The Role of ESG Scoring and Greenwashing Risk in Explaining the Yields of Green Bonds: A Conceptual Framework and an Econometric Analysis

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Abstract

This article aims to investigate the factors that most influence the yields of public sector and corporate green bonds besides those conveyed by the conventional finance theory (e.g., rating, volatility, maturity). To accomplish that, we first develop a theoretical framework that postulates the negative relationship between the size of the underlying project financed by a green bond issuance, the use of the ESG metrics to quantify such impact, as well as the positive relationship between the risk of greenwashing practices by the issuer, and the yield to maturity of the green bond. We then provide an empirical validation of our conceptual framework by estimating multiple regression models applied to two distinct samples of public and corporate green bonds issued globally in the 2012-2020 period. The reliability of our results is confirmed by further exploring the effects of some key determinants on the yield spread of green versus comparable ordinary bonds of corporate issuers. Our findings corroborate our theoretical predictions showing that investors are inclined to accept lower returns in exchange for contributing to the funding of infrastructure projects with greater impact on the sustainability of target communities or territories and require higher premia as a form of compensation when being exposed to higher risk of greenwashing by issuers. At corporate level, greenwashing risk is higher among manufacturing (rather than services) firms but more pronounced in the financial sector. At public level, greenwashing strategies may be more easily pursued by multinational or sovereign issuers rather than local governments as the former's greater distance from communities enables them to elude investors' controls. Important recommendations are drawn for investors, rating agencies, and policymakers.

Keywords: Green Bonds; Yield to Maturity; Greenwashing; Green Premium.

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1. Introduction

In the last decade, continuous climatic and environmental shocks have urged our society to accelerate the transition to a more sustainable development and, ultimately, a zero-pollution, green economy. Sustainable finance is soaring in popularity across global markets to financially support the green transition as the world aims to address these compelling climate change and clean energy issues while also recovering from the on-going COVID-19 pandemic. In response to the above challenges, sustainable finance encompasses new debt securities, such as green loans granted by multilateral and commercial banks or green bonds (GBs) issued by public sector entities and private firms, as well as ESG (Environmental, Social and Governance) investments.

The COVID-19 pandemic has led to the contraction of capital allocation away from publicly or privately-promoted sustainable investment projects, mostly causing their delay and thus jeopardizing the timely achievement of climate-related goals (Taghizadeh-Hesary, Yoshino and Phoumin, 2021; Tu and Rasoulinezhad, 2021). However, to the extent that new country or regional stimulus packages, such as the NextGenerationEU adopted by the European Commission or the US International Climate Finance Plan, are aimed at facilitating the economic recovery by redirecting capital into green investments, it is important to further investigate the characteristics of sustainable finance instruments, such as green bonds, as means for raising public and private funding.[1] Two are the main reasons why further studies on GBs are required. The global SDG-compliant, sustainable infrastructure gap that should be closed by 2040 amounts to $15 trillion (G20 Global Infrastructure Outlook, June 2018).[2] GB issuances may significantly contribute to financing the construction (and/or revamp) of sustainable, greenfield (and/or brownfield) infrastructures. Moreover, the need for studying the dynamics of the GB market is reinforced by the fact that the growth of such debt securities in international markets has not been slowed down by the COVID-19 pandemic. Since market inception in 2007, GB issuances have grown at an annual compound rate of 58% (as of December 2020). The amount of the GBs issued globally only in the first six months of 2021 reached $248.1 billion exceeding the record-breaking figure of all 2020 ($269.5 billion) (Climate Bonds Initiative, January 2021; World Economic Forum, July 2021). GB issuance is expected to further increase by 25% to about €565 billion in 2022 based on the EU Commission's pledge

[1] The EU Commission has planned to issue GBs amounting to €250 billion between 2021 and 2027 to finance the NextGenerationEU program.

[2] The Sustainable Development Goals (SDGs) are a universal call to action to end poverty, protect the planet and improve the lives and prospects of all individuals around the world. The 17 SDGs were adopted by all United Nations' Member States in 2015, as part of the 2030 Agenda for Sustainable Development.

to issue up to $280 billion in GBs under its recovery plan (2021-2027) (NN Investment Partners, October 2021).

Following their fast-growing trends across global markets, GBs have attracted the increasing attention of researchers, with extant literature seeking to study the existence of a *green premium* compared to comparable conventional bonds (Hachenberg and Schiereck, 2018; Bachelet et al., 2019; Zerbib, 2019), the impact of liquidity risk on the yield spread (Febi et al., 2018), the contribution of disclosure to the increase of secondary market liquidity (Lebelle et al., 2022), the role of third-party certification in determining market response (Flammer, 2021) for both types of public sector (Heine et al., 2019) and corporate GBs (Flammer, 2021). However, the role of the expected impact of the infrastructure financed by the GB issuance on the sustainability of the target community, the measurement of such impact through the recourse to the ESG metrics and the deceptive greenwashing practices of the issuer in explaining the yields, and more in general, the risk/return profiles of GBs is still under-investigated. Our study attempts to fill this research gap.

In this regard, it is worth highlighting that the GB market has been improved by the widespread development of ESG rating models by specialized organizations (e.g., rating agencies) leading to the assignment to GB issuers of green impact evaluation scores, typically expressed on a scale of 0-100 and converted into a synthetic (alphanumeric) judgement, aimed at measuring the degree of sustainability of the underlying project that is being financed through the bond placement. Hence, the quality of the GB issuance is linked to the actual impact of the underlying infrastructure on the sustainability of the target territory. A GB is also often certified by an independent, specialized auditor that must verify the compliance of the Green Bond Framework, a document in which the issuer explains the use of proceeds for financing the underlying target infrastructure(s), with the prevailing (voluntary, market-released) reporting standards, the so called Green Bond Principles (ICMA, 2021). Such independent certification reduces the information asymmetries between issuers and investors (Zhiyong et al., 2019). By signaling to the market their propensity for financial innovation and corporate social responsibility (Xiaoguang and Yadi, 2019), GB issuers can also enhance corporate value creation, thus benefiting shareholders in the long run (Tang and Zhang, 2020).

Despite the above advantages, GB issuing may also be characterized by the negative practice of greenwashing: that is the process of conveying (by deceptively announcing but not effectively implementing the sustainable projects to be financed through the placement of GBs move A below to here) misleading information about the extent to which the public or corporate issuer is environmentally and/or socially committed. The empirical evidence on greenwashing

is still scarce (Flammer, 2021), but its diffusion should not be underestimated considering the increasing issues of GBs in the private sector, where such deceptive strategies are less subject to investors' control mechanisms.[3]

The contribution of this article to the extant research on GBs is three-fold. First, we develop a conceptual framework aimed at hypothesizing the relationship between the sustainable impact, the ESG dimension and the greenwashing risk associated with the project financed by GBs and the yields of GBs, while also controlling for the conventional factors, such as credit rating and price volatility, employed in most studies on bond returns (Fisher, 1959; Katz, 1974; Jarrow, 1978; Litterman and Scheinkman, 1991). In so doing, we apply our theoretical framework to both public and corporate issuers. Second, we provide an empirical validation of our theoretical approach through the estimation of an econometric model applied to two distinct samples of public sector and corporate GBs issued globally over the recent decade. In line with most recent studies, we also conduct robustness checks on our empirical findings to confirm that they are reliable by explaining the spread between the yields of corporate GBs and those of their comparable ordinary bonds issued by the same firm with most of the factors used in the main econometric analysis. Third, our empirical evidence allows us to infer practical implications for investors, rating agencies and policymakers so as to improve the features and economic benefits of GB issuances to financial markets and the society as a whole.

The article is organized as follows. Section 2 briefly reviews the most relevant literature on GBs. Section 3 presents our proposed conceptual framework for advancing the understanding of GBs' yields and the related set of testable hypotheses. Section 4 highlights the emerging importance of GBs as sustainable finance instruments by outlining the most recent global trends of their issuances. Section 4 describes the data used to conduct our econometric analysis, the methodological approach to empirically validating our theoretical model, the findings obtained, and the robustness checks. Section 5 concludes by drawing some key recommendations for investors, rating agencies, and policymakers.

2. Literature Review

Although the literature on GBs is still limited, in the last five years researchers have produced several studies, mainly of empirical nature, that show how GBs are an effective tool to combat climate change especially in the post COVID era, in which capital resources to finance green

[3] For instance, since 2016 Apple has issued GBs worth $4.7 billion, including an amount of $2.8 billion issued most recently. In 2020, Bank of China issued GBs worth $44 billion in the Asian market. In 2021, Unicredit, the multinational banking group based in Italy, issued GBs amounting to €1.1 billion.

projects have been reduced. Research has mainly investigated the differences between risk and return of GBs compared to other bonds. One of the main research topics has concerned the verification of a *green premium*, also called *greenium*, associated with the issuance of GBs, which in fact makes the issuance of these bonds more convenient than that of traditional bonds. For example, Gianfrate and Peri (2019), by analyzing 121 European GBs issued between 2013 and 2017, find evidence that GBs are financially better than non-green bonds. The advantage is greater for corporate issuers and persists in the secondary market. Thus, GBs can be an effective way of achieving a lower cost of capital for organizations that need to finance or refinance green projects. Hachenberg and Schiereck (2018) compare the risk-return profiles of GBs with those of conventional (non-green) bonds by comparing the daily spreads of GBs with those of conventional bonds and study their price differentials in a sample of 7032 GBs and 14064 non-green bonds during the 2015-2016 period. Their evidence shows that the spreads of AA-BBB rating classes of GBs are marginally tighter than those of non-green bonds of the same issuers. Moreover, the spreads of corporate GBs are smaller than their non-green counterparts, while for government GBs they are marginally wider. Based on a sample of 89 bond pairs, Bachelet et al. (2019) find that GBs have higher yields, are more liquid and less volatile than their closer counterparts in traditional bonds. More specifically, institutional GBs show a negative premium, while corporate GBs have a positive premium, unless the private issuer is committed to certifying the "greenness" of the bond. Overall, GBs can enjoy a negative premium and thus green investments can be financed at a discount. Hachenberg and Schiereck (2018) provide evidence that GBs on average do not trade significantly tighter than their counterparts. Zerbib (2019)'s study reveals that the yield of a GB is lower than that of a conventional bond (- 2 basis points), thus implying a negative premium, which is more evident for financial and low-rated bonds. Another aspect that can somewhat influence GB yields is related to the total amount of the issue. As pointed out by Maltais and Nykvist (2020), another potential incentive for investors is associated with the size of the market and that of institutional investors. Similar results are obtained also by Naqvi et al. (2021) by comparing the performances of 2339 funds (416 renewable and 1923 conventional).

Only a few academic works have focused on public sector GBs. Braga (2020) surveyed the literature on GBs issued by the public sector highlighting the following: that although the public sector plays a key role in fostering the green transition and reducing the costs of green initiatives, studies on the performance of GBs issued by the public sector are still unclear. Regarding municipal bonds, Karpf and Mandel (2018) find that green issues appear to pay lower yields than comparable conventional bonds, thus leading to the so-called *green premium*.

Moreover, Abubakr Naeem, et al. (2021) investigated how GB yields react to changes in commodity yields, using the daily yields of these bonds over the period 1/12/2008 to 31/12/2019. Their analysis, using the cross-quantile methodology, shows an asymmetric relationship between the returns of GBs and commodities. Thus, the composition of green portfolios not only increases environmental commitment but also reduces portfolio risk. Slightly different results are found by Taghizadeh-Hesary et al. (2021), who conducted a comparative study of the characteristics, risks, and returns of GBs, using panel data over the period 2007-2020, with a particular focus on GBs issued in Asia and the Pacific. Their results show that GBs in Asia tend to show higher yields with higher risks associated with them, except for GBs issued by the banking sector, which tend to show below-average yields. The authors suggest that in the post-COVID era, policies that could increase the rate of return on bonds issued by the banking sector using fiscal spillover could be used to encourage the resumption of investment in green projects; in addition, diversification of issuers with greater public sector participation could also be considered.

Aside from their generally low returns and sometimes higher risks, GBs also pose a challenge to their issuers. Anh Tu et al. (2021), stemming from the lack of capital in green projects due to the pandemic, propose a study to measure the impact of the link between the energy efficiency index and GBs in 37 OECD countries, with quarterly data over the period 2007-2020. The main results identify a significant impact of GBs on the energy efficiency index: a 1% increase in GBs issued would increase the energy efficiency index in OECD countries by about 0.95%. Therefore, GBs could become a policy instrument to push energy efficiency, thereby improving environmental quality during and after the COVID period. Wiśniewski and Zieliński (2019) also argue that sovereign GB issuance is the easiest way to attract investors and potentially increase the size of issues that can help reduce the cost of financing sustainable infrastructure. In addition, Heine et al. (2019) argue that public sector GBs can help accelerate the sustainable transition, especially if such issuance is coupled with active carbon pricing policies. More specifically, they argue that the issuance of GBs helps enable immediate investments in climate change mitigation and adaptation, and the bonds would be repaid by future generations in such a way that those who benefit from reducing future environmental damage share the burden of financing mitigation efforts undertaken today.

Taghizadeh-Hesary and Yoshino (2019) propose, instead, a theoretical model by which, through credit guarantee schemes and the fiscal return of the spillover effect, one could reduce the risk and increase the return of these green projects, thus encouraging greater expansion of the GB market.

Among the factors influencing the expansion of the GB market, Anh Tu et al., by employing a multi-criteria decision-making method (MCDM) called analytical hierarchy process (AHP), highlight that financial and infrastructure-driven criteria play the most important role in the expansion of the GB market in Vietnam.

Finally, the documentation required for the issue of green bonds and its readability play a very important role in the green bond market. Flammer (2021) shows that the stock market responds positively to the announcement of GB issuance especially if they are certified by independent third parties. Moreover, albeit the liquidity risk is negligible for GBs (Febi et al., 2018), Lebelle et al (2022), using a sample of 274 green bonds issued in 23 countries between 2011-2018, find strong evidence that the disclosure of documentation together with the documents' readability may increase the liquidity of GB trading on the secondary market, especially for bonds issued from firms operating in non-financial sectors, showing that transparency efforts play an important role for the liquidity of such debt securities.

3. Hypotheses' Development and Conceptual Framework

The main results on the nature of the global GB market arising from the most recent research described above are used to develop a set of five hypotheses (H1-H5). To our knowledge, all of our hypotheses are new and, in this respect, they represent novel contributions to the extant literature on the characteristics of GBs and their market dynamics. We therefore posit that:

H1. *The higher the size of the GB issuance (reflecting that of the underlying infrastructure to be financed), the lower the yield to maturity required by investors that are compensated for by the sustainability impact increasing in the size of the infrastructural asset.*

H2. *Investors in GBs of local governments (that are closer to constituencies and their needs) require lower yields in exchange for the expected higher impact of the underlying infrastructure at local level.*

H3. *The higher (lower) the sustainability/ESG features of the infrastructure financed by the GB issuance, the lower (higher) the yield investors are willing to accept (forego) if called on to contribute to the realization of such infrastructural asset. This applies to both public sector and corporate GBs.*

H4. *A lower risk of greenwashing is associated with GB issuances made by local governments (as compared to States or SNATs) as their greater proximity to citizens/investors facilitates the latter's activity of monitoring the realization of impactful infrastructures.*

H5. *A lower risk of greenwashing is associated with GB issuances made by services firms as compared to manufacturing firms, thus requiring a lower premium by investors.*

The above set of hypotheses, which will be empirically tested through our econometric model (described in paragraph 5), can be summarized in a comprehensive conceptual framework. More specifically, we have developed two conceptual frameworks of testable predictions for public sector and corporate GBs. The first conceptual framework refers to public GBs and is reported in Figure 1, Panel A; the second conceptual framework refers to corporate GBs and is reported in Figure 1, Panel B. The public GBs' framework includes the hypotheses H1, H2, H3 and H4, while the corporate GBs' framework accounts for the hypotheses H3 and H5. Both conceptual frameworks are diagrams where solid lines represent direct effects of predictions on the yield to maturity of GBs (grey box). The white boxes positioned vertically opposite to the grey box epitomize the relationship between the issuer's credit rating and the market price volatility and the yield of GBs consistently with the standard finance theory. The white boxes of Panel A (public GBs), positioned vertically to the left of the grey box, depict our proposed theoretical predictions on the relationship between the size of the underlying infrastructure financed via the GB issuance, the type of public sector entity issuing the GB (and the related risk of greenwashing practices), the use of the ESG metrics for the selection of the GB-funded project and the yield to maturity of the bond. The white boxes of Panel B (corporate GBs), positioned vertically to the left of the grey box, depict our proposed theoretical predictions on the relationship between the use of the ESG metrics for the selection of the GB-funded project, the sector of the corporate issuer, the associated risk of greenwashing practices and the yield to maturity of the bond. The expected signs of all of these relationships are indicated at the end of the solid lines.

[INSERT FIGURE 1 ABOUT HERE]

Our theoretical framework and the empirical testing of the related set of hypotheses seeks to complement prior studies with new empirical evidence from the global GB market so as to advance the comprehension of the most relevant determinants of the performance of this new asset class.

4. Global Trends in Green Bonds' Issuances

GBs issued in international capital markets as of December 2020 accounted for 3.5% of total bond issuance (2016 was just under 1%).[4] This highlights the significant growth that this

[4] NN Investment Partners, *Green Bond Funds Impact Report 2020*, July 2021.

segment of debt securities has experienced over the last five years. As with traditional bonds, GBs can be issued by private companies (corporate segment) or by public sector institutions (e.g., states, local authorities). Although the public sector initially predominated in the placement of GBs, currently the main issuers of this type of bond are private companies operating in a variety of industries (e.g., energy, telecommunications, etc.).

Following the significant growth experienced by the GB market in the past four years, the European Central Bank has already adapted its asset purchase program by starting buying GBs issued by firms operating in less polluting industries to support the climate transition (Brunnermeier and Landau, 2022).

To explore the origins and the most recent patterns of the global GB market, we have conducted a detailed analysis based on a sample of 3,635 GBs issued internationally by both corporate and public sector entities in the period 2007-2020 (source: Bloomberg). Our sample includes GBs (with fixed and floating rates) amounting to €872.3 billion, €783.6 billion of which was still outstanding and tradable as of December 2020.

Figure 2 shows the evolution of GB issuances in international capital markets between 2007 and 2020. Since 2017, the number and volume of GBs issuances have increased significantly. In 2019, the volume of issuance increased by about 68% compared to 2018 (€219.4 billion GBs in 2019 versus 130.6 € billion GBs recorded in 2018). In 2020, the amount of GBs issued was €221.4 billion with a total number of issues of 886 (in 2017, the number of GBs issued was 456, an increase of 94.3%).

[INSERT FIGURE 2 ABOUT HERE]

The sample of GBs currently tradable on capital markets includes both corporate issues and issues from public sector institutions. In particular, the latter category of bonds includes issuers of three types: (i) states; (ii) local governments; and (iii) supranational organizations (so-called SNATs), such as the European Investment Bank (EIB), or the European Bank for Reconstruction and Development (EBRD). Figure 3 shows that the most of GBs in circulation today have been issued by private companies (68%; 532.7 € billion). The share of GBs issued by public sector entities to finance sustainable infrastructure projects is still in the minority. More specifically, States (i.e., Central Government Treasuries) have issued 10% of the outstanding GBs (€80.8 billion); local governments have issued 14% of the total GBs (€107.4 billion); SNATs the remaining 8% (€62.7 billion).

[INSERT FIGURE 3 ABOUT HERE]

Regarding the amounts placed, although the corporate segment has only started issuing GBs since 2013, the growth of their issuance over time has proceeded at a high pace so that - as shown in Figure 4 - the market is now driven by private company debt. In 2020 alone, the amount of GBs issued by the corporate segment was €158.2 billion, representing 20.2% of the market. Local authorities, in the same period, issued securities for a total of 33.4 billion euros, equal to 4.3% of the market. This was followed by sovereign issues made by governments, with a countervalue of €20.2 billion (2.6% of the market). Finally, supranational organizations issued GBs amounting to 9.5 billion euros in 2020 (1.2% of the market).

[INSERT FIGURE 4 ABOUT HERE]

5. Econometric analysis: Data, Findings and Robustness

5.1 Data

To construct a sample of GBs issued at global level and investigate the dynamics of this new asset class across the international markets and the factors that most influence their yields we have retrieved data from Bloomberg using the related Green Bond Indicator Function.[5] In particular, we have selected a sample of 199 observations related to GBs issued by the public sector and a sample of 199 observations related to GBs issued by the corporate segment (private companies). The dataset used spans the 2012-2019 period for public sector GBs and the 2013-2019 period for corporate GBs. The choice of the 2012-2019 interval for public GBs is based on the combination of three reasons: (1) 2012 is the year where the GB market only including issuances by SNATs started experiencing a significant growth; (2) GBs issued by local governments can be fully incorporated as those issuances were initiated in 2013; (3) the phenomenon of sovereign GBs can be fully blended as the first GB issuance by a State (Poland) was made in 2016. The choice of the 2013-2019 interval for corporate GBs is explained by the combination of two reasons: (1) corporate GBs were first issued in 2013; (2) the steady growth of corporate GB issuances was observed between 2013 and 2019. The number of observations

[5] Bloomberg classifies bonds with the "Green Bond" label in the Use of Proceeds field when an issuer self-labels its bond as "green" or identifies it as an environmental sustainability-oriented bond issue with clear additional statements about the company's commitment to deploy funds toward projects and activities in the above categories.

used in our econometric analysis is limited by the availability of data for the construction of our regressors (e.g., ESG metrics, price volatility). Yields to maturity of GBs are referred to December 2020. Table 1 shows the descriptive statistics of our data concerning GBs issued by public sector entities and corporates.

[INSERT TABLE 1 ABOUT HERE]

Our data show that the average yield to maturity is higher in the corporate segment (1.8%) than in the public sector (0.8%) by one percentage point; however, yields of public sector GBs show less variability, thus confirming the theoretical notion that lower yields are associated with lower risk.[6] The average size of issuances is similar for the two sectors, with an amount of just €546 million for corporate GBs and €516 million for public GBs.

Figure 5 shows the geographic distribution of corporate sector GB issuances' amounts. Our dataset includes over 92% of GBs' issuances conducted globally in Europe (70%), North America (14,3%), and Asia (8.1%). The geographic distribution of public sector GB issuances is depicted in Figure 6. In the dataset used, 84.2% of issuances are from supranational entities (SNATs) (42.9%), public entities operating in European (32.9%) and Asian countries (8.4%).

[INSERT FIGURES 5 AND 6 ABOUT HERE]

5.2 Empirical Modeling and Discussion of Findings

Our econometric analysis is aimed at studying those factors that most influence the returns (or yields) with which GBs promise to reward investors. More specifically, we employ a multiple regression technique estimated with the ordinary least squares (OLS) method leading to two distinct econometric models (Model PS, Model CR): one for public sector GBs and the other for corporate GBs. Model PS is based on a sample of 199 GBs issued by public sector entities in the 2012-2019 period. Model CR is based on a sample of 199 GBs issued by private firms (corporate GBs) in the 2013-2019 period.

In both econometric models (PS and CR), the dependent variable is the *Yield to Maturity* (YTM) of the GBs, while the independent variables are different, except for four common regressors: Standard & Poor's rating, price volatility, maturity and risk-free interest rate. The

[6] Volatility data used for public and corporate GBs are marginally different: volatility of corporate GBs is computed on the basis of market prices observed over the past 260 days; volatility of public GBs is computed on the basis of market prices observed over the last 90 days.

regressor associated with the level of the risk-free interest rate in the GB issuer's country is included as a control variable to account for the multimarket nature of our empirical analysis. Coherently with the data collected on yields to maturity, observations on country-specific risk-free rates are also referred to December 2020. It follows that our dataset is not structured as a panel-like series. Yields, ratings, volatilities of GBs, ESG scores of underlying projects and risk-free rates are observed as of December 2020. Amounts, maturities, and typologies of issuers are referred to the time of the GB issuance. The structure of our dataset warrants the use of a multivariate regression technique.

We begin by illustrating Model PS regarding GBs issued in the international markets by three types of public sector entities: supranational organizations (SNATs), States (Sovereigns), local governments. The dependent variable is the yield to maturity (YTM) of the public sector GBs, calculated on the basis of the average of the bid and ask quote prices (mid-YTM). Model PS includes the following seven independent variables as explanatory factors of public GBs' yields: (1) Standard & Poor's rating; (2) price volatility over the last 90 days of market trading; (3) the GB issued amount; (4) the type of public sector issuer; (5) a dummy accounting for the application (or non-application) of ESG (Environmental, Social and Governance) criteria for the selection of the infrastructure project financed through the GB issuance; (6) maturity; (7) the level of the risk-free interest rate in the GB issuer's country. Definitions of dependent and independent variables are shown in Table 2.

[INSERT TABLE 2 ABOUT HERE]

Model PS obtains an R-squared of 73.7% and Adjusted R-squared of 72.7%, with its results being in line with standard economic theory. Our econometric analysis based on Model PS is presented in Table 3.

[INSERT TABLE 3 ABOUT HERE]

Our empirical evidence shows that as the rating assigned by Standard & Poor's increases (i.e., as the issuer's creditworthiness improves), the yield of public sector GBs decreases. A higher rating (implying a lower default risk) translates into a higher investor demand for the bonds, which in turn raises up market prices and hence determines a downward pressure on yield (and vice versa in case of poor ratings). Indeed, the coefficient for *S&P Rating* is negative and statistically significant at 1% level. The size of the coefficient (-0.92) reflects the impact that a

change in the rating can have on average on the level of the public sector GB's yield to maturity: as the rating improves (by one category in the scale), the yield of the public sector GB decreases on average by 92 basis points.

Moreover, our regression analysis reveals that as market price volatility increases in the short run, the yield to maturity of public sector GBs increases. There exists a positive relationship between volatility and yield of GBs. The coefficient for *Volatility (90 days)* shows a positive sign and a high statistical significance (at 1% level). This result is in line with standard finance theory as higher volatility reflects a higher bond risk, which translates into higher returns required by investors to be compensated for their inherent risk exposure. The size of the coefficient (0.57) implies that for a unit increase (equal to 1%) in volatility, the return on public sector GBs increases on average by 0.57%.

More interestingly, Model PS also shows that the issued amount of public sector GBs, strictly related to the size of the underlying infrastructure that the public sector issuer intends to finance, is negatively correlated with the yield to maturity of the bonds. The coefficient of the variable *Issued Amount* is negative and strongly significant (at 1% level), unquestionably supporting H1. Investors are willing to forego a portion of their returns to facilitate the realization of impactful infrastructures. The greater the size of the infrastructure financed by the GB, the higher its expected impact on the sustainability of target territories. Such a downward pressure on the yield is exerted by the rise in market prices as a consequence of greater demand by investors for public sector GBs aimed at financing increasingly impactful infrastructures. The magnitude and the sign of the coefficient (- 0.43) imply that an increase of 1% in the issued amount of a GB reduces its yield on average by 0.43%.

Based on the positive sign and strong statistical significance (at 1% level) of the coefficient of the variable *Public Entity Typology*, our analysis also demonstrates that if GBs are issued by local governments (rather than SNATs or Sovereigns), their proximity to constituencies favors the awareness of the most important regional needs leading to construction of more impactful infrastructures. As a result, investors are more prone to underwriting GBs of local governments (rather than of SNATs or States) by accepting lower returns (on average by 0.86%) in exchange for a more direct, effective impact of the financed infrastructural assets on their territories. SNATs' or Sovereign GBs are traded at lower prices as a result of a lower market demand, which translates into higher yields to maturity. Hence, our findings provide support for H2. Additionally, the proximity of local governments to constituencies facilitates the monitoring activity of the latter on the actual realization of sustainable infrastructures promised and planned through the capital raising associated with the GB issuance. This lowers the risk that,

when issuing GBs, local governments may engage in greenwashing. Greenwashing is instead more likely to occur in the event of States or SNATs issuing GBs as it could be easier to deceive investors by carrying out less green and impactful operations if at all. Hence, H4 is also validated.

Most importantly, the coefficient for the ESG-based selection of the underlying infrastructure project (*ESG-Based Project*) is negative and significant at 5% level, which moderately supports H3. More specifically, our econometric analysis reveals that, due to the negative relationship between the yield to maturity of public sector GBs and the use of the ESG metrics for the selection of the underlying infrastructural assets, investors reward such a congruent choice by their willingness to accept a lower return on their investments. The magnitude of the coefficient (- 1.16) implies that the ESG-based selection of the infrastructure financed through the issuance of a GB lowers the yield on average by 1.16%.

Finally, our econometric analysis suggests that, in line with standard finance theory, there is a direct (positive) relationship between the yield to maturity of public sector GBs and their maturity: longer-term securities expose investors to higher interest rate risk and thus the latter are rewarded with higher returns. However, the coefficient of the variable *Maturity* is positive but not statistically significant (0.32), implying that we cannot elaborate more on such relationship. The same applies to the positive relationship between the yield to maturity of public GBs and that of government bonds. The coefficient of the variable *Risk-Free Interest Rate* is positive but (rather small and) not statistically significant (0.048): the yields of public GBs are positively correlated with those of risk-free government bonds. Such positive relationship can be explained by the fact that investors are inclined to perceive the GBs issued by public sector entities and government bonds as "substitute" assets. However, no other arguments can be formulated due to the statistical insignificance of this variable.

We next discuss the findings of Model CR aimed at detecting the key determinants of the performance of corporate GBs issued by private companies in international markets over the last decade.

The dependent variable is the yield to maturity (YTM) of corporate GBs, calculated on the basis of the average of the bid and ask quote prices (mid-YTM). Model CR includes the following seven independent variables as explanatory factors of corporate GBs' yields: (1) Standard & Poor's rating; (2) price volatility over the last 260 days of market trading; (3) the ESG score of the infrastructure project financed through the issuance of GBs; (4) a dummy accounting for the sector of the corporate GB issuer: 1 if the issuer is a firm operating in the services sector, 0 if the issuer is active in the manufacturing sector; (5) maturity; (6) the level

of the risk-free interest rate in the GB issuer's country; (7) the risk of greenwashing measured by the interaction variable resulting from the product of the ESG score and the sector dummy. Definitions of dependent and independent variables are shown in Table 4.

[INSERT TABLE 4 ABOUT HERE]

Model CR obtains an R-squared of 32.4% and Adjusted R-squared of 30.0%, with its results being in line with standard economic theory. Our econometric analysis based on Model CR is presented in Table 5.

[INSERT TABLE 5 ABOUT HERE]

Analogously to what applies to Model PS and in line with the economic theory, Model CR confirms that an improvement in the corporate issuer's creditworthiness (which translates into an upgrade of the rating class assigned by Standard & Poor's) diminishes the return required by investors on the corporate GBs they underwrite. Indeed, the negative coefficient for *S&P Rating* reflects a negative relationship between rating and yield to maturity. Higher investor demand for less risky (i.e., better rated) bonds pushes up prices in the market, which results in a downward pressure on yields. The related effect is relevant due to its high statistical significance (at 1% level). The size of the coefficient (-4.18) reflects the very high impact that a rating migration from one class to an upper one can have on average on the expected return from holding corporate GBs (- 418 basis points or – 4.18%) and vice versa.

The same empirical logic that is obtained in relation to (short-term) volatility in Model PS also applies to (long-term) volatility in Model CR. The coefficient of the variable *Volatility (260 days)* is strongly significant (at 1% level) and positive, which is consistent with the standard dynamics of bond markets: a higher risk exposure (reflected in a higher price volatility) is rewarded with a greater return (YTM). The magnitude of the coefficient (0.60) implies that for a 1% (marginal) increase in volatility, the yield to maturity of corporate GBs rises on average by 0.60%.

More interestingly, our econometric analysis suggests that there is an inverse relationship between the yield to maturity of GBs issued by private companies and the level of Environmental, Social and Governance connotation of the issuance, measured by the *ESG Score*, underlying the degree of sustainability of the infrastructure that is financed through the

bond issuance.[7] The coefficient of the variable *ESG Score* is negative and strongly significant from a statistical standpoint (at 1% level). In the same way as it occurs in the context of public sector GBs, investors in corporate GBs are willing to accept (forego) a lower (higher) return in exchange for supporting the construction and operation of increasingly sustainable infrastructures that are expected to have a higher impact at local level with a direct benefit for all citizens. The higher the sustainability dimension of the infrastructure project financed by the corporate GB, the greater the portion of yield investors are willing to give up in order to help support its construction.

The magnitude of the coefficient (-0.76) implies that, as the ESG score of the project associated with the issuance of the corporate GB increases by one unit, there is an average 0.76% decrease in the yield to maturity of these securities. Such empirical evidence corroborates H3 also for corporate GBs.

Most importantly, Model CR demonstrates that greenwashing is a key inherent risk of the relatively new asset class of corporate GBs. Our empirical analysis effectively exhibits that the phenomenon of greenwashing may lurk in the manufacturing sector while being less perilous in the services sector. This interesting perspective is offered by the dummy variable of the *Sector* where the corporate GB issuers of our sample operate: the dummy variable (1 if the sector of the issuer is services - e.g. utilities, energy, telecommunications, banks & insurance - and 0 otherwise) is negatively related with the corporate GBs' yield to maturity (the coefficient has a negative sign). The magnitude of the coefficient (-40.64) implies that the yield decreases on average by 40.64% in the case of GBs issued by companies operating in the services sector and vice versa in the case of GB issuances of manufacturing companies. Our evidence is further reinforced by the interaction variable of *Greenwashing Risk* that shows a positive (0.75) and strongly significant coefficient (at 1% level). A firm that operates in the services sector and finances an ESG-compliant infrastructure project through a GB issuance exposes investors to a lower greenwashing risk.

For investors allocating their capital resources into GBs issued by services' firms it would be easier and more immediate to monitor (post-issuance) a potential deceptive greenwashing activity carried out by the issuer: for example, in the course of construction of an infrastructure featuring impactful sustainability characteristics that, after being announced at the pre-issuance

[7] The ESG Score assigned to each corporate GB corresponds to the summary measure of ESG-related information that each issuing firm reports in the most recent available fiscal year. The number of disclosures is presented as a % of the total potentially disclosable ESG-related information. In our dataset, this percentage ranges from 9.65% to 75.21%. Such ESG scores are measured and reported by Bloomberg.

stage, are not fulfilled in the post-issuance phase. This might be the case of a solar farm or the green design of a 5G telecommunications infrastructure. For instance, it is difficult for a utility company, which announces to issue a GB to finance the construction of a photovoltaic park, not to follow up on this initiative and finance an alternative project that does not present characteristics of environmental sustainability. Hence, the risk of greenwashing is lower in the services sector and investors are more prone to accept lower returns as they need to be effectively compensated for a less costly and time-consuming monitoring activity. This form of investors' monitoring is less straightforward on issuers operating in the manufacturing sector (e.g., consumer goods, materials), thus leading to a higher probability of greenwashing practices and imposing higher risk premia for investors. Hence, our findings suggest that H5 is empirically supported and, due to their strong statistical dimension, have the merit of highlighting the practice of greenwashing and their different degree of diffusion across industries.

Our analysis reveals that there is an inverse relationship between the yield to maturity of corporate GBs and their maturity. However, the coefficient of the variable *Maturity* is negative but not statistically significant (-0.11), implying that we cannot elaborate more on such relationship.

Finally, Model CR indicates that the yields of corporate GBs are inversely related to the level of the risk-free interest rate of the issuer's country. The coefficient of the variable *Risk-Free Interest Rate* is negative and statistically significant at 5% level (- 1.07). This finding seems to be inconsistent with the standard finance theory according to which the total yield on a corporate bond is a positive function of both the Treasury yield and the credit spread (that is greater for lower-rated bonds). However, there are two reasons that may explain such a negative relationship. From an economic standpoint, if the risk-free rate rises as a result of an increase in the default risk of the country, corporate GBs issued in that specific country, to the extent that they are considered as "safe" financial assets (Pastor et al., 2021; Cornell, 2021), will be highly demanded for by investors. Such a strong demand will push market prices of corporate GBs up, thus diminishing their yields. This market mechanism will cause a negative correlation between the yields of government bonds and those of corporate GBs. From a technical standpoint, if the corporate GB is callable by the issuing company, then the latter has the right to purchase (or pay off) the bond after a minimum time period. If an investor holds a high-yielding bond and prevailing interest rates decline, a firm with a call option will want to call its corporate GB in order to issue new bonds at lower interest rates (so as to refinance its

debt). Most corporate GBs (including those in our sample) are callable, and thus it is key for investors to be compensated for the call provision with a higher yield (Duffie, 1998).

Based on the results of Model PS and Model CR, it is worth comparing the findings on the yields of public sector and corporate GBs. In line with standard finance theory, the credit rating of the issuer is negatively related and the market price volatility is positively related with the yields for both public and corporate GBs. The use of the ESG metrics for selecting the GB-funded project is negatively correlated with the yield for both public and corporate GBs, thus suggesting that investors may accept lower returns in exchange for a greater, expected impact of the infrastructure on the sustainability of the target community. The diffusion of greenwashing practices may apply to both public and corporate GB issuers. In the public sector, SNATs and States are more prone to engaging in greenwashing practices as they are less close to their constituencies and thus less easily subject to investors' controls. In the corporate sector, firms operating in the manufacturing sector are more inclined to pursue greenwashing strategies as eluding investors' controls requires less effort compared to what can be carried out in services' operations. The maturity is negatively correlated with the yield of public GBs while it is positively related with that of corporate GBs. However, in both cases the related coefficient is not statistically significant. Finally, concerning the control variable represented by the country-specific risk-free interest rate, the "substitution effect" between public sector GBs and government bonds, captured by the positive sign of the coefficient, does not apply to corporate bonds, which are instead considered as "safe assets" with prices increasing (and yields decreasing) as a result of a rise in the country's default premium.

5.3 Robustness Checks

To corroborate the findings of our Model PS and Model CR, we have conducted a robustness analysis based on standard tests applied to our OLS regressions. The performance of conventional tests shows that residuals are normally distributed with some degree of non-severe heteroskedasticity, which is common for cross-sectional data involving a wide range of values. No multicollinearity has been detected.[8] Moreover, the implementation of the Ramsey RESET test suggests that our models do not suffer from the omission of relevant variables.

To further check the robustness of our results we have collected a set of comparable ordinary (so called brown) bonds to be associated with the GBs issued by the same companies included in our sample used for Model CR for a total of 398 bonds (199 x 199 bonds). Four criteria have

[8] The mean Variance Inflation Factor (VIF) ranges between 1 and 2 for both Models PS and CR.

been fulfilled to select the brown bond matching the GB issued by the same firm: (1) similar size of the issuance; (2) proximity of the date of issuance; (3) similar maturity (within a range of 3 years apart); (4) same time period window (2010-2020). The distribution of GBs and comparable brown bond issuances made by the same sample of firms across the 2010-2020 period is displayed in Figure 7. It can be highlighted that the year characterized in our sample by the peak of GB issuances is 2019. The distribution of our sample firms across industrial sectors is shown in Figure 8. It can be noted that corporate GB issuers are concentrated in the financial and utilities/energy sector. Figure 9 shows how the apportionment of S&P's rating classes among our sample of corporate GBs; the majority of GB issuances are assigned A or BBB rating.

[INSERT FIGURES 7,8 AND 9 ABOUT HERE]

Consistently with Bachelet, Becchetti & Manfredonia (2019) and Zerbib (2019), we run an additional econometric model where the dependent variable is the spread between the *Yield to Maturity* (YTM) of the GB and that of the select brown bond issued by the same firm. Such a spread reflects the green premium (or "greenium") which is still considered as a puzzle by the recent academic research. Our model, named as Model GBS, is designed as a multivariate regression estimated with the ordinary least squares (OLS) method and is aimed at investigating whether the explanatory factors of corporate GB performance are also the drivers of a green premium required by investors. The independent variables of our Model GBS are the same as those of Model CR (*S&P Rating*, *260 days-Volatility*, *ESG Score*) with the exception of two: (i) the maturity (in years) of the GB; ii) a dummy variable with value 1 if the issuer operates in the financial sector and 0 otherwise. Table 6 exhibits the empirical findings of Model GBS.

[INSERT TABLE 6 ABOUT HERE]

Overall, the results of Model GBS corroborate our findings of Model CR. The signs of the coefficients of *S&P Rating* (-) and *Volatility (260 days)* (+) are in line with those of Model CR. Statistical significance (at 5% level) only applies to volatility. GBs' yields are negatively related with ratings: a rating upgrade lowers the risk premium required by investors and their return expectations, thus reducing the yield spread between GBs and their matched brown bonds. More volatile (and therefore riskier) GBs drive investors to demand for higher returns, thus amplifying the green premium (compared to conventional bonds).

Maturity is inversely related to the green premium implying that, consistently with standard bond dynamics, longer-term brown bonds impose higher yields while associated longer-term GBs require lower yields. This may be due to the fact that investors in GBs accept lower returns in exchange for financing underlying sustainable infrastructures with longer construction times and more enduring impact.

The negative sign and statistical significance (at 5% level) of the coefficient of the *ESG Score* confirms the inverse relationship between the ESG dimension of the underlying infrastructure and the yield demanded for by investors on GBs: investors tend to give up on return when offered the opportunity to contribute to the realization of high ESG, impactful infrastructural projects.

Finally, the coefficient of the *Financial Sector* dummy variable is positive (although not statistically significant). The green premium increases for GBs issued by firms operating in the financial sector, where potential greenwashing practices are less easily detectable by investors. Indeed, financial services are a special form of services characterized by a comparatively higher greenwashing risk as banks and/or insurance companies may need to cheat while engaging in sustainable activities to save on previously announced green investments and divert related resources toward more profitable operations.

6. Conclusion and Policy Recommendations

The findings of our study allow to draw implications and make recommendations for investors, rating agencies and policymakers.

First, our analysis recommends to investors that are willing to minimize their exposure to greenwashing risk underwriting public sector GBs issued by local governments and corporate GBs issued by firms which operate in the services' sector. Moreover, investors are incentivized to acquire public GBs whose original issuance size is comparatively larger due to the expected higher impact of the underlying financed infrastructure project on the sustainability of the target territory. Finally, investors should only buy both public and corporate GBs with an ESG rating as the availability of such scoring diminishes the information asymmetries between them and the issuer as to the expected sustainability advantages associated with the realization of the financed project for the target community.

Second, rating agencies should improve their ESG rating models for public sector GBs issued by States and SNATs and corporate GBs issued by firms that operate in the manufacturing sector so as to be able to better capture and quantify the greenwashing risk embedded in these securities.

Third, our analysis offers practical implications to policymakers who should devote more care and efforts to detecting greenwashing practices, thus being prompted to enforce new regulations aimed at reducing potentially deceptive behaviors of both public and corporate issuers when financing sustainable infrastructures via the placement of GBs in international markets. This is particularly important in view of the recent release of a GB taxonomy by the European Commission (July 2021) and similar classification systems that the authorities of other jurisdictions may adopt in an effort to replicate a widely recognized quality benchmark and thus standardize the global GB market. More specifically, to reduce the spread of deceptive greenwashing strategies pursued by issuers that may undermine the expansion of the GB market, the EU green bond standard is aimed at addressing this phenomenon with a more rigorous regime of transparency and supervision according to which only projects that comply with the new taxonomy of sustainable activities would be eligible for funding. Such newly proposed classifications should be designed to fully detect the risk of greenwashing practices among both public and corporate GB issuers so as to direct investors into higher-quality bonds and projects. The results of our econometric models may help policymakers best design such novel GB taxonomies.

The aim of this study is to explore the key determinants of the yields of public and corporate GBs beyond those conveyed by conventional finance theory to account for the sustainable impact, quantified by an ESG rating, and the greenwashing risk embedded in the local versus multinational/national (for PS bonds) or sectoral (for CR bonds) nature of the infrastructural projects whose construction and/or revamp is financially supported by the issuance of GBs. To achieve that, we have developed a theoretical framework and empirically tested it by employing simple but effective econometric models. Interestingly, our empirical analysis shows that the return on GBs is not only determined by rating and volatility as conveyed by standard finance theory, but is also influenced by the degree of the ESG dimension of the underlying infrastructure and the easiness of greenwashing practices. Our findings suggest that corporate opportunities for engaging in greenwashing may exist and their effects are tied to the issuer' sector. Issuers operating in manufacturing (rather than services) industries can more easily engage in greenwashing activities as related monitoring by investors is more complicated. This finding can also be extended to financial services' firms whose deceptive behavior may be more difficult to detect by investors. The phenomenon of greenwashing may also spread out among public sector GB issuers, with States and SNATs being more inclined to deceive investors as they are less close to their constituencies (compared to local governments such as cities, provinces or regions) and thus more likely to elude a thorough

control activity by market participants. More importantly, risk premia and related yields to maturity required by investors are strongly driven by the level of sustainability (measured by the ESG rating) of the project being financed through the issuance of GBs.

The main limitation of our study is this: the number of GBs used for our regression analysis is small, which is due to the lack of availability of observations retrievable from official data providers. In this regard, future research should be directed toward exploring more in depth the phenomenon of greenwashing across both public and corporate GB issuers relying on more numerous observations. Researchers should also make the effort into studying the effect of green evaluation (e.g., ESG rating systems) provided by external (independent) organizations on the quality of bonds issued and their underlying financed projects. In particular, when new GB standards will be fully enforced, it will be interesting to compare the quality of GBs issued across time (before and after the release of such classifications).

Our hope is to have contributed to further fill the green finance gap by advancing the knowledge and understanding of the complex market dynamics of GBs at a time when demand for such debt securities by investors and their offer by public and corporate issuers are booming at global level.

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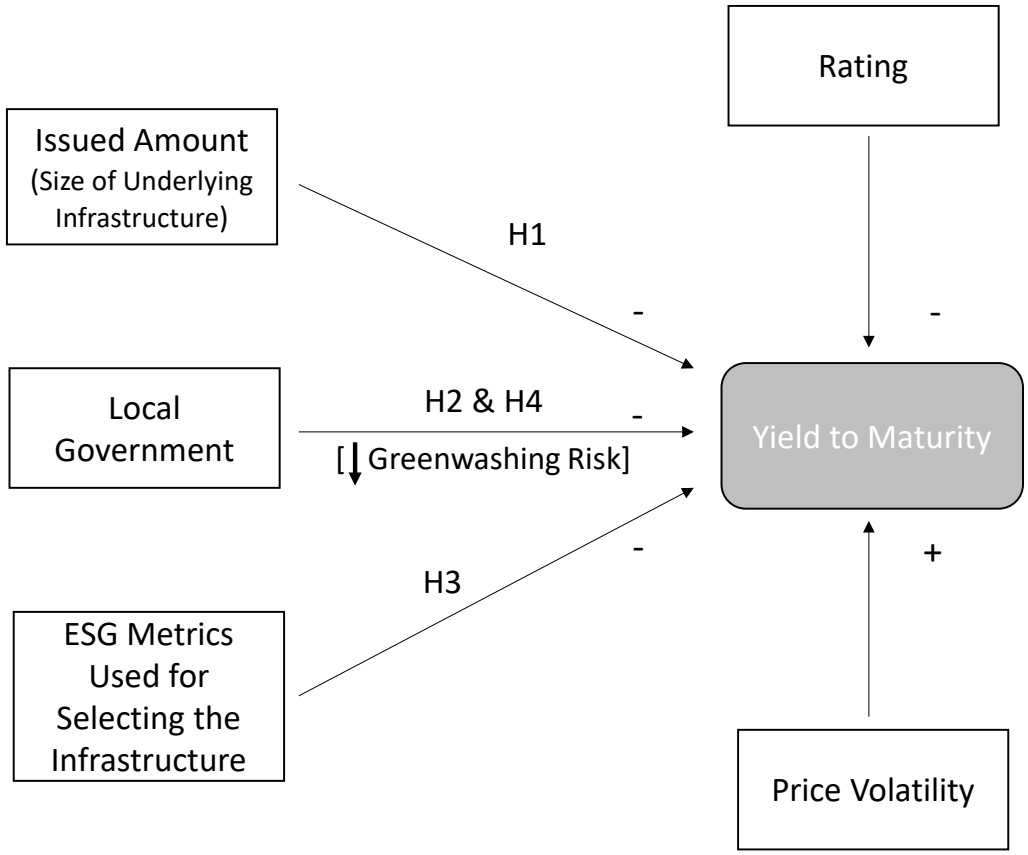
Figure 1. Conceptual Framework for Public Sector and Corporate Green Bonds

Panel A. Public Sector Green Bonds



Panel B. Corporate Green Bonds

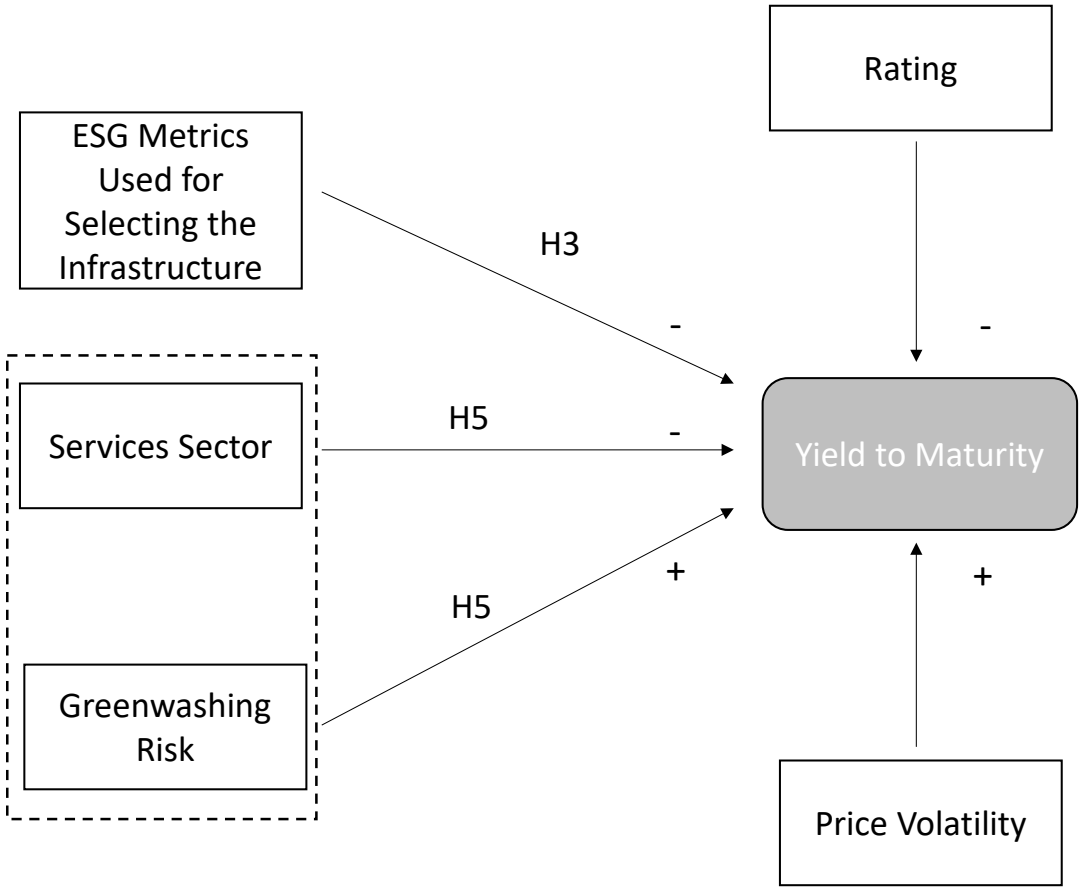
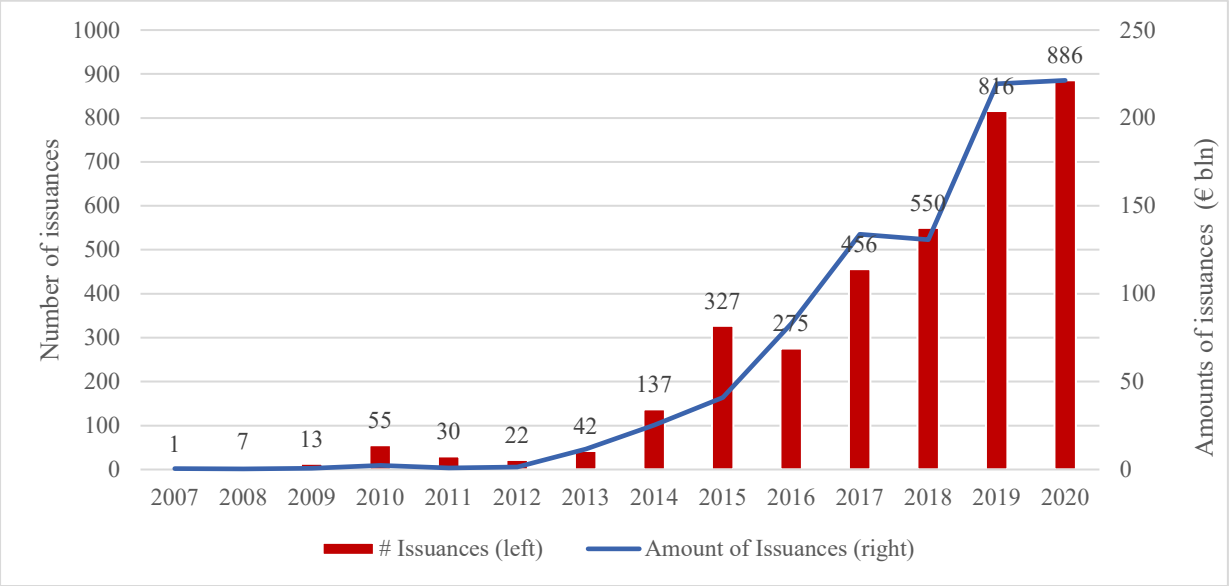
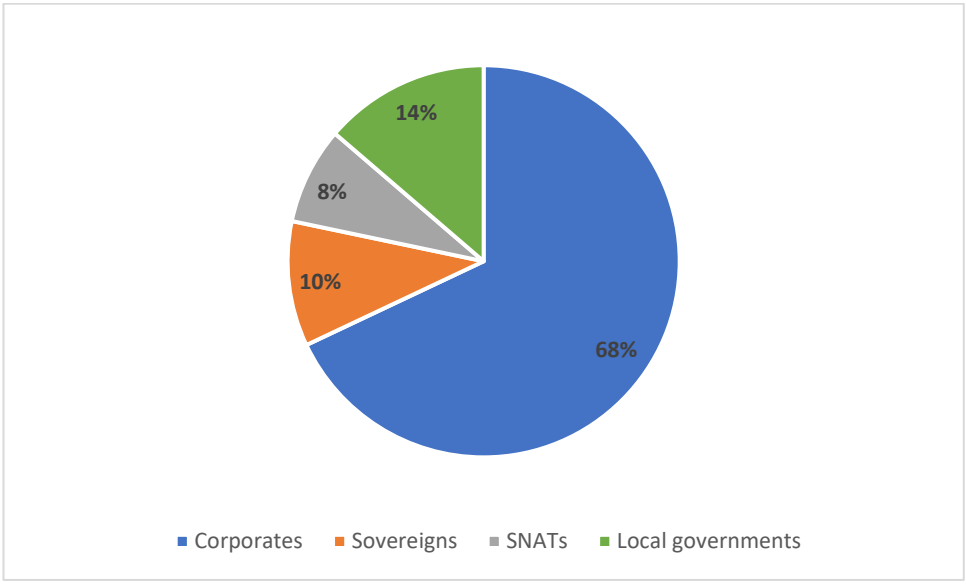


Figure 2. Number and Amounts of Green Bonds' Issuances (2007-2020)



Source: Bloomberg

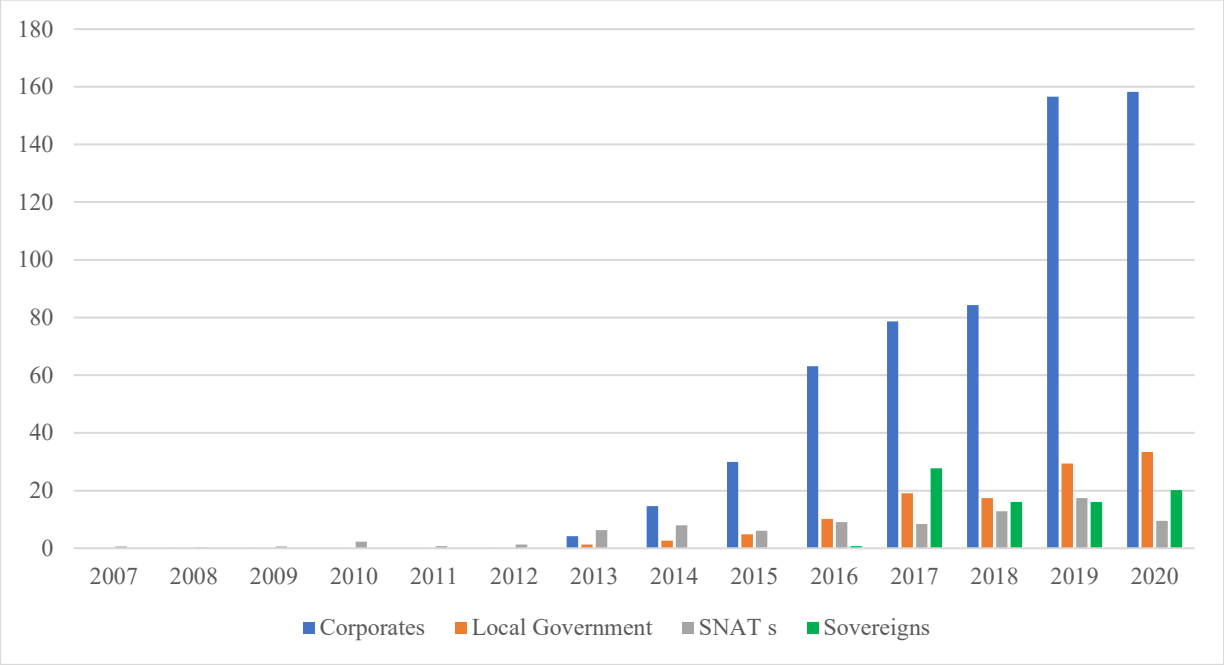
Figure 3. Distribution of Green Bonds' Issuances Among Corporate and Public Sector Issuers



Source: Bloomberg

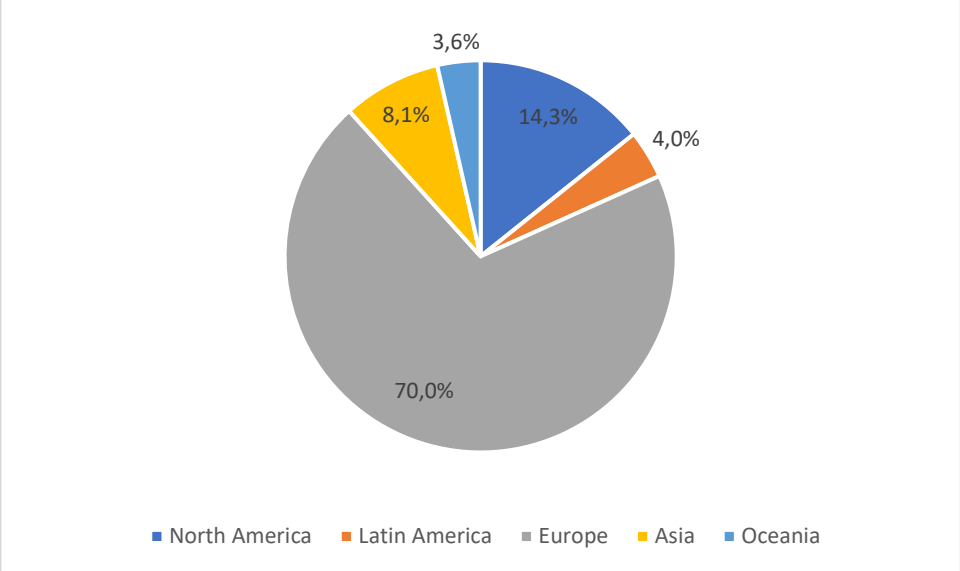
Figure 4. Amounts of Green Bonds' Issuances by Issuer Category

(€ Billions)



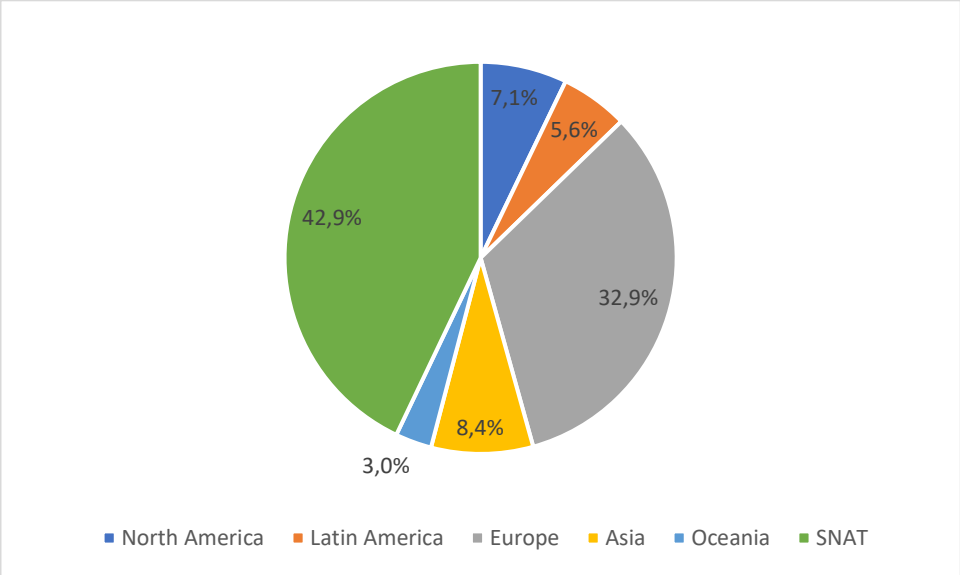
Source: Bloomberg

Figure 5. Corporate Sector: Distribution of Regional Green Bonds' Issuances



Source: Bloomberg

Figure 6. Public Sector: Distribution of Regional Green Bonds' Issuances



Source: Bloomberg

Table 1. Descriptive Statistics

		Yield to maturity	Volatility°	Amount issued#	Maturity§
Corporate	*mean*	1.8%	6.82	546,263,488	10.87
	std dev	13.5%	6.26	321,212,936	10.30
	min	-1.1%	0.29	15,817,671	1.00
	max	191.1%	34.87	1,852,766,798	70.00
Public	*mean*	0.8%	2.40	516,189,716	5.88
	std dev	3.4%	4.13	594,920,842	3.29
	min	-0.7%	0.04	875,928	1.00
	max	32.9%	35.30	6,100,399,058	17.00

° 260 days for Corporate GBs and 90 days for Public Sector GBs
Euros
§ Years

Source: Bloomberg

Table 2. Variables' Description: Econometric Model PS (*Green Bonds* Issued by Public Sector Entities)

Variable Name	Description
Yield to Maturity	Yield to maturity calculated on the basis of average prices between bid and ask quotations (so called *mid-YTM*)
S&P Rating	Official ratings assigned to Green Bonds by Standard & Poor's, converted into an increasing score ranging from 1, assigned to issuances with worst rating (in our sample, D) to 8, assigned to issuances with AAA rating
Volatility (90 days)	The standard deviation of the prices referring to the market trades of the last 90 business days
Amount Issued	Natural logarithm of the issued amount of Green Bonds
Public Entity Typology	Dummy equal to 1 if the GB issuer is a SNAT or a Sovereign, 0 if the GB issuer is a Local Government (such as municipal, province or regional entities)
ESG-Based Project	Dummy equal to 1 if the selected project to be financed with the GB issuance has been chosen applying the ESG (*Environmental, Social and Governance*) metric, 0 otherwise
Maturity	Lifespan of the GB in number of years
Risk-Free Interest Rate	Yield to maturity of the "benchmark" government bond issued by the Treasury of the State where the GB issuer operates, selected based on the closest maturity compared to that of the relevant GB

Table 3. OLS Regression Results: Green Bonds Issued by Public Sector Entities

Dependent Variable: Yield to Maturity

Regressors	Coefficient	t-Student	P value
S&P Rating	-0.92 *** (0.176)	-5.24	0.000
Volatility (90 days)	0.57 *** (0.039)	14.56	0.000
Amount Issued	-0.43 *** (0.095)	-4.55	0.000
Public Entity Typology	0.86 *** (0.302)	2.84	0.005
ESG-Based Project	-1.16 ** (0.528)	-2.19	0.030
Maturity	0.32 (0.436)	0.73	0.469
Risk-Free Interest Rate	0.05 (0.165)	0.29	0.771
Constant	15.15 *** (2.408)	6.29	0.000
N° of observations: 199			
$R^2 = 0.737$; Adj $R^2 = 0.727$; Prob > F = 0.0000			

* level of statistical significance ≤ 10%, ** level of statistical significance ≤ 5%,
*** level of statistical significance ≤ 1%

Table 4. Variables' Description: Econometric Model CR (Green Bonds Issued by Firms)

Variable Name	Description
Yield to Maturity	Yield to maturity calculated on the basis of average prices between bid and ask quotations (so called *mid-YTM*)
S&P Rating	Official ratings assigned to Green Bonds by Standard & Poor's, converted into an increasing score ranging from 1, assigned to issuances with worst rating (in our sample, D) to 8, assigned to issuances with AAA rating
Volatility (260 days)	The standard deviation of the prices referring to the market trades of the last 260 business days
ESG Score	ESG score assigned to the infrastructure project financed through the issuance of the GB
Sector	*Dummy* equal to 1 if the issuer is a firm operating in the services sector (e.g., telecommunications, energy, utilities, finance), 0 if the issuer is a firm operating in the manufacturing sector (e.g., consumer goods, industrial goods, high-tech).
Maturity	Lifespan of the GB in number of years
Risk-Free Interest Rate	Yield to maturity of the "benchmark" government bond issued by the Treasury of the State where the GB issuer operates, selected based on the closest maturity compared to that of the relevant GB
Greenwashing Risk	Interaction variable calculated as product of the ESG Score and the Sector dummy to reflect the risk of greenwashing across firms of different industries

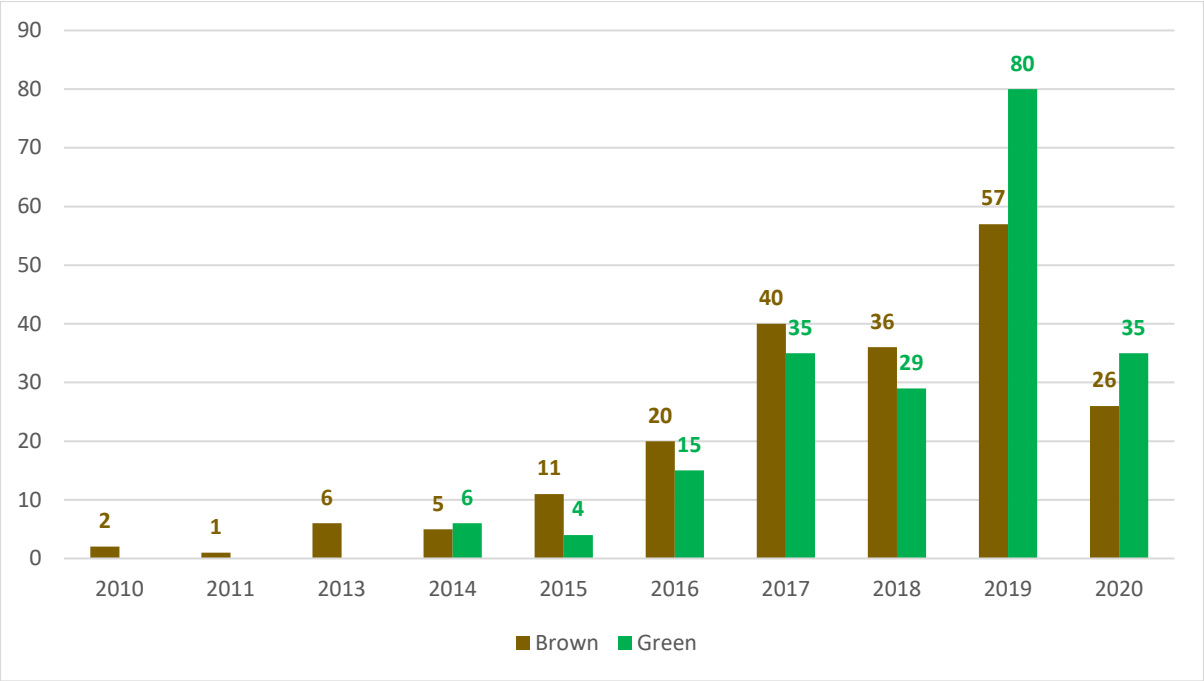
Table 5. OLS Regression Results: Green Bonds Issued by Firms (Corporate Green Bonds)

Dependent Variable: Yield to Maturity

Regressors	Coefficient	t-Student	P value
S&P Rating	-4.18 *** (0.922)	-4.53	0.000
Volatility (260 days)	0.60 *** (0.162)	3.71	0.000
ESG Score	-0.76 *** (0.150)	-5.07	0.000
Sector	-40.64 *** (9.097)	-4.47	0.000
Maturity	-0.11 (0.080)	-1.41	0.160
Risk-Free Interest Rate	-1.07 ** (0.526)	-2.03	0.044
Greenwashing Risk	0.75 *** (0.171)	4.38	0.000
Costant	62.28 *** (10.185)	6.12	0.000
N° of observations: 199			
$R^2 = 0.324$; Adj $R^2 = 0.300$; Prob > F = 0.0000			

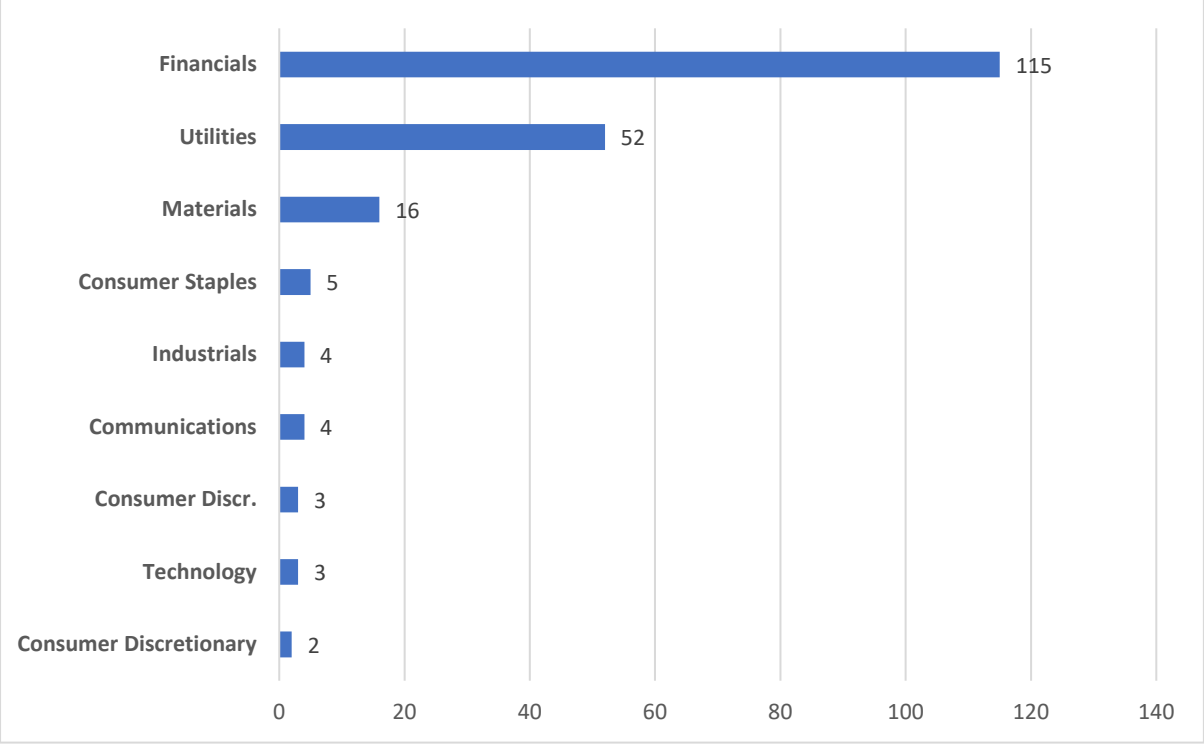
* level of statistical significance ≤ 10%, ** level of statistical significance ≤ 5%,
*** level of statistical significance ≤ 1%

Figure 7. Distribution of Green Bond and Comparable Brown/Ordinary Bond Issuances Across Years (2010-2020)



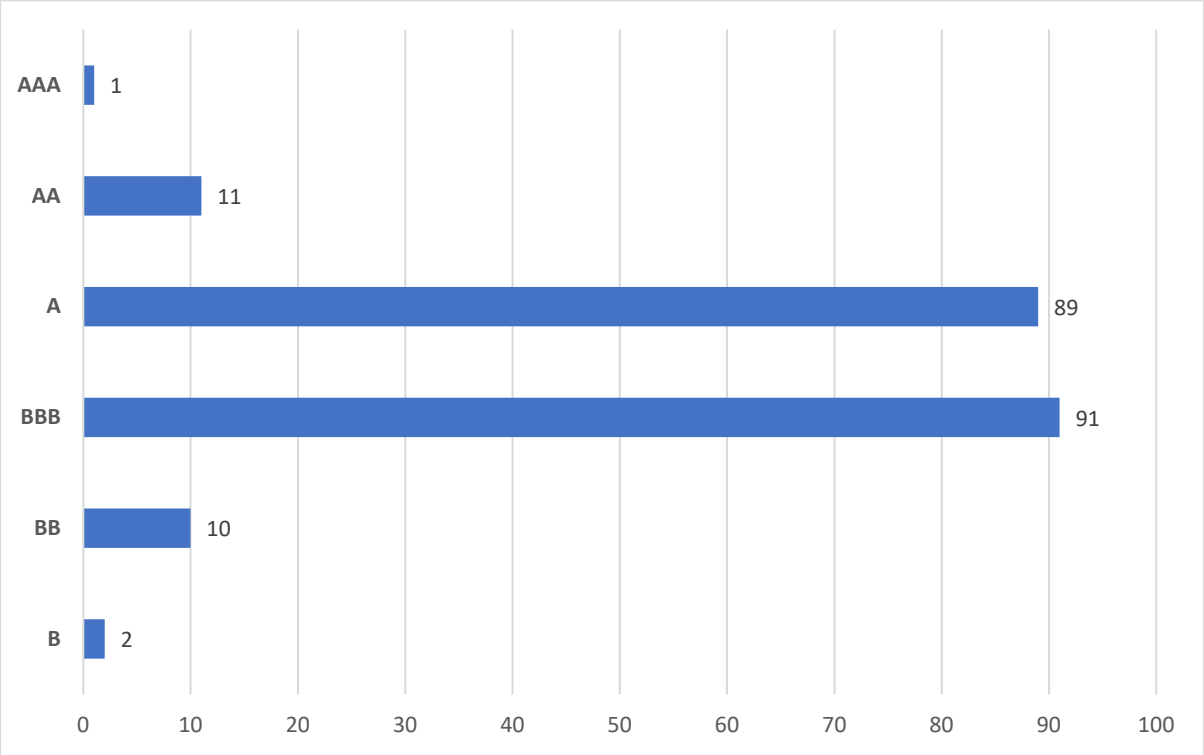
Source: Bloomberg

Figure 8. Distribution of Firms in the Sample Across Sectors (2010-2020)



Source: Bloomberg

Figure 9. Distribution of Firms in the Sample Across Rating Classes (2010-2020)



Source: Bloomberg

Table 6. OLS Regression Results: Green-Brown Bond Yield Spread (Corporates)

Dependent Variable: Green-Brown Bond Yield Spread

Regressors	**Coefficient**	**t-Student**	**P value**
S&P Rating-	-0.056 (0.108)	0.52	0.605
Volatility (260 days)	0.061** (0.029)	2.14	0.034
Maturity	-0.001** (0.001)	2.44	0.016
ESG Score	-0.001 (0.005)	-0.23	0.822
Financial Sector	0.092 (0.170)	0.55	0.587
Constant	-0.637 (0.647)	-0.98	0.326
N° of observations: 199			
$R^2 = 0.051$; Adj $R^2 = 0.027$; Prob > F = 0.065			

* level of statistical significance ≤ 10%, ** level of statistical significance ≤ 5%, *** level of statistical significance ≤ 1%