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"THE GREEN BOND PREMIUM: A FIXED-EFFECTS REGRESSION APPROACH"

RELATORE:

CH.MA PROF.SSA ELISA TOSETTI

LAUREANDO: OSKAR GIRARDI

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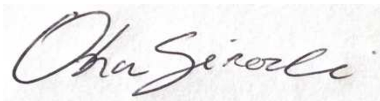
Firma (signature) 

Abstract

Pur risultando evidente come gli investitori abbiano spostato il loro capitale verso asset più sostenibili nel corso degli ultimi anni, è ancora poco chiaro se questi siano disposti ad accettare un rendimento più basso per detenere tali asset. Il mio lavoro mira, pertanto, a indagare questo fenomeno applicato ai cosiddetti green bond, ovvero bond i cui proventi sono legati a progetti riguardanti la sostenibilità. In particolare, ho analizzato la differenza media tra gli spread al momento dell'emissione dei green bond rispetto a quelli convenzionali, costruendo un modello OLS lineare a cui vengono successivamente aggiunti vari effetti fissi in modo da controllare per eventuali caratteristiche non osservabili. Tale modello è stato applicato ad un dataset, di mia costruzione, costituito da oltre 4500 bond verdi e 37500 bond convenzionali, emanati in 23 valute differenti, da 5 tipologie diverse di debitori provenienti da tutto il mondo. I risultati evidenziano che, in media, i green bond presentano uno spread inferiore di circa 4 punti base rispetto ai bond convenzionali. Questa differenza di compensazione negativa è prova dell'esistenza di un cosiddetto "greenium" nel mercato obbligazionario, cioè di un differenziale di rendimento negativo proprio dei green bond. Questi risultati rimangono statisticamente rilevanti suddividendo il campione per le principali tipologie di emittente, dove appunto si riscontrano minori rendimenti per obbligazioni aziendali, agency e, pur se non significativi, per obbligazioni sovranazionali.

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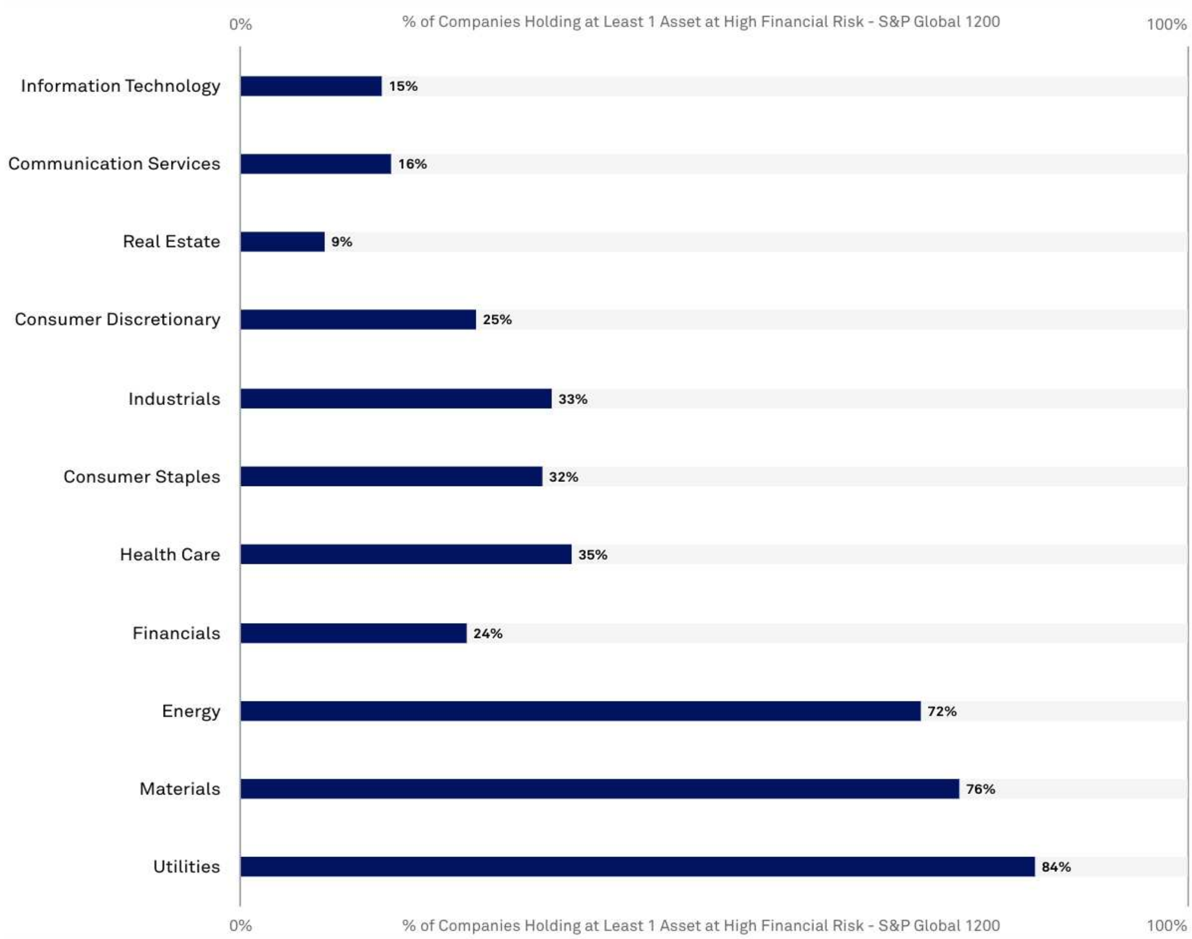
1. INTRODUCTION

Climate change is a global concern. Its effects are already being felt today and will undeniably aggravate in the next years. Among the consequences of this phenomenon, Abbass et al. (2022) mention: threats to sufficient agricultural production and food supplies due to irreversible weather fluctuations; acceleration of biodiversity loss; higher likelihood of food, waterborne and vectorborne diseases; acceleration of antimicrobial resistance; threats to the global tourism industry. In addition, we can recall rising sea levels and an increase in the likelihood of fires, floods, storms and other extreme events. The effects mentioned are called physical effects and, as one could easily guess, their economic impact differs across sectors. A study of S&P Global highlights that companies in the utilities, material and energy sectors are the most likely to hold assets at high financial risk by 2050 (Fig. 1).

Fig. 1.

Financial Impact Exposure by Sector



Source: *https://www.spglobal.com/esg/solutions/physical-climate-risk#:~:text=Physical%20risks%20resulting%20from%20climate,and%20disruption%20to%20supply%20chains*

To limit additional economic repercussions beyond those already certain, governments, central banks and international institutions decided to make an effort and encourage a transition to a carbon-neutral economy. The first legally binding climate treaty was the Kyoto Protocol of 1997, which required developed countries to decrease their emissions by 5% below the 1990 levels, however, major polluters like China, India and the USA, ended up not being involved. One of the most iconic and recent understandings was the Paris Agreement of 2015, which saw 196 countries commit to limiting global warming within 2° above pre-industrial levels.

Nevertheless, it's important to state that the makeover to a greener economy is not burdenless. In particular, this transformation carries with it what are known as transition risks. The US Environmental Protection Agency defines them as: "risks […] associated with the pace and extent at which an organization manages and adapts to the internal and external pace of change to reduce greenhouse gas emissions and transition to renewable energy." For instance, in companies with fossil fuels dependent assets and processes, we will surely observe more write-downs and early retirement of assets and processes due to increased carbon pricing or reduced demand, higher operating costs because of unexpected changes in energy costs, stigmatisation of sectors and reputational risks and, finally, unforeseen policy changes and market uncertainty. Moreover, all these factors will contribute to downward pressure on market valuations. Therefore, while committing to a carbon-neutral economy, it seems crucial to simultaneously limit the impact of transition risks to avoid exacerbated damages. In this conclusion lies the reason why we should act immediately and steadily to contain global warming. Should policy changes be abrupt, tardive and uncoordinated, losses resulting from stranded assets will not be efficiently distributed throughout the financial system, whose stability could be undermined (ESRB 2016).

A signal of systemic and serious commitment came in 2020, when the European Commission finally approved the European Green Deal, a set of strategic initiatives with the overarching aim of climate neutrality by the year 2050. The package includes initiatives covering the environment, the climate, agriculture, transport, industry, energy and sustainable finance. The plan has several goals, such as a circular economy action plan, a sustainable and smart mobility strategy, an EU forest strategy and a review of all the relevant climate-related policy instruments. In this setting, it becomes pivotal for companies and other organizations to secure the necessary funds to comply with the transition costs. McKinsey (2022) estimated that, in order to reach carbon neutrality by 2050, there should be global investments of $9.2 trillion per year on average, an annual increase of as much as $3.5 trillion from today. For this reason, many financial products have been developed, over the last years, to reach this goal: climate transition indices and portfolios, dedicated climate transition funds and exchange-traded funds, green loans and green bonds. As of today, the most mature sustainable instrument remains the green bond. A bond is "a certificate issued by a government or a public company promising to repay borrowed money at a fixed rate of interest at a specified time"-*Oxford Languages*. Companies, governments and other organizations issue bonds to borrow money for undergoing projects, repay pre-existing debt or for the fulfilment of working capital needs. A green bond, instead, differs in that the funds obtained through the issuance must be directed towards financing or re-financing, in part or in full, initiatives focused on environmental causes such as the construction of energy-efficient buildings, implementation of renewable energy, conservation of biodiversity, sustainable transportation and many more.

The focus of this work is going to be precisely this latter instrument: the green bond. In particular, after presenting the history of green bonds and their regulatory framework, I am going to ascertain whether this product is being sold for a premium in the primary market compared to a conventional bond. Often, the premium linked to the greenness of a bond is called "greenium" in the related literature. The confirmation of this hypothesis would be good news for their issuers, since it would imply a lower cost of debt, which could, at least partially, offset the particular expenses related to the issuance process of this instrument, such as for third-party certification, monitoring and periodical reporting. For some issuers, depending on the size of the identified greenium, it could take even several issues to recover from the additional costs of this product. The analysis I carry out is, to my best knowledge, original, both in terms of dataset and regression construction. However, my study was influenced by the existing literature. The rest of this work is organised as follows: for the remaining part of this section, I am going to talk about the history of green bonds and the regulatory framework. Chapter 2 is dedicated to the review of the most pertinent literature. In chapter 3, I describe the sample construction, data sources and methodological approach and empirical results. Section 4 concludes this work by summing up my main results.

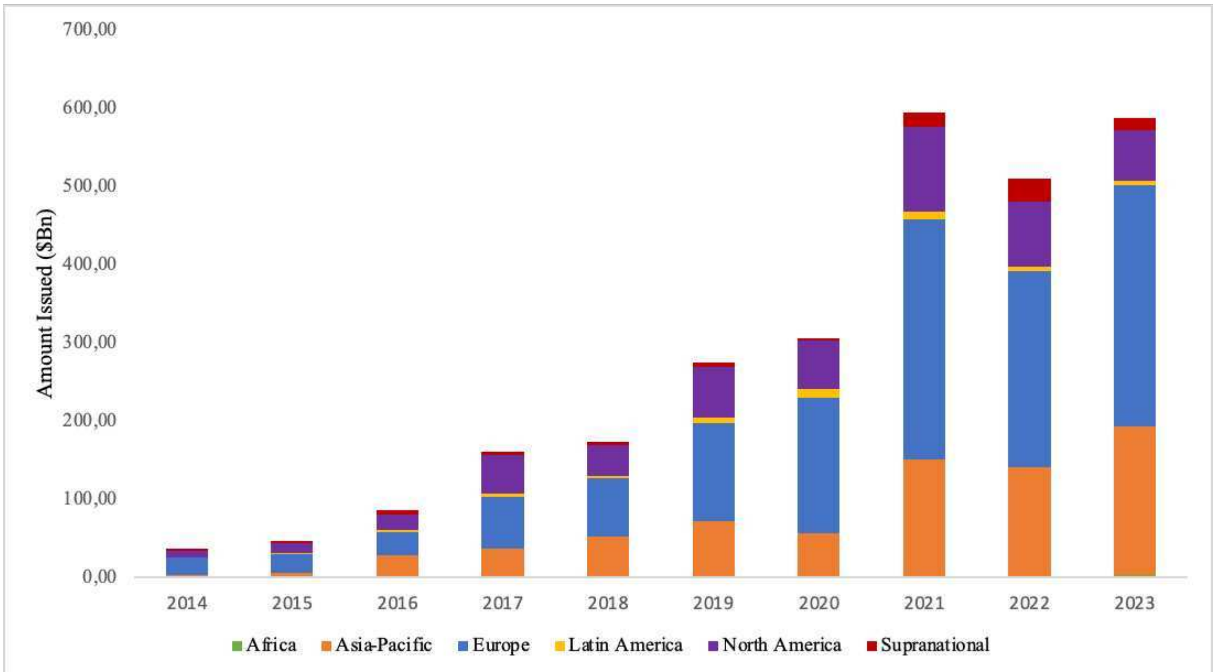
1.1 The History of Green Bonds

At the end of the 2000s, investors were looking for a way of knowing with certainty that they were buying sustainable financial products, meanwhile, the European Investment Bank (EIB), was trying to integrate sustainability in their funding programme. In 2007, Aldo Romani and his team from the EIB came up with the idea of creating a financial instrument that was able to direct investments towards projects with the aim of fighting climate change and, at the same time, enable investors to monitor the efforts of the issuer in the unwinding of the project (EIB 2022). With a maturity of 5 years and a value of 600 million euros, the first Climate Awareness Bond was born. One year later, in November 2008, after the publication of the IPCC Forth Assessment Report, which undeniably linked anthropomorphic activity to climate change, the World Bank issued its first green bond too. The bond created defined the criteria for eligibility of the green label, involved CICERO (Centre for International Climate Research) as a second opinion provider and added impact reporting as part of the process (World Bank 2019). This innovation sparked great interest among investors and soon four green bonds funds were launched: Nikko Asset Management World Bank Green Bond Fund (2010), State Street Green Bond Fund (2012), Calvert Green Bond Fund (2013) and Mirova Global Green Bond Fund (2015). In 2014, as the demand around these products kept on increasing, regulators felt the need to provide guiding principles to issuers. Consequently, by the joint efforts of JP Morgan, Citi, Bank of America, Merrill Lynch, Credit Agricole, BNP Paribas, Daiwa, Deutsche Bank, Goldman Sachs, HSBC, Mizuho Securities, Morgan Stanley, Rabobank, SEB and the ICMA as secretariat, the Green Bond Principles were born.

Since the first green bond was issued in 2007, the market has considerably expanded. As the Climate Bond Initiative reports, at the end of 2023, the total issued volume was nearly $590 billion, almost 3.5 times the volume of 2018. Fig. 2 displays the amount issued in the 2014-2023 period per region. It is possible to say that the Asia-Pacific area and especially Europe made the most progress in increasing their issued volume over the years. North America also incremented its effort in some years, but was not consistent throughout the period, thus reaching an average issuance size just half as big as the Asia-Pacific. As a result, it ended up being only the third largest issuer of green bonds, with a cumulative value of $513 billion, more than $200 billion behind the Asia-Pacific region (standing at $728 billion) and $710 billion behind Europe, as shown in Fig. 3.

Fig. 2.

Amount Issued per Region (2014-2023)



Source: *Climate Bonds Interactive Data Platform.* https://www.climatebonds.net/market/data/

Fig. 3.

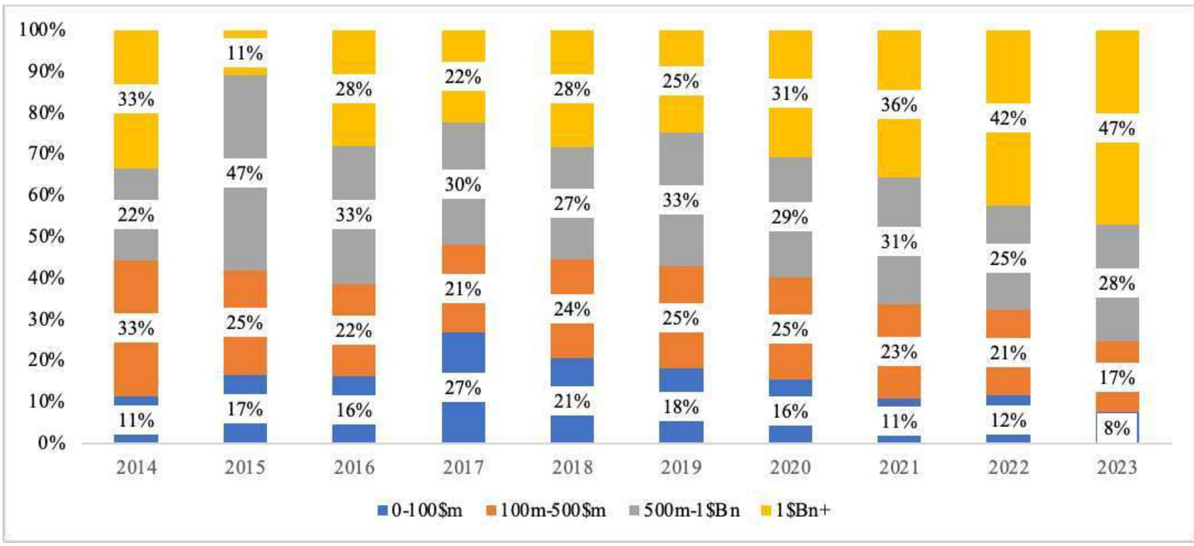
Cumulative Amount Issued per Region (2014-2023)

Source: *Climate Bonds Interactive Data Platform.* https://www.climatebonds.net/market/data/

An interesting feature of the green bond issuance phenomenon is the evolution of the deal size over the years. If we observe Fig. 4, we will see that, starting from 2017, bonds with an issuance volume larger than $1 billion started to become more and more common, to the detriment of the smaller issue (0-$100 million), while medium-sized issues remained quite constant. The increase in average deal size is closely related to the growing role of supranational issuers, which tend to be involved in larger issues. Another possible explanation is the attempt to curtail the impact of fixed costs by spreading them over a larger issuance, possibly also benefitting from a bigger greenium.

Fig. 4.

Deal Size Breakdown (2014-2023)



Source: *Climate Bonds Interactive Data Platform.* https://www.climatebonds.net/market/data/

1.2 Regulatory Framework

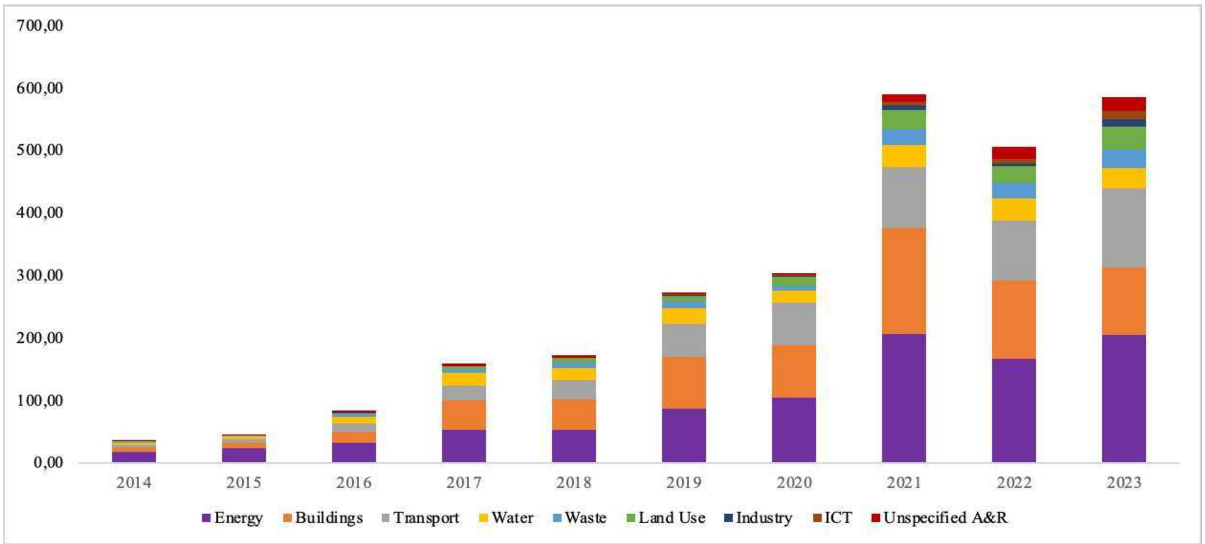
1.2.1 The Green Bond Principles

In 2014, ICMA (International Capital Market Association) published a document containing voluntary process guidelines for issuing green bonds, namely The Green Bond Principles (GBP). The goal of this document was to support the role the global debt capital market can play in financing efforts against climate change and social sustainability and underpinning the integrity of the market. The Principles outline the best practices when issuing environmental bonds and provide issuers with guidance on the most important aspects related to the launch of a credible green bond. The latest version of the document (ICMA 2021) is comprised of four different sections: use of proceeds; process for project evaluation and selection; management of proceeds; reporting. At the end of the document are also present key recommendations for enhanced transparency.

In the first section, the GBP highlight the importance of appropriately describing the use of proceeds in the legal documentation of the security. It is recommended that the issuer provide an estimate of the portion of resources dedicated to the re-financing vs. financing and clarify which investments may be refinanced. In this section are also listed some of the eligible green projects categories, namely: renewable energy, energy efficiency, pollution prevention and control, environmentally sustainable management of living natural resources and land use, terrestrial and aquatic biodiversity, clean transportation, sustainable water and wasteful management, climate change adaptation, circular economy adapted products, production technologies and processes, green buildings. Fig. 5 shows how the use of proceeds varied over time.

Fig. 5.

Use of proceeds (2014-2023)



Source: *Climate Bonds Interactive Data Platform.* https://www.climatebonds.net/market/data/

As depicted, energy-related projects have always been the most undergone. Building projects were the second most chosen, however starting from 2022 we observe a reduction of investment in this category to the benefit of other smaller categories such as land use, ICT and industry. This trend is motivated by the fact that more issuers are starting to finance a broader range of projects to the detriment of traditional sectors.

In the second section, the GBP state that issuers should clearly communicate to investors: the environmental sustainability objectives of the projects, the process employed for the determination of the aptness of the project and other complementary information on the project.

The third section recommends tracking the raised funds appropriately and encourages the use of an external auditor to support the management of proceeds.

In the last section, the GBP underline the importance of publishing annually reviewed information on the use of proceeds until full allocation. Moreover, it is highlighted the importance of transparency in public communications, which is encouraged through the use of qualitative and, where possible, quantitative performance measures.

1.2.2 Regulation (EU) 2023/2631

The issue with the GBP is their voluntary nature, which deprives them of all legal power. A mandatory framework in Europe was born on the 20th December 2023, when the EU regulation 2023/2631 on European Green Bonds and optional disclosures for bonds marketed as environmentally sustainable and for sustainability-linked bonds, also known as "The Green Bonds regulation", became law. As stated in article 1, it: "lays down uniform requirements for issuers of bonds who wish to use the designation 'European Green Bond' or 'EuGB' for their bonds that are made available to investors in the Union; establishes a system to register and supervise external reviewers of European Green Bonds; and provides optional disclosure templates for bonds marketed as environmentally sustainable and for sustainability-linked bonds in the Union."

In summary, to use those labels the regulation poses various requirements regarding the use of proceeds, transparency and external review.

The use of proceeds is regulated by article 4, which states that, before the maturity of the green bond, its proceeds shall be allocated in full to fixed-nonfinancial assets, financial assets created no more than five years later than the green bond, assets and expenditures of households, capital expenditure that falls under point 1.1.2.2. of Annex I to Delegated Regulation (EU) 2021/2178 and operating expenditure that falls under point 1.1.3.2. of Annex I to Delegated Regulation (EU) 2021/2178 and was incurred no more than three years before the issuance of the green bond.

Regarding transparency, article 10 states that issuers should complete the bond factsheet, which contains, amongst others, the intended allocation of bond proceeds and an estimate of the environmental impact of the funds. Article 11 posits that, until all the proceeds have been allocated, every 12 months the issuer shall draw up an allocation report which has to contain information on the progress made in the implementation of the CapEx plan. Article 12 explains that issuers shall at least once during the lifetime of the bond, after the full allocation of funds, publish an impact report on the environmental impact of the bond proceeds. Article 14 establishes that issuers shall publish a prospectus where the bonds are designated as "European Green Bond" or "EuGB" throughout the prospectus which has to state that the European Green Bond is issued accordingly with this regulation. Lastly, article 15 dictates that all the mentioned documents shall be published on the issuer's website and be accessible free of charge. The transparency requirements imposed by the regulation aim to dramatically enhance the level of transparency in the green bond market, previously unsatisfactory.

Regarding the external review mechanism, the Regulation provides for 3 different supervising figures. Firstly, private authorized reviewers must evaluate the issuer and issue conformity to the regulation, in their pre- and post-issue review. Secondly, public national supervisory authorities ensure that issuers adhere to their audit and reporting obligations. Thirdly, ESMA (European Securities and Markets Authority), responsible for public supervision at the European level, is empowered to both register and oversee external auditors.

2. LITERATURE REVIEW

Since the first green bond was issued in 2007, multiple authors have tackled the problem of whether a greenium for the debt market actually exists. Academics have looked at this question from different angles and, although a great amount of articles points towards its existence, a definitive consensus is still to be reached. This is due to a great heterogeneity in the literature regarding samples size and period, unit types and empirical techniques employed.

Magnanelli and Izzo (2017), for example, analysed a sample comprising 1,641 observations of the cost of debt of 332 different firms between 2005-2009 and through a simple linear regression found evidence that an increased corporate social performance (CSP) leads to an increase in the cost of debt. Similarly, Stellner (2015), by investigating 872 corporate bonds issued by non-financial companies in the European Monetary Union area through pooled time-series, cross-sectional regressions of yearly corporate bond z-spreads, presented weak results supporting the claim that a good CSP can systematically curtail credit risks. Moreover, I4CE (2017) reports evidence of "flat pricing", meaning that investors are not willing to pay a premium for acquiring at issuance a green-labeled asset. Another important study is that of Larcker and Watts (2020), which analysed tranches of green municipal bonds that were bundled with tranches of conventional municipal bonds. The authors argued that their setting was the most likely to find a greenium, if it existed. In particular because of the small average issue size of their sample, which meant, in their view, that there was an abundant probability that small traders would influence the data, making a premium emerge. Nonetheless, their study on 640 green ordinary municipal bonds matched pairs didn't provide evidence, in the end, of a greenium at issue. However, Baker et al. (2022) argued that their decision of bundling green and ordinary bonds is totally endogenous and, therefore, raises potential concerns over the validity of the study. Thus, they decided to apply their own fixed effects model to bundled issues and were able to identify a greenium oscillating between 4.5 to 6.3 bps[1] at issuance and of 2.5 bps in the secondary market, in the first month.

Conversely, Oikonomou et al. (2014), working on a sample of 3240 bonds traded between 1993 and 2008 through pooled ordinary least squared regressions (OLS), showed that for U.S. corporate bonds, environmental transgressions were associated with higher yield spreads. Also, Bauer and Hann (2010), analysing 2,242 bonds of U.S. corporations issued between 1995-2006 with a fixed effects regression model, document that environmental concerns are linked to shrunk credit ratings and an increased cost of debt. Among the studies fully dedicated to the primary market, Ehlers and Packer (2017) examined 21 euro or US dollar-denominated

[1] Basis points

matched bond pairs issued between 2014 and 2017 and found a negative greenium of 18 basis points. Fatica et al. (2021), investigating 1,397 green bonds through an OLS model with the addition of time- and issuer-fixed effects, were able to estimate an impressive 80 bps greenium for supranational issuers, but for corporate bonds results didn't hold. That's because they found out that investors do not blindly invest in green-labelled products, but are actually cautious about whether an external certification is present. A certification does not seem to be necessary in the case of supranational bonds as the authors assume they benefit from a strong reputational advantage. This is in line with findings of Bachelet et al. (2019) and Kapraun et. al (2021), which showed that green bonds issued by more official entities encounter larger demand and are more "green-credible", as they reduce informational asymmetries, both in the primary and secondary market. The concordance of results that we observe regarding the importance of an external certification in specific contests is very much relevant because, thanks to the different samples built and investigation techniques used, we are able to be certain of its universality.

Bachelet et al. (2019) for instance, created a dataset spanning from 2013 to 2017, from which they were able to match 179 different bonds into 89 pairs. In the regression specification, the authors decided to add not just one but two regressors to control for liquidity differences, moreover, they included inexactly matched bond characteristics (coupon, size and maturity) and a term that captures differences in the bonds variance. Kapraun et al. (2021) instead, built a considerably bigger sample: ranging between 2009 and 2021, it counts 2,099 green and 21,872 conventional bonds. They chose to employ both a multivariate regression framework with the addition of fixed effects (controlling for currency, seniority, time and issuer ID) and a matching analysis as a robustness check similar to that of Zerbib (2019).

Focusing on the secondary market, Barclays (2015) used OLS estimation to linearly regress the option-adjusted spread on a series of bond controls and was able to find an increasing premium, which amounted to slightly more than 0 as of March 2014 and, by the end of the sample period, in August 2015, reached nearly -17 bps. Zerbib (2019), who analyzed a sample of 37,503 bonds spanning from 2013 to 2018 with a matching technique, registered a premium equal to -2 bps and established that sector and rating are significant drivers of the greenium, after discovering a greater impact on the yield for financial bonds and low-rated investment-grade bonds. Partridge and Medda (2018) constructed a sample of 521 matched US municipal bond pairs and examined their yield spreads by building a yield curve for each type of bond with the Svensson technique. Results indicated a small but growing premium between 2015-2017 in both the primary and, especially, secondary market. Baker et al. (2022), looking at a sample beginning in 2013 and running through the end of 2018 of municipal bonds, also found evidence of green bonds selling at a premium of about -6 bps and attributed it to a supply-demand imbalance, an occurrence whereby a subset of investors sacrifice some return in order to hold scarcely issued green bonds. The author showed this to be particularly true for smaller and riskless green bonds. This phenomenon can be pinned down on the lack of an official and universal classification system for green bonds, such as the Green Bond Principles (Cochu et al. 2016), on an excess of investment demand attributable to the specificity of green bonds and on an insufficiently large volume of bonds issued, for which an antidote could be fiscal support policies (Zerbib 2019). Flammer (2018) possibly brought to the fore the inner working mechanism of this imbalance by illustrating that, after the issuance of green bonds, companies not only enhance their environmental performance, but also experience an increase in long-term ownership and green investors, in accordance with a signalling argument (by issuing green bonds, they signal their commitment towards the reduction of emissions). Bour (2019) highlights the importance of non-financial disclosure and provides a hierarchy of it, based on what investors value more, namely: alignment with the Green Bond Principles, issuance of a second party opinion, assurance provision, and CBI certification.

Most recently, Caramichael and Rapp (2024) analyzed a sample of 1,169 green and 129,043 conventional bonds issued by corporations. They used a multivariate regression framework with the addition of currency, issuer, time, seniority, bond option and industry fixed effects. They included an exhaustive list of controls, namely: bond levels numeric variables, indicators of aggregate credit risk, general condition of credit markets and interactions for capturing potential non-linearities. The authors registered a greenium of nearly 11.5 bps for corporate bonds yields at issuance, mainly because of oversubscription in euro-denominated bonds; they also found evidence of a correlation between the emergence of a significant greenium and the release of the European Union Sustainable Finance Action Plan (EU SFAP) by the European Commission in March 2018 and showed that, once time-varying fixed effects are introduced in their model, there is no proof of a "green halo", a phenomenon whereby all the other conventional bonds of a green issuer experience a discount in the yield at issuance.

As shown by the reviewed literature, in order to measure the significance of a greenium, two main approaches can be implemented: matching methods or OLS regressions with fixed effects. To paraphrase Nguyen (2020): the goal of matching methods is to minimize potential bias by creating comparable groups based on a set of matching variables. By pairing a green bond with its regular synthetic equivalent, we are able to eliminate the role played by common variables and therefore isolate the effect of the green label, which should be therefore the only determinant of the yield at this point, although it is still necessary to control for differences in liquidity, which persist even after the matching procedure. Zerbib (2019) and Bachelet (2019), for example, use an exact matching technique, which matches treated units to all possible control units with the same values on all covariates (e.g. for currency, rating, bond structure, coupon type). Larcker and Watts (2020) use instead nearest neighbors matching, which pairs treated and control units based on maximum similarity in the covariates. However, the matching approach has 2 main problems. First, it drastically reduces the sample, as it needs a triplet of bonds from the same issuer or a set of comparable conventional bonds to mitigate the confounding bias from inexactly matched pairs. Second, this technique biases the sample towards firms with stronger access to capital markets, since they can issue bonds more frequently, potentially causing an underrepresentation in small and medium-sized firms. The fixed effects approach, which I thoroughly explain in section 3.2, is not immune from criticism as well. Larcker and Watts (2020), for example, worry about the possible inadequacy of the chosen fixed effects. They argue that: “green issuers (which tend to be significantly larger) may outperform non-green issuers over the sample period” [and therefore,] “even when controlling for rating-maturity-issuance month fixed effects and issuer fixed effects, a greenium would be observed in this setting when it does not actually exist.”

3. EMPIRICAL ANALYSIS

My work is an original contribution to the reviewed literature for two reasons. First, the dataset I have built differs from the ones examined in that: it is an up-to-date sample not focused just on one type of issuer, but rather on various kinds, namely: corporate, agency, supranational, non-US municipal and government issuers. This broad-spectrum sample will give us a universal picture of the existence of a greenium and, through subsample analysis, it will also yield more detailed insights. Second, with more than 40,000 observations, it is amongst the largest samples considered for such studies. Moreover, due to the outlined problems for matching techniques, I will adopt a fixed effects framework thanks to which I will be able to control for unobserved heterogeneity and differences across the sample that may influence our dependent variable.

3.1 Dataset

To document the existence of a greenium, I have collected data from LSEG Eikon (London Stock Exchange Group). I downloaded detailed information on the bonds coupon and coupon type, currency and country of issue, amount issued, seniority, issue date and price, maturity, credit rating, yield spread to maturity at issuance, the issuer's sector, whether the bond is callable, extendible or putable and whether the bond is green or not.

I curtailed the sample by requiring that each issuer has at least one conventional bond and one green bond. Moreover, following the approach of Caramichael and Rapp (2024), I only considered plain vanilla fixed coupon bonds and zero-coupon bonds with an issuance size bigger than $500,000, a maturity between 1 and 30 years and whose currency of issue had at least $10 billion in total issuance over the sample period. However, unlike them, I did not require green bonds to be exclusively issued in euro or US dollars. Lastly, I dropped bonds with an issue price bigger than 250 or lower than 90 and with yield spreads bigger than 1,000 basis points, as these observations are likely data errors, outliers or distressed bonds.

The final dataset contains 4,503 green bonds and 37,605 conventional bonds issued between 2014 and 2024. These bonds were issued by 1,666 different entities, both public and private companies, from developed and underdeveloped economies. Detailed summary statistics of the sample can be found in Table 1.

Table 1

	Observations	Mean	S.D.	25th	Median	75th
Green Bonds						
YSTM	4,503	106.4	116.6	48.56	84.80	137.9
Amount Issued ($M)	4,503	439.9	1,274	64.78	164.7	533.5
Coupon (%)	4,503	2.708	1.944	0.875	2.730	4.000
Rating	2,139	16.13	3.434	14.00	16.00	19.00
Issue Price	4,343	99.85	0.560	99.79	100.0	100.0
Maturity	4,503	8.214	5.426	5.003	7.000	10.01
Conventional Bonds						
YSTM	37,605	40.57	356.6	22.21	67.19	121.2
Amount Issued ($M)	37,605	776.5	3,782	25.54	77.23	276.3
Coupon (%)	37,605	2.446	1.936	0.660	2.350	3.700
Rating	13,776	17.40	2.732	15.00	17.00	20.00
Issue Price	36,345	100.0	1.240	100.0	100.0	100.0
Maturity	37,138	9.734	7.069	5.003	8.010	10.18

Comparison of descriptive statistics between green and conventional bonds for different variables. S.D. is the standard deviation, 25^{th} and 75^{th} are respectively the first and third quartile, YSTM is the yield spread to maturity.

In Table 2 a breakdown of the general sample for issuer type is provided. As it stands out, nearly 70% of our sample is comprised of corporate bonds, agency bonds follow with almost 11.5%, supranationals account for 9.5% and finally, non-US municipal bonds and treasury bonds are present with 6% and 3.4% respectively.

Table 2

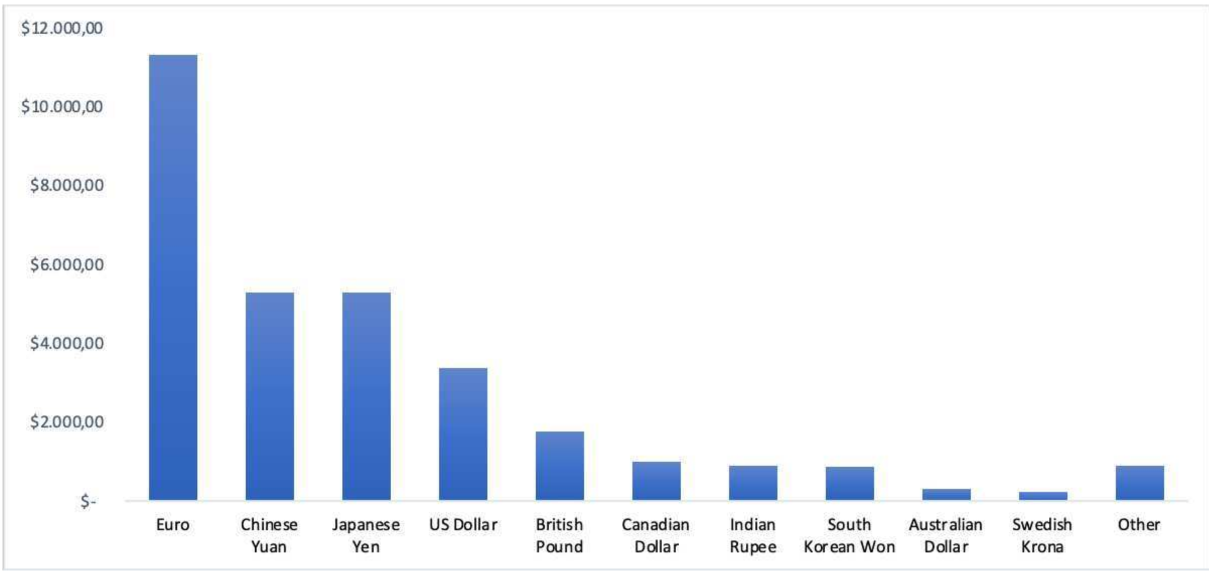
Issuer Type	Observations
Agency	4,834
Corporate	29,296
Govt/Treasury/Central Bank	1,415
Non-US Munis	2,548
Other Gov/Supranational	4,015

Breakdown of the sample for issuer type.

The bonds in the sample are issued in 23 different currencies. As Fig. 6 shows, the currency with the largest total issue size throughout the sample period is the Euro, with more than double the quantity of the Chinese Yuan, the second most important. The US Dollar is only fourth, preceded by the Japanese Yen.

Fig. 6.

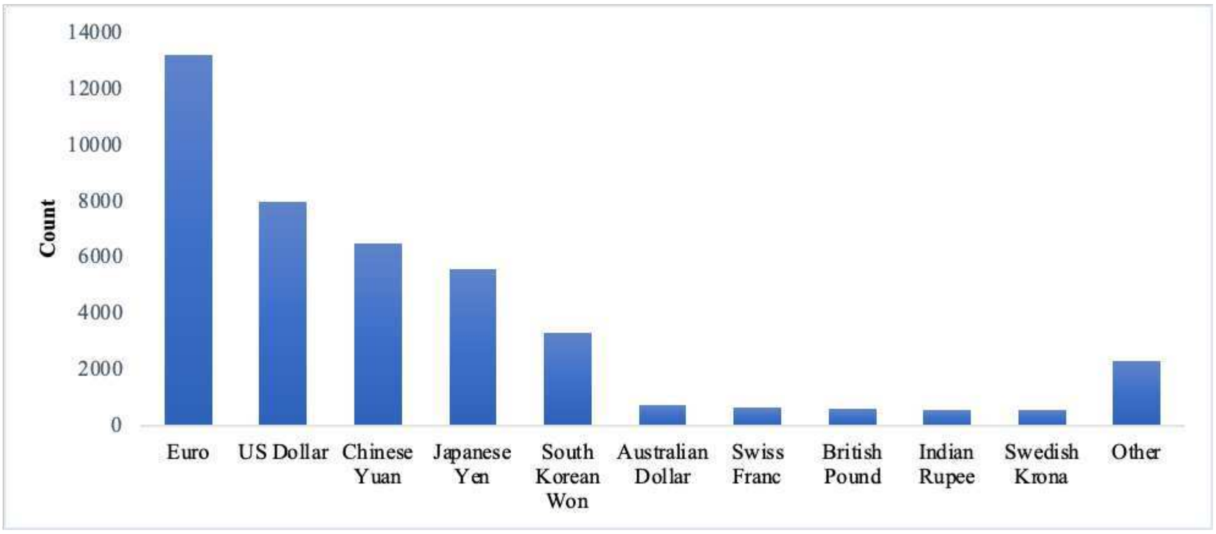
Total Issue Size per Currency (Billion $)



However, if we look at the total number of bonds emitted per currency in Fig. 7, the US Dollar is the second most prolific currency after the Euro, which means that bonds emitted in Chinese Yuan and Japanese Yen have an average larger size compared to those in US Dollar. The same is true for the British Pound, Canadian Dollar and Indian Rupee, while the Australian Dollar and South Korean Won have an average smaller size just like the US Dollar.

Fig. 7.

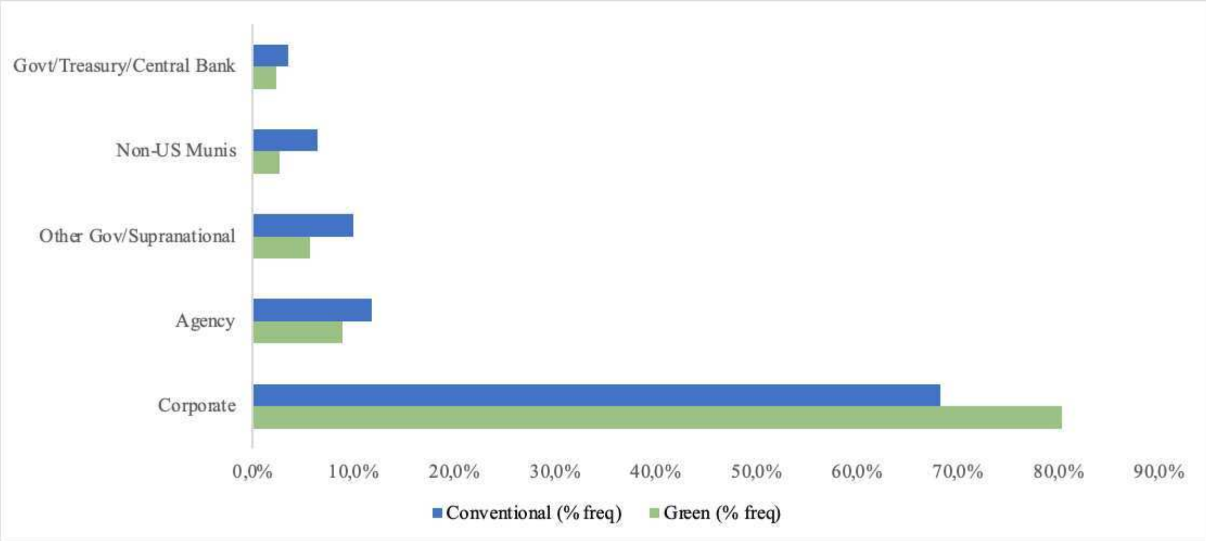
Total number of Bonds Emitted per Currency



Lastly, let's look at the issuer's type distribution of green and conventional bonds. Fig. 8 highlights the fact that the two kinds of bonds have a very similar distribution, with corporate issuers being by far the most represented category in the sample (80.4% of green bonds, 68.3% of conventional bonds) and treasury bonds being the least represented one (2.3% of green bonds, 3.5% of conventional bonds). The only difference can be found in the degree of concentration of the distribution, with conventional bonds being slightly more homogenously distributed than green ones.

Fig. 8.

Green vs Conventional Bonds Issuer Type Distribution



3.2 Empirical Approach

In order to measure the significance of a greenium, I decided to follow Caramichael and Rapp (2024), Baker et al. (2022) and Quan, L. et al. (2022), who use a multivariate regression framework with the addition of fixed effects. The dependent variable is the yield spread to maturity, I preferred to focus on yield spreads in order to account for differences in the interest rates across currencies. By definition, the yield spread of a given bond at a given point in time is equal to the yield of the bond minus the yield of a sovereign bond that is identical to the other bond in every characteristic (maturity, coupon rate, frequency of payments per year) except for credit risk.

The baseline regression specification is the following:

$$Yield\ Spread_i = \alpha Green_i + \beta' \boldsymbol{X}_i + \eta_{s,c,w,n} + \varepsilon_i \,, \qquad (1)$$

where Green$_i$, the main variable of the model, is a dummy variable equal to 1 if bond *i* is green and 0 otherwise. The coefficient attached to Green, α, measures the average difference in yield spreads between green and conventional bonds in the primary market. A negative α would confirm the existence of a greenium in the bond market, as it indicates a lower cost of borrowing related to green issues *ceteris paribus*. The vector $\boldsymbol{X}_i$ contains bond-level controls, in particular, I used 3 different variables: $Rating_i$ is the credit rating for bond *i*, $Maturity_i$ is the years to maturity of bond *i* and $Size_i$ is the natural log of the notional amount issued. I decided to include these controls following Merton (1974), who poses that the price of a bond is determined by the risk free rate of return, characteristics of the issuance (e.g. maturity, call terms, coupon rate) and the probability of default. Since the dependent variable of the model is the yield spread, there's no need to control for the risk free rate, I therefore control directly for the maturity and indirectly for the probability of default by using the credit rating as a proxy. Newer studies by Houweling (2005), de Jong and Driessen (2006) and Lin (2011) have proven that by adding bond liquidity proxies to these classical determinants the overall explanatory power of the model can be significantly enhanced. Houweling (2005) and Bao et al. (2011) showed that the liquidity effect can be captured by including regressors for the issue amount and issue date or bid-ask spread. Therefore I chose to include the issue amount as a regressor and the issue date as a fixed effect. The great majority, if not all, of the controls chosen are being employed in the most recent publications. See for example Karpf and Mandel (2017), Bour (2019), Kapraun et al. (2021), Slimane B. M. et al. (2020), Quan, L. et al. (2022), Baker et al. (2022) and Caramichael and Rapp (2024).

The vector $\eta_{s,c,w,n}$ include bond, currency, time and geographical fixed effects for issuer *s*, currency of issue *c*, week-year of issue *w* and the country of issue *n*. Lastly, ε_i is the error term. Explicitly, the model assumes the following form:

$$Yield\ Spread_i = \beta_1 Green_i + \beta_2 Rating_i + \beta_3 Maturity_i + \beta_4 Size_i + \gamma_s + \delta_c + \rho_w + \phi_n + \varepsilon_i \quad (2)$$

The fixed-effects approach aim is to remove constant heterogeneity between observations, controlling for variables that are fixed over time. Therefore, by including fixed effects in our regression, I am able to control for unobserved heterogeneity and differences across the sample that may influence our dependent variable. Formally, adding firm-specific fixed effects, the general specification would change from:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \varepsilon_{it}, i = 1, \dots n, t = 1, \dots T$$

to:

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \varepsilon_{it},\ i = 1, \dots n, t = 1, \dots T\ , \quad (3)$$

where α_i represents the fixed effect term specific for each firm *i*. Since α_i is unobservable, we need to apply a transformation that can make it disappear from the model. This can be done either by adding a dummy variable for each individual *i* (except for 1 to avoid multicollinearity problems), or, alternatively, through the within transformation, which works as follows:

We take the sum of each term of equation (3) and then also divide it by T:

$$\frac{\sum_{t=1}^{T} Y_{it}}{T} = \beta_1 \frac{\sum_{t=1}^{T} X_{it} + T\alpha_i}{T} + \frac{\sum_{t=1}^{T} \varepsilon_{it}}{T}$$

by simplifying, we get:

$$Y_i = \alpha_i + \beta_1 X_i + \varepsilon_i \quad (4)$$

Now, if we subtract (4) from (3) what we finally obtain is:

$$Y_{it} - Y_i = \beta_1(X_{it} - X_i) + (\varepsilon_{it} - \varepsilon_i) ,$$

which is equal to:

$$\check{Y}_{it} = \beta_1 \check{X}_{it} + \check{\varepsilon}_i \qquad (5)$$

Lastly, we have to regress $\check{Y}_{it}$ on $\check{X}_{it}$ in order to estimate our β_1^{FE}.

In a fixed effects model, 4 assumptions need to be satisfied (Stock, J. H., Watson, M. W. 2015):

1. The error term is uncorrelated with all observations of the variable X over time, formally:

$$E(\varepsilon_{it}|X_{i1}, X_{i2}, \dots, X_{iT}, \alpha_1) = 0$$

2. Variables relative to a certain unit need to be distributed identically and independently from variables relative to another unit. Formally:

$$(X_{i1}, \dots, X_{iT},\ \varepsilon_{1t}, \dots, \varepsilon_{1T}),\ i = 1, \dots, n\ are\ i.i.d\ draws.$$

   This is going to be true if units are drawn from the population through a simple random sampling.

3. All variables, even omitted ones, have finite fourth moments. This means that outliers are highly unlikely. Formally:

$$E(X_{it}^4) < \infty,\ \ E(\varepsilon_{it}) < \infty$$

4. There is no perfect multicollinearity.

Assumption 1 implies absence of distortion from omitted variables, if violated, the OLS estimator is going to be biased $E(\widehat{\beta_1}|X_{it}) \neq \beta_1$and one or more explanatory variables are endogenous. Assumption 2 implies that variables are independent between units, but a certain X_{it} can be correlated over time for a given unit. Assumption 3 and 4 are analogous to two of the assumption for sectional data.

3.3 Results

Table 3 presents the empirical results. I started by simply regressing the yield spread at issuance on the green indicator. Initially, the coefficient on *Green* is positive and highly significant, however, as pointed out by the degree of significance of the intercept, many factors are probably still to be included in the model. In the second specification, I added issuer- and time-fixed effects. Now the coefficient on *Green* assumes the expected negative sign, although it is not statistically meaningful yet. By adding also currency and country fixed effects it becomes significant at the 10% level and amounts to more than 11 basis points. In the fourth specification, I included the issue credit rating and the years to maturity[2]. The newly added terms have the expected sign, are both significant at the 1% level and drastically improve the

[2] The years to maturity are the years that need to pass before the bond is repaid by the issuer.

fit of the model. I expected the coefficient on Rating to be negative by construction, since I had dealt to better ratings a higher number, during the dataset building. The coefficient on Maturity should instead be positive, as a further maturity implies the bearing of more risks by the investor, namely, that the issuer is not able to repay his debt. The coefficient on Green increases to -5.5 basis points but is now significant at the 1% level. In the last regression, I also added the natural log of the amount issued, which, like Rating and Maturity, is significant at the 1% level. The sign of the coefficient on Size is negative. As Kapraun et al. (2021) hypothesize, this could be because investors have a preference for financing projects that have a higher environmental impact, for which the amount issued could be a proxy, or simply a matter of liquidity, since larger bonds are more easily tradable on the secondary market. Finally, the coefficient on Green, now significant at the 5% level, indicates that investors are willing to accept a lower remuneration of nearly 4.4 basis points to hold a green bond in their portfolio.

Table 3

	Yield Spread				
Variables	(1)	(2)	(3)	(4)	(5)
Green	65.80 ***	-2.791	-11.26 *	-5.509 ***	-4.356 **
	(1.749)	(4.805)	(6.519)	(1.979)	(1.969)
Rating				-13.90 ***	-13.65 ***
				(2.078)	(1.985)
Maturity				0.005 ***	0.005 ***
				(0.001)	(0.001)
Size					-4.004 ***
					(1.316)
Intercept	40.84 ***				
	(5.348)				
Issuer FE		Yes	Yes	Yes	Yes
Week FE		Yes	Yes	Yes	Yes
Currency FE			Yes	Yes	Yes
Country FE			Yes	Yes	Yes
Observations	42,108	42,108	42,095	15,902	15,902
Adjusted R^2	0.004	0.121	0.143	0.332	0.334
Within R^2		0,000	0,000	0.036	0.039

The table shows the results of the regressions of the yield spread at issuance. *Green* is a dummy variable equal to 1 if the bond is green and 0 otherwise. *Rating* is the average credit rating of the bond provided by Fitch, Moody's and S&P, coded with 1 equal to SD and 21 equal to AAA. *Maturity* is the years to maturity. *Size* is the ln of the amount issued in USD. ***, **, * indicate statistical significance respectively at the 1%, 5% and 10% levels. I clustered standard errors to account for potential heteroscedasticity or correlation, they are in parentheses.

In the next analysis, I am going to investigate how the preferences of investors for green bonds vary for different types of issuers.

In the first column, we use the baseline specification for a subsample of corporate bonds. As we can see, the coefficients are pretty much similar to those in column 5 of Table 3. The green indicator is still comparable to the one in the baseline regression, but, unfortunately, it is no longer meaningful. For agency bonds in column 2, namely a bond issued by a governmentsponsored enterprise or by a federal government department except for the U.S. Treasury, the coefficient on *Green* is significant at the 1% level and amounts to nearly -6.5 basis points, the lowest up until now. For the first time, *Rating* is no longer meaningful, but still, this specification has the highest R^2 (both adjusted and within) of all the others. Lastly, in column 3 I analyze supranational bonds. Supranational bonds are emitted by multi-national organizations that go beyond national boundaries. In the specification, both *Green* and *Rating* are not statistically significant, probably due to the low amounts of observations compared to the other regressions. Some of these results could be bettered by slightly changing the specification.

For example, by adding a new regressor, *Callable*, which is a dummy variable that equals 1 when the bond is callable[3], the results of the agency subsample improve. Additionally, if I remove the regressor *Size*, then the green indicator becomes significant again at the 5% level for the corporate specification and amounts to nearly -5.7 basis points.

[3] A callable bond is a bond that gives the right to the issuer to redeem it before the maturity date at a pre-specified call price. Callable bonds have a higher yield spread at issuance *ceteris paribus*.

Table 4

	Issuer Type				
	(1)	(2)	(3)	(4)	(5)
Subsample	Corporate	Agency	Supranationals	Corporate	Agency
Green	-4.571	-6.478 ***	-6.911	-5.685 **	-5.712 ***
	(2,856)	(2.118)	(4.747)	(2,776)	(1.793)
Rating	-14.93 ***	-0.777	8.603	-14.89 ***	0.180
	(2.001)	(0.934)	(7.251)	(1.953)	(0.920)
Maturity	0.006 ***	0.002 ***	0.004 ***	0.005 ***	0.002 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Size	-3.953 **	-5.383 ***	-4.861 ***		-3.274 ***
	(1.831)	(0.815)	(1.041)		(0.892)
Callable				48.00 ***	15.25 **
				(15.87)	(6.991)
Issuer FE	Yes	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes	Yes
Currency FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Observations	10,933	2,168	1,189	10,933	2,168
Adjusted R^2	0.197	0.827	0.235	0.207	0.832
Within R^2	0.039	0.259	0.046	0.051	0.280

The table shows the results of the regressions of the yield spread at issuance for different issuer types. *Green* is a dummy variable equal to 1 if the bond is green and 0 otherwise. *Rating* is the average credit rating of the bond provided by Fitch, Moody's and S&P, coded with 1 equal to SD and 21 equal to AAA. *Maturity* is the years to maturity. *Size* is the ln of the amount issued in USD. *Callable* is a dummy variable equal to 1 if the bond is callable and 0 otherwise. ***, **, * indicate statistical significance respectively at the 1%, 5% and 10% levels. I clustered standard errors to account for potential heteroscedasticity or correlation, they are in parentheses.

4. CONCLUSION

In a scenario where the European Commission estimated that additional investments of €620 billion per year will be necessary between 2023 and 2030 to reach the EU's green transition objectives, instruments designated for this purpose, like the green bond, can prove themselves very useful. For this reason, it is crucial to understand their characteristics and financing dynamics.

In this work, I examine whether investors are systematically willing to give up some remuneration in order to hold environmentally sustainable bonds. By using an OLS fixed effects regression approach on a dataset spanning from 2014 to 2024, I was able to find evidence of the existence of a greenium, which I estimated on average at -4.356 basis points. By splitting the sample for different issuer types, a premium still emerged for corporate and agency bonds of -5.685 and -5.712 basis points on average respectively. Therefore, a slight borrowing cost advantage over conventional bonds exists, however, considering the size of the advantage, the net financial benefit of issuing a green bond is likely small or potentially negative once we account for fees, emissions, monitoring and reporting costs. The greenium could be a result of supply-demand imbalances but, if this was the case, given the current trend of global increased issuance volume we should witness this phenomenon fade over the next years. An additional advantage of issuing a green bond likely comes from the indirect signal that it sends about the issuer's environmental concern, which, if credible, would ameliorate the issuer's reputation. A final relevant consideration to make regards the implementation of common regulatory standards: as global mandatory principles take shape, we should witness a reduction in information asymmetries and a repositioning of investors towards authentic and impactful green projects, thus minimizing the risk of greenwashing.

The main limitations of this study arise from the lack of data about some possible controllers, such as an external certification, to insert in the regression specification, which could have enhanced the model better explaining the yield spreads at issuance.

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