuers and stimulate further investments.

Even though the government maintains a comparative advantage, when looking specific country characteristics, we find that the cost of green issuance is negatively correlated with the level of development and positively correlated with the debt to GDP ratio. Thus, policymakers in highly indebted countries and less developed economies should be aware of the potential penalty green bond issuers could face and implement a set of comprehensive measures providing certainty and long-term support for green projects. In several periods, we also find a negative correlation between climate scores and the cost of green issuance. This puzzling evidence may be partly related to the circumstance that in countries explicitly pricing carbon through tax

and/or cap-and-trade programs, the international economic competitiveness of some companies may be negatively affected (IEA 2020, Bento et al. 2021).

In summary, the study highlights the multi-faceted policy implications that arise from the analysis of green bonds in the global financial market. Policymakers are encouraged to adopt a proactive approach in creating an encompassing environment that sustains the heterogeneous set of green bond issuers. To achieve this, policymakers should consider implementing tailored policies, providing targeted financial incentives, and fostering market development. By designing specific policies that address the diversified challenges faced by different types of issuers, they can encourage broader participation in the green bond market. This, in turn, will expedite the transition to a more sustainable and resilient future by financing initiatives aimed at carbon neutrality and CO2 emissions reduction.

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Appendix

Table A1. List of entities included in the Government aggregate

Issuer	Nationality	Sector	Bonds
Banco Nacional de Desenvolvimento Economico e Social	Brazil	Government Entity	2
Export Development Canada-EDC	Canada	Government Entity	5
Export-Import Bank of China	China	Government Entity	1
Agricultural Development Bank of China	China	Government Entity	5
China Development Bank Corp	China	Government Entity	9
Banco de Comercio Exterior de Colombia SA	Colombia	Government Entity	1
KommuneKredit	Denmark	Government Entity	5
Municipality Finance plc	Finland	Government Entity	6
Bpifrance SA	France	Government Entity	1
Caisse Francaise de Financement Local	France	Government Entity	1
Caisse des Depots et Consignations - CDC	France	Government Entity	1
Societe de Financement Local-SFIL	France	Government Entity	1
Agence Francaise de Developpement - AFD	France	Government Entity	4
Landwirtschaftliche Rentenbank	Germany	Government Entity	7
NRW.Bank	Germany	Government Entity	9
KfW Bankengruppe - KFW	Germany	Government Entity	61
Indian Railway Finance Corp Ltd	India	Government Entity	1
Power Finance Corp Ltd	India	Government Entity	1
REC Ltd	India	Government Entity	1
PT Adira Dinamika Multi Finance Tbk	Indonesia	Government Entity	1
PT Sarana Multi Infrastruktur (Persero)	Indonesia	Government Entity	2
Development Bank of Japan Inc	Japan	Government Entity	2
Japan Finance Organization for Municipalities	Japan	Government Entity	2
Japan Housing Finance Agency	Japan	Government Entity	24
Nacional Financiera SNC - Nafinsa	Mexico	Government Entity	2
Nederlandse Financierings-Maatschappij voor Ontwikkelingslanden	Netherlands	Government Entity	2
BNG Bank NV	Netherlands	Government Entity	4
Nederlandse Waterschapsbank NV	Netherlands	Government Entity	24
Kommunalbanken AS	Norway	Government Entity	23
Slovene Export & Development Bank dd - SID Banka	Slovenia	Government Entity	1
Korea Land & Housing Corp	South Korea	Government Entity	2
Korea Development Bank - KDB	South Korea	Government Entity	8
Export-Import Bank of Korea - KEXIM	South Korea	Government Entity	9
Instituto de Credito Oficial - ICO	Spain	Government Entity	3
Svensk Exportkredit AB (Swedish Export Credit Corp-SEK)	Sweden	Government Entity	16
Kommuninvest i Sverige AB	Sweden	Government Entity	20

Table A1. List of entities included in the Government aggregate (continued)

Issuer	Nationality	Sector	Bonds
FREMF Mortgage Trust	United States	Government Entity	6
Fannie Mae Multifamily REMIC Trust	United States	Government Entity	26
United States International Development Finance Corp	United States	Government Entity	32
Province of La Rioja	Argentina	Local Authority	5
City of Ottawa	Canada	Local Authority	3
City of Toronto	Canada	Local Authority	3
Municipality of Laukaa	Finland	Local Authority	1
City of Paris	France	Local Authority	1
Tokyo Metropolitan Government	Japan	Local Authority	10
Auckland Council	New Zealand	Local Authority	3
City of Oslo	Norway	Local Authority	1
City of Cape Town	South Africa	Local Authority	1
City of Johannesburg South Africa	South Africa	Local Authority	1
Linkoping Municipality	Sweden	Local Authority	1
Municipality of Nacka	Sweden	Local Authority	1
City of Norrkoping	Sweden	Local Authority	2
City of Stockholm	Sweden	Local Authority	2
City of Vasteras	Sweden	Local Authority	2
City of Vellinge	Sweden	Local Authority	5
Municipality of Lund	Sweden	Local Authority	5
Municipality of Ostersunds	Sweden	Local Authority	5
City of Malmo	Sweden	Local Authority	7
City of Orebro	Sweden	Local Authority	12
City of Gothenburg	Sweden	Local Authority	16
City of Long Beach (CA)	United States	Local Authority	2
Placer County Public Financing Authority	United States	Local Authority	2
San Diego County Water Authority	United States	Local Authority	4
San Rafael Joint Powers Financing Authority	United States	Local Authority	14
Fairfax County Economic Development Authority	United States	Local Authority	16
City & County of Honolulu	United States	Local Authority	17
City of Saint Paul (MN)	United States	Local Authority	19
City of Berkeley (CA)	United States	Local Authority	20
City of Spokane (WA)	United States	Local Authority	20
Midpeninsula Regional Open Space District	United States	Local Authority	21
King County (WA)	United States	Local Authority	22
City of Tampa (FL)	United States	Local Authority	23

Table A1. List of entities included in the Government aggregate (continued)

Issuer	Nationality	Sector	Bonds
Public Utility District No 1 of Pend Oreille County (WA)	United States	Local Authority	24
National City, Minneapolis	United States	Local Authority	25
City of Los Angeles (CA)	United States	Local Authority	30
Metropolitan Transportation Authority (NY)	United States	Local Authority	44
Public Utilities Commission of the City & County of San Francisco	United States	Local Authority	48
Province of Jujuy	Argentina	Provincial Authority	2
Treasury Corp of Victoria	Australia	Provincial Authority	2
New South Wales Treasury Corp	Australia	Provincial Authority	3
Queensland Treasury Corp	Australia	Provincial Authority	3
Province of Quebec	Canada	Provincial Authority	6
Province of Ontario	Canada	Provincial Authority	9
Departement de l'Essonne	France	Provincial Authority	2
Region Limousin	France	Provincial Authority	2
Region des Pays de la Loire	France	Provincial Authority	3
Federal State of Baden-Wuerttemberg	Germany	Provincial Authority	2
Federal State of Hessen	Germany	Provincial Authority	2
Federal State of North Rhine-Westphalia	Germany	Provincial Authority	2
Kanagawa Prefectural Government	Japan	Provincial Authority	2
Nagano Prefectural Government	Japan	Provincial Authority	2
Autonomous Community of Madrid	Spain	Provincial Authority	2
Vastra Gotalandsregionen (VGR)	Sweden	Provincial Authority	2
Skane County	Sweden	Provincial Authority	8
Stockholms Lans Landsting (Stockholm County Council)	Sweden	Provincial Authority	15
Kanton Basel-Stadt	Switzerland	Provincial Authority	3
Canton of Geneva	Switzerland	Provincial Authority	5
California Health Facilities Financing Authority	United States	Provincial Authority	2
Louisiana Local Government Environmental Facilities & Community DA	United States	Provincial Authority	2
Pennsylvania Economic Development Financing Authority	United States	Provincial Authority	2
State of Nevada	United States	Provincial Authority	2
Connecticut Green Bank	United States	Provincial Authority	2
California Pollution Control Financing Authority	United States	Provincial Authority	3
State of California	United States	Provincial Authority	4
Commonwealth of Massachusetts	United States	Provincial Authority	7
State of Michigan	United States	Provincial Authority	7
New York State Energy Research & Development Authority	United States	Provincial Authority	8
California Statewide Communities Development Authority	United States	Provincial Authority	16

Table A1. List of entities included in the Government aggregate (continued)

Issuer	Nationality	Sector	Bonds
New York State Dormitory Authority	United States	Provincial Authority	17
California Educational Facilities Authority	United States	Provincial Authority	22
Massachusetts Clean Water Trust	United States	Provincial Authority	22
State of Connecticut	United States	Provincial Authority	24
Massachusetts Water Resources Authority	United States	Provincial Authority	25
Rhode Island Infrastructure Bank	United States	Provincial Authority	27
Illinois Finance Authority	United States	Provincial Authority	34
California Infrastructure & Economic Development Bank	United States	Provincial Authority	39
Indiana Finance Authority	United States	Provincial Authority	77
New Jersey Environmental Infrastructure Trust	United States	Provincial Authority	78
New York State Housing Finance Agency	United States	Provincial Authority	100
Kingdom of Belgium	Belgium	Sovereign	5
Republic of Chile	Chile	Sovereign	8
Arab Republic of Egypt	Egypt	Sovereign	2
Republic of France	France	Sovereign	13
Federal Republic of Germany	Germany	Sovereign	3
Hong Kong Special Administrative Region-HKSAR	Hong Kong	Sovereign	8
Republic of Hungary	Hungary	Sovereign	4
Republic of Indonesia	Indonesia	Sovereign	10
Republic of Ireland	Ireland	Sovereign	3
Republic of Italy	Italy	Sovereign	1
Republic of Lithuania	Lithuania	Sovereign	1
Kingdom of the Netherlands	Netherlands	Sovereign	4
Republic of Poland	Poland	Sovereign	4
Kingdom of Sweden	Sweden	Sovereign	2

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