Is there a Greenium in the Corporate Green Bond Market?

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ABSTRACT

This paper examines the pricing of green bonds *vis-à-vis* standard corporate bonds. Using a cross-section of green bonds issued by corporates in the 2014–2021 period, we build a matched sample of quasi-identical conventional bonds and find a statistically insignificant green bond premium of -7.2 bps. These results remain identical when creating subsamples according to the currency of denomination (euro *versus* USD) and issuer types (financial *versus* nonfinancial firms), and when controlling for contractual, macroeconomic, and several fixed effects. Our findings imply that there is no pricing difference between bonds that mainly differ with respect to their green label, and investors are not willing to exchange financial returns for non-pecuniary environmental benefits.

Keywords: green bonds; corporate bonds; greenium; ESG
JEL Codes: G12; G23; G32; Q56

THE CHALLENGE OF CLIMATE CHANGE is one of the most difficult and pressing matter of humanity recent history of. A topic surrounded by uncertainty and discussion, which requires urgent adaptation and change, and that is vital to the economy and society (Stern, 2008). From the Kyoto Protocol in 1997 to the Paris Agreement in 2015, progress has been made to ensure a low carbon future. More recently, the Glasgow Climate Pact was adopted during the 26th Conference of The Parties (COP26), which aims to turn the 2020s into a decade of climate action and support.

Although the scientific consensus regarding the urgency and severity of the problem seems evident, the actions and measures needed to try and stop the process are still far

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from ideal.[1] Objections from China and India resulted in changing the promise to 'phase out' coal to 'phase down' with India's climate and environment minister Bhupender Yadav (Reuters, 2021) claiming that poorer countries cannot stop subsidizing fossil fuels and that lower income households rely on fossil fuels to lower their energy costs. As stated by Niklas Hoehne (Forbes, 2021), the 'COP26 seems to have closed the gap but not solved the problem.' In addition, the efforts towards COP26 have been severely impacted by the Russian invasion of Ukraine. An act that wreaked havoc across energy markets, forcing many countries to go back on their decisions towards renewable energy to the detriment of fossil energy.

Strong actions and measures require large-scale investments to mitigate the risks associated with climate change. The role of finance, more specifically, green finance, is key in directing funds towards green growth (Fatica *et al.*, 2021; Cicchiello *et al.*, 2022), helping to mitigate climate-related disasters and, most importantly, gearing the world economy towards sustainability.

The largest component of green finance is the green bond market, which has been growing exponentially since 2014, after the introduction of the Green Bond Principles. In 2021, green bonds represented about 50% ($488.8 billion) of the sustainable bond market, nearly double 2020 levels, and 5% of the overall bond market.[2] Green bonds are fixed income securities issued to fund firms' environmentally friendly projects, such as renewable energy, sustainable water management, pollution prevention, and climate change adaptation (ICMA, 2018).

This paper contributes to recent but growing literature that examines a 'greenium' effect in bond markets. Three strands of the literature can help explain this phenomenon. First, investors might have a "taste" for holding bonds issued to fund environmentally friendly projects (Fama and French, 2007). Under this framework, investors are willing to trade-off financial returns for environmental benefits, pricing the green bond at a premium compared to nongreen corporate bonds (Flammer, 2021; Löffler *et al.*, 2021). Second, green bonds may reduce asymmetric information problems, namely when heterogeneous investors have different private information and different capabilities to screen firms. The 'green' certification and third-party review as well as periodic monitoring and reporting reduce asymmetric information (Yu, 2005; Gao and Schmittmann, 2022). Finally, Pedersen *et al.* (2021) and Pastor *et al.* (2021) point out that green assets can work as a hedging mechanism against climate risks.

Empirically, extant literature presents mixed evidence, depending on samples and periods analyzed, as well as on the type of market (primary or secondary), and different issuers. While Ehlers and Packer (2017) and Baker *et al.* (2018) find a green bond premium in the primary market, most studies concerning yield spreads in the secondary market show that such a premium also persists there (Hachenberg and Schiereck 2018; Zerbib 2019). On the contrary, Karpf and Mandel (2018) find a green bond discount. Larcker and Watts (2020) revisited prior empirical studies and find that the green bond

[1] See, among other, Barrett (1994,2003), Dietz and Stern (2008), Labatt and White (2007), Saunders (2019), and Scoville-Simonds (2016).

[2] Sustainable Finance Review, 2021. Source: Refinitiv (https://www.refinitiv.com/dealsintelligence).

premium is essentially zero. However, this literature focuses essentially on the market for municipal, supranational, and sovereign green bonds.

Our paper is closely related to the emerging literature studying this phenomenon in green bonds issued by corporates. Although Tang and Zhang's (2020) and Flammer's (2021) focus on the analysis of green bond issuance impact on announcement returns and real effects, authors find that the yields of green *versus* brown bonds do not differ significantly. On the contrary, several studies find a negative yield spread. Findings related to the size of the premium range from -8 bps (Caramichael and Rapp, 2022) up to -33 bps (Wang *et al.*, 2020) in the primary market. Löffler *et al.* (2021) provide evidence of a "greenium" in both primary and secondary markets, with the yield for green bonds being, on average, 15-20 bps lower than that of conventional bonds. Similarly, Fatica *et al.* (2021) find that corporate green bonds are issued at a premium (-22 bps).

In this paper, we extend this literature by comparing corporate green bonds with a matched sample of standard corporate bonds and using a worldwide and extended sample of bonds closed in the 2014-2021 period.

We do not find evidence consistent with the cost of capital motivation of corporates in issuing green bonds *vis-à-vis* traditional corporate bonds (Tang and Zhang, 2020; Flammer, 2021; Lin and Su, 2022); i.e., our results do not seem to support the existence of a green bond premium within our specified sample and subsamples.

We start by using a matching methodology along with Zerbib (2019), Larcker and Watts (2020), and Flammer (2021). For each green bond, we identify a matched corporate bond issued by the same firm and with the most similar contractual attributes (rating, maturity, and size), but differing with regards to the one property we are studying, the green label. Next, we computed kernel density estimates for yield differences, and find a large concentration at zero. In addition, we run parametric t-tests and non-parametric Wilcoxon rank-sum tests to compare yields in our samples and four additional sub-samples and show that both tests reject the null hypotheses at a 5% level of significance. Results are robust for sub-samples of bonds denominated in EUR or USD, issued by financials or by corporates belonging to the Utility & Energy sector. Finally, we estimate a regression model to study if green bonds have lower yields than matched corporate bonds, controlling for contractual, macroeconomic, and several fixed effects. Results show, in line with Tang and Zhang (2020) and Flammer (2021), that there is no significant difference between the yield of green *versus* standard corporate bonds. We thus find that investors are not willing to trade-off financial returns for societal benefits.

According to Tang and Zhang (2020), green bonds have several limitations: (*i*) green bond issuers suffer from more information disclosures and upfront and ongoing costs - fees paid to third-party certifiers and auditors to perform annual reviews - for certification; (*ii*) there are no unified green bond standards; and (*iii*) there is limited enforcement of the law for supervising green integrity. In addition, compared to conventional corporate bond financing, green bonds are more restrictive. Finally, in line with Tang and Zhang (2020) and Flammer (2021), we find that there is no significant yield difference between the two bond types. Therefore, it is not a straightforward decision for firms to issue green bonds. We thus raise the following question: what are the firm-level countervailing benefits that explain firms' decisions to choose green *vis-à-vis* corporate bonds? We leave the answer to this question as an opportunity for further research.

This paper is organized as follows. Section 1 presents the background and literature review. Section 2 describes the sample selection and matching method used and presents the univariate analysis. Section 3 examines the existence of a 'greenium' in the corporate green bond market, while Section 4 provides the concluding remarks.

I. Literature Review

A. Background

Sustainability has become much more than just a fad or a phase, as it may have initially been perceived, and its impact on the everyday reality of firms across the world is at an all-time high. Sustainable development is perceived as 'meeting the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Sustainability, 1987).

In the field of finance, sustainability is shaping businesses and strategies alike, aiming to fill the gap between finance and corporate strategy (Soppe, 2009) and contributing to the fact that individual success is becoming more and more tied to societal improvement as part of a cultural change. Since the Paris Climate Agreement in 2015, several industry guidelines have been developed considering climate-related risks and integrating environmental, social, and governance (ESG) factors within investment decision-making (e.g., Edmans, 2022; Edmans and Kacperczyk, 2022; Pollman, 2022).

No longer can we understand profit for the shareholders as the sole purpose of a corporation (Friedman, 1970), but instead, modern businesses are striving to create value for all stakeholders and sustainability is now understood as a critical driver for value creation. Therefore, Corporate Social Responsibility (CSR) and Sustainable/Socially Responsible Investments (SRI) are intrinsic aspects of the reality of modern corporations.

CSR is seen as the contribution of business and civil society to the sustainable development of the economy (Kakabadse *et al.*, 2006). However, due to the intrinsic complex nature of theoretically analyzing such a concept, consensus on what the concept actually encompasses and how it should be regulated is still proving hard to reach, incentivizing the emergence of literature that affirms the need to regulate this area (Abah, 2016; Amao, 2013; Buhmann, 2006; Buhmann, 2011; Idemudia et al., 2018; Malesky et al., 2017; Malesky et al., 2019; Nieto, 2005; Okoye, 2016; Osuji, 2011; Osuji, 2015; Situ et al., 2018; Thirarungrueang, 2013).

There is already an extensive line of research and bodies of work regarding the beneficial nature of CSR for firms. Parastoo *et al.* (2015) argue that CSR has a positive effect on competitive advantage, reputation and customer satisfaction, which in turn leads to better performance. Flammer (2012) also demonstrates that close call CSR proposals lead to positive announcement returns and superior performance. According to Shalchian *et al.* (2015), a firm's irresponsible behavior is perceived as additional financial risk and potential losses. Socially responsible firms are also associated with lower cost of debt when compared to firms with social responsibility concerns (Goss *et al.*, 2011; Raimo *et al.*, 2021). Additionally, Cheng *et al.* (2016) show that firms with better CSR performance face lower capital constraints and these constraints are reduced even further when there is better stakeholder engagement and transparency around CSR performance.

As is the case with the large majority of topics, the literature is not unanimous, and conclusions are contextualized and varied. While there is extensive research that argues for the superior performance of sustainability, there is also the common view that firms may face a trade-off between social responsibility and financial performance (e.g., Vance, 1975; Aupperle *et al.*, 1985; Ullmann, 1985 Hamilton *et al.*, 1993; Hutton *et al.*, 1998; Lankoski, 2000; Wagner, 2001; Mill, 2006; Renneboog *et al.*, 2008; Xiao *et al.*, 2013; Nollet *et al.*, 2016; Johnston *et al.*, 2019).

Concurrently, the relationship between ESG scores/disclosures and financial performance continues to be a major point of dissensus, with authors arguing over the overall importance of ESG reporting and the individual impact of its factors. Almeyda and Darmansya (2019) point out that the Social and Governance factors of ESG are not related to financial performance, despite confirming a positive relationship between the Environmental factor and the company's Return on Capital (ROC) and its stock price and a positive relationship between the disclosure of ESG and Return on Assets (ROA) as well as ROC. On the other hand, a stream of the literature shows that the Governance factor seems to have the biggest positive impact on financial performance (Velte, 2017; Orazayeva *et al.*, 2021) or that Environmental performance correlates negatively with financial performance (Horváthová, 2010; Verbeeten *et al.*, 2016; Miroshnychenko *et al.*, 2017) or even that ESG scores, as a whole, have a weak correlation with financial performance (Siew *et al.*, 2013). Moreover, Adams *et al.* (2012) argue that sustainability efforts by corporations seem to have no effect on their short-term performance when measured by their stock price and shareholder returns, emphasizing the notion that sustainability might be the attraction for building customer loyalty and brand reputation on a long-term basis.

B. Green Finance

As a relatively new term, Green Finance has conveyed a variety of meanings and definitions over the past decade. Höhne *et al.* (2012) present green finance as a comprehensive term that includes climate finance but is not limited to it, consisting of financial investments that flow into different initiatives, products, projects and policies that contribute towards a sustainable economy. Bloomberg New Energy Finance, on the other hand, considers green finance to be a more inclusive iteration of green investment that also takes into account land acquisition and project preparation costs (Zadek and Flynn, 2013).

PricewaterhouseCoopers (PWC, 2013) defines green finance through the lens of the financial sector as being a collection of 'financial products and services, under the consideration of environmental factors throughout the lending decision making, ex-post monitoring and risk management processes, provided to promote environmentally responsible projects and stimulate low-carbon technologies, projects, industries and businesses.'

As a more extensive definition, Lindenberg (2014) proposes that green finance should comprise not only the overall financing of public and private green investments (along with their preparatory and capital costs), which work either on environmental goods and services or in the prevention, minimization and compensation of damage to the environment and climate, but also the financing of public policies that encourage the implementation of projects and incentives, serving the adaptation and mitigation of environmental damage. The author also proposes that green finance includes the components of the financial system that deal with green investments such as green bonds, green loans and green structured funds along 'with their specific legal, economic and institutional framework conditions.'

More recently, the European Parliament (2021) defined green finance as the collection of funds used to address climate and environmental issues (green financing) and managing financial risk related to these aforementioned issues (greening finance). This distinction considers green financing to represent the 'financing of the green economy' while greening finance stands for 'greening the financial system.' Furthermore, it provides clear differentiations of (*i*) climate finance, which serves to address the funding needed for mitigation and adaptation of climate change; (*ii*) green finance, as encompassing climate finance, while also covering several different environmental goals, and (*iii*) sustainable finance, as an evolution of the previous that includes the other ESG factors, namely, Social and Governance issues.

The pivotal role that green finance is set to play on the road towards sustainability is not without its flaws and challenges ranging from information asymmetry to the lack of clear-cut definitions, the suboptimal political commitment and the legal/regulatory concerns that have been an obstacle ever since its inception. In emerging markets, the problems do not arise from raising capital but instead, the challenge is the selection of suitable projects and structuring the associated finance (Guild, 2019). These are crucial concerns surrounding the future of green finance and its markets, as the consensus around the scientific community is that of a mismatch between ambition and implementation that has the potential to undermine the efforts and progress of the recent past (Wang and Zhi, 2016; Sachs *et al.*, 2019; Ozili, 2022).

C. Green Bonds

Green bonds can be separated into four different categories (ICMA, 2018). Use-of-proceeds bonds and use-of-proceeds revenue bonds are two types of green bonds whose proceeds are 'earmarked for green projects in the issuer's portfolio' with the latter having its 'recourse limited to an issuer's pledged revenue stream, not its entire balance sheet', unlike the former. Project bonds are tailored to specific projects or groups of projects and the recourse is 'limited to those project(s) assets and balance sheet'. Lastly, securitized bonds are collateralized by revenue-generating green projects, which in turn are used to repay the bond and 'recourse is limited to the collateralized asset' (Jones *et al.,* 2020). Additionally, De Spiegeleer and Schoutens (2019) introduce a variant of vanilla green bonds: reverse green bonds, which offer a higher yield in exchange for the extra risk of missing coupon payments, contingent on pre-agreed climate triggers.

The Green Bond Principles define green bonds as being ‘any type of bond instrument where the proceeds or an equivalent amount will be exclusively applied to finance or re-finance, in part or full, new and/or existing Green Projects and which are aligned with the four components of the GBP’ (ICMA, 2021). Following the issuance of the first green bond - first referred to as Climate Awareness Bond (CAB) - in 2007 by the European Investment Bank (EIB), which managed to raise $0.9 billion, the green bond market had a rough start. Be it the lack of a clear definition, the ambiguity in the taxonomy of the green bond projects, the slow acceptance from investors worldwide or some less than transparent issuers, the green bond market was not without its flaws. The work of a coalition of banks, investors, and issuers (IMCA), the Green Bond Principles, whose inception dates back to 2014, established a multitude of guidelines and recommendations that were globally accepted and paved the way for the issuance of credible green bonds. The creation of this standard, followed by the Paris Agreement in 2015, allowed for the steady growth of the green bond market, which has nearly doubled in size every year (Bachelet *et al.*, 2019).

Following the Green Bond Principles, other green bond standard initiatives such as the CBI’s Climate Bond Standard or the EU Green Bond Standard, developed by the EU Commission, have contributed to the pursuit of transparency and integrity in the green bond market. A market that has been mostly dominated by the European Union, followed by the United States of America and China. Accordingly, the EU’s role in the development of the market has been crucial with the European Green Deal, presented in 2019, at the forefront of the strategic roadmap.[3]

D. Greenium

Alongside the exponential growth of the green bond market, the literature covering such fixed income instruments has also thrived in recent years with a multitude of empirical works on the subject (Cortellini and Panetta, 2021). The majority of papers focus on the analysis of the pricing structure of these instruments when compared to non-green/conventional bonds and the eventual existence of a green bond premium or ‘greenium’ (Hachenberg and Schiereck, 2018; Karpf and Mandel, 2018; Febi *et al.*, 2018; Kapraun *et al.*, 2019; Zerbib, 2019; Partridge and Medda, 2020; Larcker and Watts, 2020; Flammer, 2021; Zheng and Zhong, 2021). The existence of a ‘greenium’ would imply a contrast to ‘modern portfolio theory which assumes rational investors, efficient markets and expected returns as a function of risk’ (Dorfleitner *et al.*, 2021) and suggests that investors may be willing to accept a lower yield in exchange for non-fungible benefits. There is no consensus in sight regarding the existence and explanations of the said premium within the literature, with the most common explanation being associated with investors’ pro-environmental and social preferences being responsible for the acceptance of lower risk-adjusted returns (Zerbib, 2019).

[3] The European Commission has decided to use green bonds as a significant part of its diversified funding strategy, promising to issue up to EUR 250 billion as green bonds under the Next Generation EU. The recent EU Taxonomy Regulation (Regulation 2020/852 of the European Parliament and of the Council of 18 June 2020) along with the related EU Green Bond Standard have played a critical role in fostering the European sustainable finance market.
See: https://ec.europa.eu/commission/presscorner/detail/es/speech_21_1743.

Gianfrate and Peri (2019) found green bonds to be more 'financially convenient' than conventional bonds with this difference assuming a more significant role in the primary market *versus* the secondary market. Authors conclude that green bonds have a key role to play in transforming the economy without financially jeopardizing investors. Hyun *et al.* (2020) show that externally reviewed green bonds have a significant discount when compared to synthetic conventional bonds but find no significant yield difference when comparing generalized green bonds, which supports the notion that the greenness standard of these instruments is a large contributor to their success and the development of the market. Additionally, Hachenberg and Schiereck (2018) find that green bonds are trading tighter than conventional bonds of the same issuer, with an emphasis on financial and corporate bonds. In addition, they attribute the difference in pricing to industry and ESG ratings, and point out that issue size, maturity and currency had no significant influence on the premium. According to Kanamura (2020), green bond investment performance has outperformed its conventional counterpart in recent years, but this superiority is diminishing over time.

Contrastingly, Larcker and Watts (2020) show that investors do not seem willing to exchange financial returns for environmental benefits as they find no pricing difference between green and nearly identical non-green securities, implying the absence of any greenium. With resort to the same aforementioned methodology of comparing bonds that only differ with regards to their 'greenness', Flammer (2021) supports these findings of a lack of a pricing difference and claims that those results are consistent with qualitative evidence from interviews and surveys, where investors indicate that they would not invest in green bonds if the returns were not competitive. With the primary objective of studying the inherent rationale associated with green bond issuance, the author finds evidence of increased environmental rating and equity ownership by long-term investors and green investors alike post-issuance, which indicates that signaling the company's commitment towards environmental causes constitutes the main motivation behind green bond issuance.

The first empirical study on announcement returns and real effects on green bond issuance is attributed to Tang and Zhang (2020). The authors compile data of green bond issuance by firms in 28 countries over a 10-year period (2007-2017) through the CBI and Bloomberg datasets. They find that stock prices of issuers react positively to green bond issuance announcements, with statistical significance and economic meaning. Regarding a potential green premium, authors find no pricing difference for the same issuer in the same year. Additionally, there seems to be an increase in institutional ownership of green bond issuers. Finally, the study points out the increase in stock turnover, google search volume and liquidity of ask-bid spreads, indicating that the market pays attention to a firm's development regarding green bonds. The authors suggest that labelled green bond issuance increases media exposure and firm visibility, which attracts a large investor base and higher demand, resulting in benefits to existing shareholders.

Overall, the existence of a greenium is still open to debate and our paper aims at shedding some light on the discussion.

II. Sample selection and Methodology

A. Data

With the objective of comparing green and equivalent conventional corporate bonds and analyzing if green bonds are indeed a cheaper source of capital or if investors are willing to pay an extra price for their non-pecuniary benefits, data regarding both types of bonds were retrieved and matched, to minimize the effects of other characteristics and to try to encapsulate the impact of a bond's green label.

As such, we created a dataset of green and conventional investment-grade corporate bonds issued between 2014 and 2021. By focusing on investment-grade bonds only and disregarding high-yield bonds, we are minimizing the eventual effect of price volatility. The choice of restricting the sample to this time period is, on the one hand, due to the implementation of the aforementioned green bond principles in 2014, which allowed for greater transparency and the exponential increase in green bond issuance and consequent sample size. On the other hand, 2021 was a record-breaking year for the green bond market, which positively contributes to a broader and more comprehensive sample size needed for the analysis of a market that is still in its early stages (Flammer, 2021).

Given the emphasis on transparency regarding the green label of corporate bonds, the dataset was extracted from DCM Analytics and those bonds classified as green were crosschecked with the CBI's database, which allows us to minimize the eventual effects of greenwashing and helps solidify results and the validity of the green bond sample.

The initial sample of investment-grade corporate bonds issued between 2014 and 2021 was comprised of 2,536 green bonds and 91,378 conventional corporate bonds. The sample was then filtered based on different criteria. All callable bonds were removed from the sample as the difference in coupon rates for callable bonds and the subsequent effect on the value of the internal interest rate option impede a proper comparison between securities (Larcker and Watts, 2020). Furthermore, the sample was also filtered to remove any bonds with missing values regarding issue date, transaction size, price, rating, currency or maturity. The final sample is comprised of 553 green bonds and 15,079 conventional bonds, which are all senior, bullet, fixed-coupon bonds, following the methodology of Zerbib (2019).

B. Matching Method

As the main objective of this work is to study the difference in pricing between bonds labelled green and comparable non-green corporate bonds, we must ensure that the other intrinsic characteristics of these instruments are matched to the fullest extent possible. Accordingly, and in line with the matching method used in previous work such as Zerbib (2019), Larcker and Watts (2020), Flammer (2021), among others, we used an exact matching method also known as a model-free approach or a direct approach (Zerbib, 2019). Our main objective was to create pairings of securities that possess similar attributes but differ with regard to the one property we are studying, the green label. Given this method, we take each corporate green bond from our sample and juxtapose it with the most similar conventional bond. The identified bond pairings share the same currency, issuer, bond structure, seniority, coupon type and rating.

Unlike Larcker and Watts' (2020) work on municipal bonds, aiming to match corporate bonds with coinciding issuance dates is close to impossible. Following Zerbib (2019), and to minimize the effects of liquidity risk, the following constraints were applied to the matching process: (*i*) a given eligible bond could not have been issued more than six months earlier or later than its counterpart and its issue amount could not have been less than one-quarter or more than four times that of its counterpart; (*ii*) as liquidity is essential for bond pricing, and considering that smaller issuances may suffer from a given liquidity premium demanded by the market, we decided to exclude issuances with a total face value below $100 million;[4] and (*iii*) we allowed matched pairings to have maturities that differ by no more than two years, which helped enable a broader sample while simultaneously controlling for the aforementioned maturity risk. Therefore, we took every bond from the green bond sample and matched it with the most similar conventional bond according to our criteria. Every bond was only allowed to have one match in order to create unique pairings within our criteria. Bonds that could not be matched were dropped from the sample. Table 1 summarizes the matching criteria used.

Table 1
Criteria used in the matching process given a bond's characteristic and the applied constraint

Bond Characteristic	Matching Criteria
Issuer	Same
Issue Date	± 6 months
Rating	Same (Investment Grade)
Currency	Same
Coupon Type	Same (Fixed Coupon)
Structure	Same
Maturity	± 2 years
Seniority	Same (Senior)
Issue Amount	± 25% - 400% & > $100 Million

C. Data Analysis and Descriptive Statistics

The final matched sample is comprised of 219 pairings of green and non-green bonds of which 133 were perfect matches, i.e., pairings of bonds sharing the same issuer, currency, rating and exact maturity. The sample of bonds originates from 158 individual issuers, which operate across 16 different industries.

Table 2 presents the distribution of the sample of green bonds by year (Panel A), industry (Panel B), and currency (Panel C). As mentioned previously, 2021 was a record-breaking year in terms of green bond issuance and our sample of paired bonds is a clear indication of that, as it is the most represented year throughout the whole sample, with

[4] These constraints were put in place to better control for the differences in liquidity, given the limitation of not being able to retrieve the closing bid-ask spreads for our sample of bonds, which would have allowed for the creation of a liquidity proxy as in Zerbib (2019).

55 green bonds being issued. In fact, as expected, our sample denotes a generalized year-on-year increase. Also unsurprising is the predominance of the financial sector, which represents more than half of the issued bonds in our sample: 40% and 50% of Löffler et al.'s (2021) and Flammer's (2021) samples are composed of green bonds issued by financials. Additionally, bonds denominated in EUR and USD dominate our sample with 141 green bonds denoted in the two most common currencies worldwide.

Comparing both samples of paired bonds in Table 3, we can observe the similarity between the median values for the total issuance value, maturity, price at issuance and coupon rate as well as the differences in the average values for those same parameters. The average green bond is characterized as having a lower coupon rate (-7.8 bps), being issued at a lower price, maturing later, and having a lower size than the average conventional bond in our samples. After an initial glance, we can analyze the difference between the yields of both bond samples and confirm that there seems to exist a small greenium of -7.2 bps. This can indicate that investors are, in fact, willing to accept lower returns in exchange for non-pecuniary benefits. It would also mean that green bond issuance would be a cheaper source of financing when compared to conventional bonds. However, we must perform additional univariate and regression analyses to draw meaningful conclusions.

Table 2
Distribution of the sample of green bonds by year, industry, and currency

Panel A: by year	**N**	**%**
2021	55	25.11%
2020	38	17.35%
2019	46	21.01%
2018	30	13.70%
2017	22	10.05%
2016	17	7.76%
2015	8	3.65%
2014	3	1.37%
Total	**219**	**100.00%**
Panel B: by sector	**N**	**%**
Auto/Truck	4	1.83%
Computer & Electronics	1	0.46%
Construction/Building	2	0.91%
Consumer Products	1	0.46%
Finance	134	61.19%
Food & Beverage	1	0.46%
Holding Companies	1	0.46%
Insurance	5	2.28%
Machinery	3	1.37%
Metal & Steel	1	0.46%
Oil and Gas	3	1.37%
Real Estate/Property	9	4.11%
Retail	1	0.46%
Telecommunications	1	0.46%
Transportation	11	5.02%
Utility & Energy	41	18.72%
Total	**219**	**100%**

Panel C: by currency	N	%
Australian Dollar	2	0,91%
British Pound Sterling	2	0,91%
Canadian Dollar	3	1,37%
Chinese Renminbi Yuan	34	15,53%
Euro	82	37,44%
Indian Rupee	1	0,46%
Japanese Yen	21	9,59%
New Taiwan Dollar	3	1,37%
Philippine Peso	1	0,46%
South Korean Won	2	0,91%
Swiss Franc	5	2,28%
Thai Baht	4	1,83%
US Dollar	59	26,94%
Total	**219**	**100,00%**

Table 3
Descriptive statistics of the matched sample of bonds

Panel A: Green Sample	**N**	**Mean**	**St. Dev**	**Min.**	**Median**	**Max.**
Total Value ($Million)	219	701	669	102	500	4,100
Maturity (years)	219	5.764	3.122	1.500	5.000	31.000
Price (% of par)	219	99.819	0.316	97.406	99.952	101.546
Coupon (%)	219	1.744	1.494	0	1.250	7.375
Yield (bps)	219	177.635	149.037	-1.748	131.100	748.000
Panel B: Conventional Sample	**N**	**Mean**	**St. Dev.**	**Min.**	**Median**	**Max.**
Total Value ($Million)	219	1,040	1,300	106	631	7,910
Maturity (years)	219	5.663	3.106	1.000	5.000	31.000
Price (% of par)	219	99.842	0.371	98.506	99.940	101.971
Coupon (%)	219	1.818	1.513	0	1.375	7.250
Yield (bps)	219	184.015	151.211	-17.903	137.700	728.000

III. Testing and Results

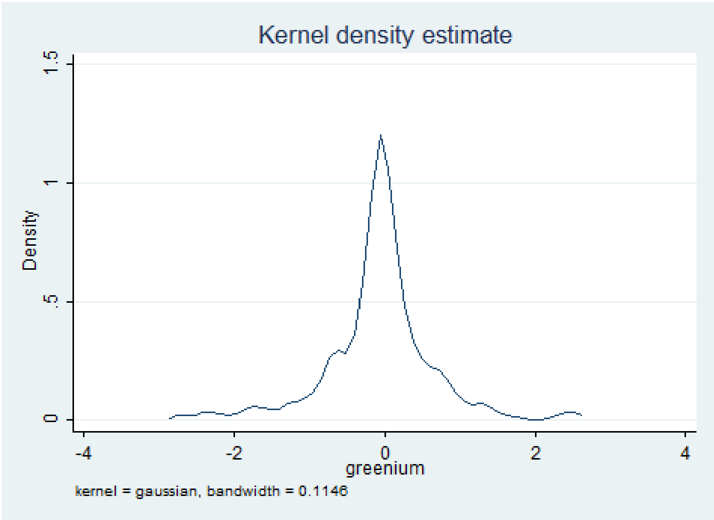
A. Preliminary Testing of the Dataset

As a prelude, we begin our analysis by testing and studying the distribution of our dataset, more specifically, the univariate distribution of the calculated greenium, defined as the difference between the yields of our matched pairs ($Y_i^{GB} - Y_i^{CB}$).

As per Larcker and Watts (2020), we computed kernel density estimates for our variable of interest. This non-parametric estimation of the probability density function of our variable allows for a better understanding of the variation of yield differences within our sample and their frequency. Figure 1 shows a large concentration directly at “0”, which supports the notion of a general null price differential, with some extreme values within the sample, both positive and negative.

As a follow-up, a Shapiro-Wilk normality test was performed to support the choice of significance test to be used later in the analysis. The test allowed for the rejection of the null hypotheses, which signifies that the variable is not normally distributed and that non-parametric tests allow for more sound results.

Figure 1
Kernel density estimates



Note: This figure details the kernel density estimate for the yield differentials of the matched sets described in section II. The graph was plotted using a Gaussian kernel and the Silverman rule for bandwidth selection.

B. Greenium – Univariate Analysis

Table 4 contains the results of parametric t-tests and non-parametric Wilcoxon rank-sum tests to compare yields in our samples and four additional sub-samples. Both t-test and Wilcoxon rank-sum tests reject the null hypotheses at a 5% level of significance. As such, we do not have enough statistical evidence to reject the null hypothesis and thus conclude that the average difference in yields of -7.2 bps is not statistically different from zero. Therefore, we reject the existence of a greenium in our overall sample. Subsequently, to identify potential variation within our sample, the same set of tests was performed on a series of subsamples that were created based on the bonds' characteristics described in the previous section: currency and general industry group.

Results show that while bonds denominated in EUR displayed a green bond premium of -8.124 bps, green bonds denominated in USD have a lower yield to maturity *vis-à-vis* matched corporate bonds of -17.492 bps. Bonds issued by financials also have a green premium of -2.675 bps as well as those issued by corporates belonging to the Utility & Energy (-9.614 bps) sector. In line with the results from the overall sample, each of the subsamples reveals a green bond premium, but yields do not differ significantly between green and conventional corporate bonds at the 5% significance level.

As mentioned in previous sections, the literature is incredibly divisive with regard to the existence and magnitude of a premium in the green bond market. Even within the same methodology used in this paper, results and conclusions are vastly different. Given the usage of the exact matching, our results are in line with those of Larcker and Watts (2020), who find an insignificant yield differential for a sample of US municipal bonds and conclude that the greenium in their analysis was essentially zero. On the other hand, Zerbib (2019) found a significant, albeit small, greenium of -2 bps, for both EUR and USD bond subsamples. However, it should be noted that despite the similarity in matching methodology, it is impossible to generalize any conclusion given the differences in the samples used: as this work only deals with corporate bonds and not municipal US bonds (Larcker and Watts, 2020) or corporate and government green bonds (Zerbib, 2019). In addition, contrary to Wang *et al.* (2020) and Caramichael and Rapp (2022), we exclude green bonds issued by state-owned enterprises.

Table 4
Paired tests for yield difference

Variable of interest: Yield to maturity	Full Sample	EUR	USD	Financials	Utility & Energy
N	438	164	118	268	82
Mean difference (bps)	-7.167	-8.124	-17.492	-2.675	-9.614
p-value Wilcoxon rank-sum	0.075	0.167	0.308	0.321	0.517
p-value *t* test	0.141	0.291	0.140	0.615	0.510

Note: We test for yield differences using the parametric t-test (two-sided t-test), as well as the non-parametric Wilcoxon rank-sum test (as the yield to maturity variable is not normally distributed), with a null hypothesis that the greenium was equal to zero.

C. Greenium – OLS Regression Analysis

To further examine the green bond premium and the pricing differences between quasi-identical green and conventional bonds, we use the model described in equation (1). The dependent variable is the yield to maturity, in basis points. We employ OLS regression techniques and adjust for heteroskedasticity. Due to time-varying risk premia and cross-country differences, we estimate standard errors clustered by year and country.

$$YTM_{i,t} = \alpha + \beta Green_{i,t} + \theta_{i,t} + \gamma Contractual\ characteristics_{i,t} + \varphi\ Macroeconomic\ factors_t + \varepsilon_{i,t} \quad (1)$$

Where i identifies the bond and t the time. The dependent variable (YTM) is regressed on a set of dummy variables (θ_i). These include year, country and industry fixed effects in models [1] to [4]. In models [2] to [4], we add rating fixed effects and, finally, we add firm fixed effects in model [4]. The contractual characteristics include bond maturity and deal size. We also control for the following macroeconomic factors: market volatility, yield curve slope, and country risk. Lastly, the *Green* variable is a dummy variable that is equal to 1 if the corporate bond is a green bond and 0 if it is, instead, a conventional corporate bond. The greenium is, then, captured by the estimator of β. Table 5 provides detailed definitions and sources for all the variables used.

Table 5
Definition of the variables used and their sources

Variable	Description	Source
Yield to maturity (YTM)	The internal rate of return for a bond assuming that the investor holds the asset until its maturity date. In basis points (bps).	DCM Analytics
Green	Dummy equal to 1 if the bond is labeled as a green bond, and 0 otherwise.	DCM Analytics

Maturity	Maturity of the bond, in years.	DCM Analytics
Log Transaction Size	Natural logarithm of the deal size ($ Million).	DCM Analytics
Country Risk	S&P's country credit rating at close. The rating is converted as follows: AAA = 1, AA+ = 2, and so on until BBB- = 9.	S&P Global Ratings
Volatility	The Chicago Board Options Exchange Volatility Index (VIX). The index reflects a market estimate of future volatility.	Datastream
EUSA5y-Libor3M	The slope of the Euro swap curve as the difference between the 5-year Euro swap rate and the 3-month Libor rate.	Datastream

Table 6 presents the results of the aforementioned regression models. In accordance with the results obtained from the paired statistical tests, all models show that the YTM of green bonds does not differ significantly from standard corporate bonds issued by the same corporate with similar characteristics. These findings indicate that there seems to be no extra incentive regarding green bonds *vis-à-vis* conventional bonds and that investors are not willing to forgo returns for non-pecuniary benefits. Despite the continued global increase in green bond issuance, investors are likely to retain their preference for the best investment possible regardless of its nature. This perspective is supported by industry practice, which shows that investors require a given project to offer competitive returns in order to invest (Flammer, 2021; Larcker and Watts, 2020).

These results are also consistent when focusing on specific subsamples regarding currency and industry group. Bonds denoted in hard currencies such as the EUR and USD are correlated with more liquid markets and are expected to be able to attract a larger investor base. Even so, our results find no statistical evidence of a greenium when isolating the subsamples of bonds denominated in such currencies.

Table 6
Regression analyses of the green bond premium

This table presents the results of an OLS regression analysis of the determinants of bond YTM for a sample of 219 green bonds and a matched sample of quasi-identical standard corporate bonds, issued worldwide in the 2014-2021 period. For a definition of the variables, see Table 5. ***, ** and * indicate that the reported coefficients are significantly different from zero at the 1%, 5% and 10% levels, respectively. The t-statistics reported in parentheses are based on heteroskedasticity-consistent standard errors. Due to time-varying risk premia and cross-country differences, we estimate standard errors clustered by year and country.

Dependent variable: YTM	**[1]**		**[2]**		**[3]**		**[4]**	
Independent variables:								
Intercept	3.38	***	3.41	***	2.45	**	0.68	
	(8.14)		(3.69)		(2.15)		(0.54)	
Green	3.76		3.32		4.08		3.92	
	(0.50)		(0.45)		(0.57)		(0.65)	
Maturity			0.05	**	0.05	**	0.06	***
			(2.20)		(2.04)		(2.81)	
Log Transaction Size			-0.01		-0.01		0.06	
			(-0.12)		(-0.12)		(0.77)	
Country Risk					0.10		0.13	
					(0.51)		(0.74)	
Volatility					0.01		0.01	

			(0.70)	(1.42)
EUSA5y-Libor3M			0.01 ***	0.01 ***
			(2.80)	(2.98)
Year fixed effects	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Rating fixed effects	No	Yes	Yes	Yes
Firm fixed effects	No	No	No	Yes
Number of observations	438	438	438	438
Adjusted R^2	0.68	0.7	0.71	0.87

A considerable amount of the extant literature on green bond pricing concluded that a significant greenium exists (Preclaw and Bakshi, 2015; Ehlers and Packer, 2017; Baker et al., 2018; Hachenberg and Schiereck, 2018; Gianfrate and Peri, 2019; Nanayakkara and Colombage, 2019; Zerbib (2019). Larcker and Watts (2020) argue that some of these analyses are based on a small set of securities and that misspecifications considering the methodological design are to blame for some of the mixed evidence of previous studies. The exact matching methodology applied in this paper, following the methodologies of several recent studies such as Zerbib (2019), Larcker and Watts (2020), and Flammer (2021), as well as the ever-growing pool of green securities and the subsequent potential to apply the necessary constraints while maintaining considerable sample sizes, confirm the robustness of the results obtained. Our results are in line with those of Tang and Zhang (2020) and Flammer (2021), who also find no evidence of a greenium effect in the corporate green bond market.

Another explanation for our results is related to the green bond market supply-demand and its impact on bond pricing dynamics. The additional costs associated with green bond issuance and certification have proven to be significant barriers in the early stages of market development. The uncertainty and inexperience regarding green bonds as a financial instrument and the need for companies to shift their strategy to accommodate the required preference towards green projects have also posed threats to the growth of the green bond market (I4CE, 2017). In spite of this, as we have already mentioned, supply has been growing at a staggering pace in recent years, both in the number of issuances and volume. This continuous growth in supply may have alleviated the buying pressure, which would have been an important factor behind the green bond premiums identified in previous studies. On the other hand, authors such as Chiang (2017) and Partridge and Medda (2019), as well as some industry professionals, suggest that a greenium may become more common in years to come. In a market still in its early stages, intrinsic changes to its microstructure and dynamics may be responsible for the continuous shift in findings, accentuating the need for updated research.

As pointed out by Larcker and Watts (2020), perhaps the most likely explanation behind the inexistence of a greenium is simply that green projects offer competitive returns and, therefore, attract investors regardless of their green label or investors' preferences.

IV. Concluding Remarks

This paper compares the pricing of green *versus* standard corporate bonds, using a cross-section of worldwide bonds closed in the 2014–2021 period. Green bonds play a key role in channeling capital to projects, technologies and businesses that contemplate environmental, social and governance considerations to, ultimately, pave the way for a zero-carbon, resource-efficient and fair economy.

We extend extant literature that explores a potential greenium in bond markets, i.e., examine if investors are willing to exchange economic returns for non-pecuniary benefits. Using an exact matching methodology, we create a paired dataset of green and conventional corporate bonds, which share the same issuer, currency, and credit rating. We only retain bullet, fixed-coupon, senior, and non-callable investment-grade bonds, and analyze the yield to maturity difference between these pairings of quasi-identical bonds. We find a non-significant green bond premium. Results hold for sub-samples of bonds issued by financials, nonfinancial firms belonging to the utility & energy industries, bonds issued in EUR or bonds issued in USD.

These findings are consistent with Tang and Zhang (2020) and Flammer (2021), who also conclude that there seems to be no pricing difference between green and conventional bonds of near identical characteristics in the corporate bond market. The lack of proof of a green bond premium implies that investors are not willing to forgo returns in exchange for environmental benefits and contradicts the idea that green bonds represent a cheaper source of financing.

The generalization of these results is nigh impossible as the intricacies of the corporate bond market are fundamentally different from those of other markets. Additionally, the limited amount of data regarding green bonds and, more specifically, corporate green bonds, inhibits the creation of perfect matches between bonds within a considerable sample size and results could vary drastically according to the constraints that are used.

As such, more research is needed in this area, which would benefit from the increase in quality and quantity of green bond data to produce more sound results. These results could then provide better insight concerning the long-term implications of green bonds and investors' preferences. Considering that when compared with conventional corporate bond financing, green bonds are more restrictive, entail more transaction costs namely for first-time issuers, and there is no significant yield difference between the two bond types, analysis of what the other firm-level countervailing benefits are, other than borrowing costs, should play a key role in firms' decisions to choose green vis-à-vis corporate bonds and is also an avenue for further research.

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