UNIVERSIDADE CATÓLICA PORTUGUESA

The Pricing of green bonds

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Resumo

A mudança climática tem sido há anos uma das principais prioridades da gestão global de riscos. Apesar do reconhecimento crescente dos seus impactos, a abordagem a este problema tem sido prejudicada por uma série de obstáculos políticos, econômicos e sociais. As green bonds representam uma das ferramentas mais recentes e inovadoras para ajudar tanto o setor público quanto o privado a alcançar as metas ambientais das Nações Unidas. O presente estudo, aborda a possível existência de um efeito de "greenium" no mercado de obrigações, para além de fornecer um estudo empírico dos determinantes dos spreads de títulos verdes versus convencionais. Também examinamos como a liquidez pode afetar ambos instrumentos de dívida.

Os nossos resultados apontam para um greenium de 7,47 pontos-base (e 8,48 pontos-base se incluirmos o rating da empresa emitente) no mercado, apoiando a teoria de que os investidores estariam dispostos a renunciar a benefícios financeiros em ativos ambientais. Também verificamos que tanto os títulos verdes quanto os títulos "brown" são afetados de maneira diferente por variáveis de preço comuns, como a maturidade, o número de bancos envolvidos e o rating da empresa, entre outros. Por fim, o presente estudo confirma que a liquidez de mercado afeta mais os spreads dos títulos verdes do que seus pares "brown"; e que o greenium é efetivo apenas para as obrigações investment-grade.

Palavras-chave: Green bonds; corporate bonds; spreads; greenium; liquidity; pricing determinants.

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Abstract

Climate change has been for years one of the top priorities of global risk management. Despite the growing recognition of its impacts, addressing this problem has been hindered by a range of political, economic, and social barriers. Green bonds represent one of the most recent and innovative tools to help both public and private sector reach the United Nation's climate targets. Our study sheds light into the possible existence of greenium in the bond market, additionally providing an empirical study of both green and corporate bond spreads determinants. We also take a closer look at how liquidity may affect both debt instruments.

Our results point towards a 7.47 bps (and 8.48 bps if controlling for issuing firms' credit risk) greenium in the market, given support to the theory that investors would be willing to trade-off financial for environment benefits when investing in green assets. We are also able to verify that both green and brown bonds are differently affected by common pricing variables, such as *maturity*, *number of banks* and *company rating*, among others. Lastly, the present study confirms that green bond spreads are more impacted by an increase in liquidity than their brown counterparts, and that the greenium is effective for investment-grade bonds only.

Keywords: Green bonds; corporate bonds; spreads; greenium; liquidity; pricing determinants;

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Introduction

The inability to sufficiently address climate change through international cooperation has been a longstanding challenge for the world community. Despite three decades of global climate advocacy and diplomacy, the international system has encountered considerable difficulties in making adequate progress on the issue of climate change. Such trends have not only limited the goal of controlling the global temperature rise to within 1.5°C above pre-industrial levels, but also threaten to exacerbate existing environmental and social problems.

According to the World Economic Forum, 2023 – Global Risk Report, the Intergovernmental Panel on Climate Change (IPCC) has estimated that there is a 50% likelihood of surpassing the 1.5°C temperature threshold as early as 2030, underscoring the urgency of taking immediate and effective action to address climate change. The severity of this predicament is further accentuated by the projected increase of 2.7°C by mid-century, according to the current commitments made by the G7 private sector. This outcome would significantly exceed the objectives outlined in the Paris Agreement and further amplify the detrimental impacts of climate change.

It is imperative that both public and private sectors work collaboratively and lead the change by setting challenging targets and develop flexible strategies as they will be expected to serve as an example of worldwide best practices and are a fundamental part of the solution. One of the most promising tools developed to aid the achievement of such targets and strategies are green bonds. Green bond refers to a fixed asset class which while similar in financial structure to conventional corporate and government bonds, differs in the use of proceeds since they are earmarked to climate-related or environmental projects (Reboredo

2018; Cortellini and Panetta 2021). The European Investment Bank (EIB) issued the first-ever green bond, dubbed the Climate Awareness Bond (CAB), in 2007, and while it was mainly used by government-related or supranational development banks in its first years of inception it has now been widely adopted by the private sector. The market has been experiencing what experts call "green bond boom" (Morgan Stanley 2017). While in 2008 green bonds issuance amounted to less than $1 billion, it has been most recently reported by the Climate Bonds Initiative (CBI) that in 2021 the market surged to the $1 trillion mark.

Despite the growing in popularity, there are still many unknowns around this new financial instrument. It seems puzzling that companies would rather issue green bonds in detriment of brown bonds, as they limited their investment policies to green projects. More so, the qualification of a bond as green gives rise to compliance and certification costs as companies would need to go through third-party certification. We then question, given the restraints and costs that the asset entails, why are companies increasing their green bond issuance when they could bypass this restrains and costs issuing brown bonds and then allocating the funds to environmental projects?

Signal theory is frequently cited as a plausible rationale for the observed phenomenon (Flammer 2021; Fatica and Panzica 2021), arguing that the issuance of green bonds may serve as a channel to credibly signal to investors the corporation's dedication towards environmental concerns, triggering a positive stock market reaction (Roslen et al., 2017; Baulkaran 2019). Companies may also be looking to achieve cheaper financing. Green bonds have been closely associated with *grenium*, implying that investors are willing to forgo financial benefits on socially responsible assets (Larcker and Watts 2020), and as such, are prepared to accept them at lower yields (Flammer 2021).

Greenwashing also constitutes a possible motivator as issuers would look to take advantage of the asset popularity and produce misleading claims about their environmental responsibility by not taking tangible actions (Flammer 2021). Lastly, we look at liquidity from a pricing perspective and try to understand if it may affect green bonds differently than corporate debt instruments (Su and Lin 2022).

From these proposed motivations, this study focuses in understanding if green bond market experiences a greenium, and how do the different common variables affect both debt instruments. We will also be taking a closer look at liquidity and try to understand if it may differently affect both asset classes. We believe that by focusing on these perspectives we will be better suited to understand green bond dynamics and present meaningful contributions to the literature.

We begin our analysis with a sample of 28,615 bonds, of which 878 are green bonds and 27,736 are corporate bonds. To answer our questions, we make use of an OLS regression while controlling for both company, year, and industry variables. Robustness tests were also conducted. Our results pointed towards a 7.47 bps (and 8.48 bps when controlling for issuers' credit rating) greenium in the market, given support to the theory that investors would be willing to trade-off financial benefits for environmental positive impacts. We are also able to provide insights on the pricing dynamics of both assets, by showing that both green and brown bonds, although similar, are priced differently by common pricing variables such as *maturity*, *company rating* and *number of banks*, among other. This phenomenon was also found when we focusing on liquidity. Whereas corporate bonds verify a decline between 44.26 and 42.38 bps for each 100 million increase in the transaction, green bonds verify a decrease between 73.76 and 72.6 bps.

The study is organized as follows. Chapter 1 reviews the literature and describes the research hypotheses. Chapter 2 describes and analysis the sample.

Chapter 3 examines the methodology and presents the variable description. Chapter 4 provides the results and analysis the determinants of bond spreads for both green and conventional corporate bonds. Section 5 concludes the paper.

Chapter 1
Literature Review and hypothesis development

1. Literature Review and hypothesis development

This chapter aims to consolidate the extant literature on green bonds as a debt choice and its pricing, as well as the possible motivations that have been fulling the most recent "green bond boom". We will also be introducing our hypotheses.

1.1 "Green bond boom": Motivations

The European Investment Bank (EIB) issued the first-ever green bond, labelled "Climate Awareness Bond" (CAB), in 2007. According to the European Parliament (2022), this novel fixed-income asset class possessed similarities to traditional bonds, including similar legal characteristics and credit features. The distinguishing factor resided in its exclusive use of proceeds for (re)financing projects aimed at combating climate change, as opposed to conventional bonds (Reboredo 2018).

In the market inception, between 2007 and 2013, the definition of "green" investment was not well established, resulting in a limited green bond market composed primarily of small issuances from multilateral development banks. However, with the release of the Green Bond Principles (GBP) by the International Capital Markets Association (ICMA) in 2014, the market started to experience significant growth (Monk and Perkins 2020; Ehlers and Packer 2017).

These voluntary principles offered the first global definition of what could be considered a green project and, as a result, what could be financed through green bonds. Since then, several other guidelines have emerged, such as the Climate Bond Standard (CBS) by the Climate Bond Initiative (CBI), the European Green Bond Standard (EU GBS) proposed by the European Parliament, the China Green Bond Endorsement Project Catalogue endorsed by the People's Bank of China (PBOC), and the ASEAN Green Bond Standards published by the ASEAN Capital Market Forum (ACMF), (Cortellini and Panetta 2021).

The increased clarity and integrity brought by these principles, although still limited, encouraged the participation of government and private institutions in the market (Monk and Perkins 2020), leading to a boost in green bond issuances. From 2015 to 2020, the green bond market grew by an average of 50% annually (European Parliament 2022).

Today's structure of the green bond market showcases complex dynamics. Despite being similar in structure to conventional bonds, the investment opportunities for issuers are limited. Nevertheless, the demand for green bonds continues to increase annually (European Parliament 2022), with frequent oversubscription of their issuances (MacAskill et al., 2020).

It is important to notice that this growth is however still somewhat limited by the lack of standardization in what defines a green investment (Ehlers and Packer 2017). Despite the presence of numerous guidelines, the market continues to suffer from a deficit of transparency and standardized definitions (Tang and Zhang 2020). This presents challenges for both issuers and investors in determining environmentally sustainable investments, leading to elevated costs for both parties and opening the door for concerns regarding greenwashing, which can harm the market and the issuers reputation (Jones et al., 2020). Issuers looking to minimize risk in the green bond market must undergo bond certification and external review. This process can incur costs of up to 0.3-0.6 basis points (Hachenberg and Schiereck 2018).

Despite the constraints and similarities between green and conventional bonds, some experts argue that issuing traditional bonds and investing the proceeds in green projects may be a more cost-effective strategy (Flammer 2021). In spite of that, many companies are still choosing to pursue certification for their green bonds.

The question then arises: why are issuers willing to bear the extra cost and effort to go through this process and choose green debt over traditional debt instruments? In the following sections, four potential reasons will be explored: 1) Signaling Effect, the emission of green bonds serves as a credible signal of a company's environmental commitment leading to a positive stock market reaction. 2) Greenwashing, due to the lack of uniform regulation in the market some issuers use green bond issuances as a facade to appear environmentally conscious, capitalizing on the benefits without actually taking action. 3) Greenium, green bonds offer lower yields compared to traditional bonds, leading to a reduction in the cost of capital. 4) Liquidity, green bonds may more exposed to liquidity premium reduction with higher transaction sizes.

1.1.1 Signaling effect

As the significance of environmental, social, and governance (ESG) practices continues to grow, companies are becoming increasingly focused on corporate social responsibility (CSR) initiatives (Uyar et al., 2020; Leonard and McAdam 2003). There is academic evidence to suggest that companies who engage in such activities and produce ESG/CSR disclosure reports experience improved financial performance (Pulino et al., 2022; Wang et al., 2017; Friede et al., 2015; Kaiser 2020). This information even though it holds relevant value to investors in their evaluation and decision-making process it may not always be readily available (Wahba 2008; Flammer 2013).

The availability and credibility of information plays a significant role in shaping investors' decision-making. Due to the disparity in information between companies and investors, companies gain an incentive to credibly communicate their private information - sending a signal (Spence 1973). This concept is referred to as signaling theory, which states that companies voluntarily communicate their positive private information to convey their favorable organizational qualities to investors, thereby reducing information asymmetries (Connelly et al., 2011; Taj 2016).

The disclosure of ESG information can be seen through the lens of signaling theory (Pulino et al., 2022; Uyar et al., 2020; Ching and Gerab 2017). In order to gain legitimacy in the market and reduce information asymmetry (Pulino et al., 2022), companies will look to signal their environmental commitment.

Despite the common practice of corporations signaling their commitment to environmental concerns through CSR reports (Alon and Vidovic 2015) green bonds are increasingly being regarded as a reliable new indicator (Flammer 2021; Fatica and Panzica, 2021; Hada´s-Dyduch et al., 2022). Their credibility is supported for both the substantial amount of funding committed towards green projects (Flammer 2021) and the rigorous standards and costly procedures imposed by independent entities that companies go through in order to certify their green debt (Flammer 2021).

Accordingly, given the signal credibility and the signal theory argument, there are several possible implications to take into account for the issuance of green bonds, one of them being the stock market reaction.

Roslen et al. (2017) were the first to study this relation. Their pioneering study not only reported a positive stock reaction to green bond issuance but also an average abnormal return (AAR) over market return of 1.166% on the day after the announcement. They were however not the only ones, Baulkaran (2019) in a 21-day window of the bond issuance found a 1,48% CAR in the issuer share price with a sample of 54 green bonds. It was also possible to find a positive correlation between the company growth and CAR, therefore concluding that green bonds are value-enhancing for the firm. (Zhou and Cui 2019; Wang et al., (2020); Tang and Zhang 2020; Jakubik and Uguz 2021) have all found evidence of positive stock market reaction to green bond issuance at the corporate level.

Lebelle et al. (2020) on the contrary reported negative market reactions to the issuance of green bonds. The authors found evidence of negative CAR in the range of -0.5% to -0.2% depending on the asset pricing model (CAPM, Fama and French's three-factor model, Carhart's four-factor model). The evidence points out that investors react to the issuance of green debt in a manner similar to their response to traditional bonds, whereby the announcement of an issuance is subsequently met with a decline in stock prices (Ammann et al., 2004; Y. Dann and H. Mikkelson 1983).

1.1.2 Greenwashing

The green debt market is faced with a challenge in terms of the reliability and authenticity of its financial products (Jones et al., 2020). As we mentioned before, the market created a multitude of guidelines and frameworks that classify an investment as green, however, even though compliance with such rules is considered good practice it is not mandatory by law (Wang 2018).

The lack of consistency and transparency in the classification of green projects is a significant challenge faced by both issuers and investors in the green debt market. This is due to the fact that different taxonomies and frameworks may be followed by different players, leading to a lack of standardization in the market (European Commission 2021). This can result in difficulties for issuers and investors to identify suitable green projects.

Looking from the investor perspective, without a widely accepted definition of what is *green* and a mechanism capable of holding issuers accountable to international guidelines, fears of greenwashing limit the market potential and create a source of reputational risk (Talbot 2017). For issuers, the lack of common definitions creates ambiguity about what project may be deemed green, leaving them exposed to accusations of greenwashing (European Commission 2021).

Generally, greenwashing can be considered "the means that an issuer tries to create an image of being environmentally friendly, despite conducting operations that are more or less damaging to the environment" (Ferlin and Fryxell 2020), and it comes in many scenarios, for example, misleading visual imagery, dubious eco-labels, and selective disclosure (Flammer 2021).

An argument could be made that green bonds are not suitable as a greenwashing tactic due to their high issuing costs (Flammer 2021), however, there have already been reported cases of controversial allocations of green funds. Them being a 725-parking garage (Berensmann et al., 2018; EuroMoney 2019) coal-fired power and petrochemical refinery in China.

In the case of green bonds, greenwashing practices arise when the proceeds from the issuance are used for projects that are not contributing to environmental causes and may be in fact financing polluting activities (Wang 2018). Certification of the issuance seems to be the most effective way of addressing such concerns (Bachelet et al., 2019; Ehlers and Packer 2017).

Flammer (2020) has found that public companies that are issuers of green bonds experience long-term improvements in both financial and environmental performance therefore debunking the hypothesis of greenwashing in the market. These results however were only significant for companies that had their bonds certified, suggesting that not only certification is effective as a governance mechanism and of significant importance but also that companies that are trying to signal their environmental commitment to the market need to do so in a credible way to separate themselves from greenwashing speculation. Simeth (2022) adds that on top of certification, second party opinion (SPO) are an effective tool for issuers to signal the credibility and quality of greenness information.

Europe has so far led the way in finding solutions to reach greater market harmonization having recently, in 2021, published the EU GBS. The proposal serves as foundation for a common framework on the green bond market (European Commission 2021). It is based on the EU taxonomy and builds on both the 2018 action plan of sustainable finance[1] and the 2021 new strategy of sustainable finance[2] (European Parliament 2022).

Nevertheless, Tuhkanen and Vulturius (2020) found evidence that European corporations fail to meet their green bonds climate targets, showing a lack of connection between these targets and international green bond frameworks leading to post-issuances shortcomings.

Even though the limited literature on the topic dismisses greenwashing concerns (Flammer 2021), it's clear that the lack of a universal and cohesive regulation leaves a gap in the market that creates an environment of doubt and skepticism around green bond environmental benefits diminishing the product integrity (Jones et al., 2020) and crippling investor confidence (Wang 2018).

1.1.3 Greenium

In mainstream finance, the value of a financial asset should be given by the discounted value of its future cash flows. The rate at which these cash flows are discounted should represent the opportunity cost of such investment, reflecting the issuer's rating, the maturity, and liquidity of the bond among other important factors (Cheong and Choi 2020).

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[1] https://finance.ec.europa.eu/publications/strategy-financing-transition-sustainable-economy_en

[2] https://finance.ec.europa.eu/publications/strategy-financing-transition-sustainable-economy_en

Following normal finance pricing models, a green bond with similar characteristics to a conventional plain vanilla bond, such as issuer, maturity, and credit rating diverging only in its use of proceeds, should be priced similarly to its brown counterpart, since their risk/return profile are identical (Larcker and Watts 2020). However, the bullish sentiment in the green debt market has led academics to find evidence of a “Greenium”.

Greenium can be defined as the yield differential between a conventional and a green bond with similar characteristics (Agliardi and Agliardi 2019), implying that investors are willing to forgo financial benefits on socially responsible assets, (Larcker and Watts 2020; MacAskill et al., 2020), and are prepared to accept lower yields (Nanayakkara and Colombage 2019; Ehlers and Packer 2017). This would suggest that green bonds that show evidence of Greenium would be trading at a higher price (lower yield) than a conventional bond of similar characteristics (MacAskill et al., 2020).

This characteristic can significantly impact the issuer's decision-making process, as companies see green bonds as an opportunity to lower their cost of debt when obtaining new financing (Cortellini and Panetta 2021; Nanayakkara and Colombage 2019). It is also a tool for companies to align their investment practices with ESG values, which have become increasingly more aligned with economic objectives (MacAskill et al., 2020). This rationale is in line with the growing academic literature that reports a positive relationship between ESG and performance (Shrivastava and Addas 2014; Flammer 2015; Koedijk et al, 2011).

As for the buy side, the main motivation resides in the willingness of investors to pay to be a part of green investing (Cortellini and Panetta 2021). Maltais and Nykvist (2020) conducted a survey and reported that investors are mainly incentivized by non-financial reasons, with all of them having a sustainability agenda with their organizations. According to Larcker and Watts (2020), asset allocation towards ESG-driven projects is now more than one-quarter of the $88 trillion of assets under management globally.

Various studies have tackled this phenomenon. Zerbib (2019) examined a sample of 110 worldwide green bonds in the secondary market from 2013 to 2017. Using a matching approach followed by a fixed panel regression they found a statistically significant negative green premium of 2% in the entirety of the sample. The authors highlight that the premium is stronger among financial and low-rated bonds. Karpf and Mandel (2018) studied an 1,880 US municipal green bond sample where they found evidence of a - 7.8 bps difference between green and conventional bond yields. The study used data from 2010-2016 while being grounded on Oaxaca–Blinder decomposition.

Gianfrate and Peri (2019) investigated both the EU primary and secondary green bond market. Their study covered a sample of 121 bonds in the 2013- 2017 period. This, to my best knowledge, represents the most updated study in the EU market. The authors found evidence of a green premium between -5 and -13 basis points, on both markets with stronger evidence on the primary. A propensity scoring matching analysis was the used methodology.

Immel et al. (2021), were also able to find Greenium evidence, they however had a different approach to their study. The authors focused their work into understanding the influence that ESG ratings have on spreads. They found a negative premium of 8 to 14 basis points for un-rated green bond issuances and a negative premium between -9 and -19 basis points for ESG-rated issuances. The study goes further and affirms that an increase in the ESG rating of 1-point leads to a decrease in the spread of 6 to 13 basis points. Baker et al. (2018), also find a 6-basis points premium on U.S. corporate and municipal green bonds markets. Their evidence is stronger for externally certified bonds.

On the other side of the spectrum, Hachenberg and Schiereck (2018) study covers a sample period from 2015 and 2016 comparing i-spreads of 63 green bonds and 126 non-green bonds. Their results varied according to the bonds rating. AAA-rated bonds were found to be priced wider than their non-green counterpart while AA-BBB showed possible sins of Greenium however without statistical significance. Therefore, the study is not able to acknowledge the existence of a Greenium showing inconclusive results. Tang and Zhang (2020) originally found evidence of a 6,9-bps premium, however, after adding firm and year-by-month fixed effects, therefore only examining bond emissions of the same issuer in the same year, Greenium statistical significance was lost. The study analyzed a global bond sample from 2007 to 2017 using a matching method and a regression model.

Another study with controversial results was Bachelet et al. (2019). The research breaks down the institutional/private issuer relationship with the green debt market. While they are able to find that institutional green bonds display a negative premium and are more liquid assets, privately issued bonds show the opposite having a positive premium and low liquidity. The private issuer relation is further decomposed with results showing that non-certified green bonds have much stronger evidence of positive premium. The results suggest that in order for green bonds to be able to enjoy a negative premium, the market requires the issuer to have an establish reputation and a certified emission so that information asymmetry can be reduced.

Larcker and Watts (2020), in their article revised Baker et al. (2018); Karpf and Mandel (2018) and argued that their results were product of "methodological design misspecifications that produce biased estimates" (p.4). For example, it is noted that Karpf and Mandel (2018) ignore the role of taxes in their analysis which biases the results into finding negative premium. It is also argued that Baker et al. (2018), pooled fixed effects are insufficient to control for differences between green and brown bonds.

In their study Larcker and Watts (2020) chose to use a very tight matching methodology. While using this model the authors conclude that there is no pricing difference between the two bond categories. Flammer (2021) followed the same methodology and with a sample from 2013 to 2018 found results consistent with the ones of Larcker and Watts (2020), no green premium.

Even though there are reasons to believe that green bonds may be priced differently from conventional bonds (Nanayakkara and Colombage, 2019; Gianfrate and Peri, 2019; Karpf and Mandel., 2018) the literature, overall, hasn't reach a consensus regarding the existence of a green premium in green debt assets.

1.1.4 Liquidity

Another relevant bond pricing variable is liquidity. Ericsson and Renault (2006) defined liquidity as "the ability to sell a security promptly and at a price close to its value in frictionless markets" with an illiquid market being "one in which a sizeable discount may have to be incurred to achieve immediacy".

Liquidity alongside credit risk has for long been perceived as one of the two main contributes for the existence of yield spreads above the benchmark risk free rate (Ericsson and Renault 2006; Wimmer et al., 2016; Longstaff and Mithal 2005). In the bond market, illiquidity is translated in the inability of investors to hedge their risk, thus, forcing them to demand a risk premium by lowering prices. As so, for the same cash flows, illiquid bonds will trade less frequently realizing lower prices and present higher yields spreads (Chen et al., 2007).

Amihud and Mendelson (1986) introduced this notion that investors demand a liquidity premium for illiquid securities which in turn enlarges bonds yields spread. This idea has been supported by both Chen et al. (2007); Ericsson and Renault (2006); Dick-Nielsen et al. (2012); Wimmer et al. (2016); Longstaff and Mithal (2005) since all have found evidence that liquidity is priced in bonds yield spreads. The literature suggests that improvements in the liquidity position of the bond translates in a reduction of the yield spreads and vice-versa. This relation is important to understand the role liquidity plays in the green bond market pricing mechanisms.

The green bond market as it has been previously discussed, faces a problem of oversubscription, meaning that current supply is not enough to meet the high demand from investors (Wulandari et al., 2018). On top of that the market also suffers from a lack of consensus on what can be considered "green", leading to increased costs for both issuers and buyers as we discussed before. Cochu et al. (2016) highlights that since most of green bonds are backed by the issuer's financial performance instead of the performance of the underlying asset their risk profile is unclear as investors will consider the risk quality of the issuer rather than the profile of the underlying investment.

This considerations of oversupply, additional transaction costs; e.g., the costs of complying with frameworks and external reviews, and the unclear credit risk profile in green bonds suggests that liquidity risk premium can be a significant variable in the green bond market pricing since a frictionless market may not be achieved (Wulandari et al., 2018).

The literature in the area is however lackluster. Wulandari et al. (2018) the preliminary study about green bond liquidity, concluded that liquidity risk in green bonds is negligible. The study used 120 EU bonds.

Su and Lin (2022) pointed out that Wulandari et al. (2018) used measures in their study, that may not aways be consistently reliable and therefore their results have inadequate effectiveness. Alternatively, Su and Lin (2022) concluded that liquidity premium in green bonds is estimated to be 28.14 bps representing 16.92% of the whole green bond yield spread. This average value is found larger than of counterpart conventional bonds, which comes in at 19.40 bps, indicating a worse liquidity position for green bonds.

1.2 Hypotheses

Although our literature review covers four different reasons to justify investors choice of green bonds over traditional bonds, our research will be looking to focus on the existence of greenium in the fixed income market while also trying to understand if the two typologies of bonds are differently affected by the same pricing variables, with a special focus on liquidity.

We believe that our study will me making important contributions to the literature for the following reasons: First, with most of the papers only covering sample periods up to 2018-2019 there seems to be a lack of up-to-date analysis on a market with fast-growing data access. As so, we will be updating the period of analysis by making use of a sample that goes from 2014 up to the end of 2022. This will provide new insights with possible new dynamics not yet captured by previous studies. Second, the use of a global sample will allow us to capture up-to-date macro dynamics of the market and complement previous results by understanding if they can be replicated on a global scale in a new time frame. Lastly, we will provide needed insights in the liquidity field literature that still proves to be lackluster and without consensus results.

Following the literature review and our previous reasoning we formulate our research hypothesis as follows:

Hypothesis 1 (H1): Green bonds have lower spreads than similarly rated bonds.

Hypothesis 2 (H2): Green bonds and similarly rated brown bonds are affected differently by common pricing variables.

Hypothesis 3 (H3): Liquidity has a stronger impact on GB spreads vis-à-vis brown bonds.

Chapter 2
Sample Selection

In this section, we address the selection criteria of our sample, providing an overview and presenting the univariate analysis. Data on green versus traditional corporate bonds was extracted from DCM Analytics. This study draws upon this data to examine individual corporate bonds issued worldwide over the 2014-2022 period. Certain limitations were imposed upon the original sample. The bonds analyzed were restricted to those with a classification of "corporate bond investment-grade" or "corporate bond high-yield." Furthermore, bonds originating from companies within the "Finance" sector were excluded, as well as those with a use-of-proceeds classification of "project finance" or "securitization". Additionally, countries and sectors without any registered green bonds during the sample period were omitted. Information regarding the countries risk-rating was extracted from Moddy´s.

Finally, the sample was cleaned of any missing or outlier data in order to be as objective and clean as possible. As so, the final sample consisted in a total of 28,615 bonds, of which 878 are green bonds and 27,736 corporate bonds. The data is in US Dollars and the spread is in basis points.

Panel A presents the geographic distribution of both green and corporate bonds around the world. The panel shows that even though both debt assets are highly concentrated in the three same areas, Europe, Asia and North America, their distribution varies according to the instrument type. For green bonds, Europe (61,15%) stands out as the region with the higher concentration of issuances, with the Netherlands (18,98%) as the largest contributor. North America (22,87%) comes in at second place, with the United States aggregating the bulk of bond financing (19,93%). Lastly, Asia (13,66%) appears as our final meaningful issuer. This goes in line with the Climate Bonds Initiative (2021), which reports that not only the European green bond market is the most prolific and developed in the world is also where the majority of the issuances occur.

Looking at corporate bonds landscape, North America (70,03%) stands out as the dominant region, leaving both Europe (19,71%) and Asia (7,22%) far behind. Once again, the United States (67,45%) make up the bulk of the issuances of their region and are by far the largest issuer in the world.

In Panel B we find the industrial distribution for both fixed income assets. With a total of 25 different industrial category, green bond issuances show an expressive concentration in the Utility & Energy (44,88%) category, followed by a smaller but still significant concentration in Real Estate/Property (18,20%). No other category has more than an 8% concentration.

In regard to the corporate bond industrial allocation, there is a more balanced distribution with Computers & Electronics (16,25%) and Healthcare (16,15%) being the top issuances and the remain volume being distributed for industries such as Oil & Gas (8,02%), Telecommunications (8,63%) and Utility & Energy (6,77%).

Regarding Panel C and D, we can see, respectively, the top bond originators and total bond issuance by year. Upon examining Panel C, it is apparent that Apple Inc is the sole entity that appears on both top originators lists. Concerning green bonds issuers, TenneT Holding BV (8,60%) leads the list, with a considerable margin ahead of ENGIE SA (3,73%). In terms of corporate bonds, Apple Inc (2,15%) holds the top position, followed closely by Verizon Communications Inc (1,36%). This observation further reinforces the trend that green bonds tend to be more focused in specific categories, such as a particular company, industry, or region. It is worth noting that the concentration of issuances in specific regions may pose risks to the market in case of regional economic or political crises. As for Panel D, a clear trend of growth in green bond issuance emerges from the data.

Finally, Panel E shows the information on the purpose of debt funding. To aggregate the use of proceeds I use the same system as F. Kanda et al. (2022) and Kleimeier and L. Megginson (2000)[3]. For both green bonds (85,7%) and traditional bonds (49,5%), General Corporate Purpose category aggregates the majority of the funding. Traditional bonds divide the rest of the allocation between Corporate Control (26%) and Capital Structure (24%).

Table 1 - Geographic and industrial distribution, top issuers, bonds by year and purpose of funding panels.

Panel A: Geographic distribution

Geographic location of bond issuer	Green Bonds: Number of tranches	Green Bonds: Total value [$ Million]	Green Bonds: Percent of total value	Corporate Bonds: Number of tranches	Corporate Bonds: Total value [$ Million]	Corporate Bonds: Percent of total value
North America	258	138 149	22,87%	29504	24 684 939	70,03%
Canada	49	17 743	2,94%	2060	911 292	2,59%
United States	209	120 406	19,93%	27444	23 773 647	67,45%
Europe	746	369 362	61,15%	10508	6 945 747	19,71%
France	89	77 646	12,85%	1479	1 174 930	3,33%
Germany	73	56 085	9,28%	804	620 120	1,76%
Italy	27	17 258	2,86%	319	211 127	0,60%
United Kingdom	66	27 025	4,47%	2330	1 337 460	3,79%
Portugal	7	5 839	0,97%	63	9 221	0,03%
Poland	1	610	0,10%	17	3 603	0,01%
Netherlands	159	114 661	18,98%	2090	1 824 159	5,18%
Sweden	169	14 973	2,48%	814	143 371	0,41%
Switzerland	8	2 030	0,34%	170	55 647	0,16%
Luxembourg	35	19 943	3,30%	1086	965 328	2,74%
Belgium	5	3 422	0,57%	152	158 709	0,45%

[3] (i) corporate control category, which includes funding used for acquisitions, leveraged and management buyouts, private placements or spin-offs; (ii) capital structure category, which entails borrowing for refinancing, debt repayment, recapitalization, dividend recapitalization and restructuring; (iii) fixed asset based proceeds are used for purchases of aircraft, shipping and general capital expenditures; (iv) general corporate purpose category, which includes funding with general corporate purpose stated as its purpose, credits for working capital, public finance and investments, as well as funding with an empty loan purpose code;

Other	107	29 870	4,95%	1184	442 072	1,25%
Latin America	16	5 979	0,99%	1163	348 123	0,99%
Asia	266	82 509	13,66%	11280	2 544 531	7,22%
Australia and Pacific	11	2 616	0,43%	858	193 818	0,55%
Africa	9	278	0,05%	66	9 483	0,03%
Atlantic Islands	10	5 148	0,85%	722	520 191	1,48%
Total	**1 316**	**604 042**	**100%**	**54 101**	**35 246 833**	**100%**

Panel B: Industrial distribution

Industrial category of originator/issuer	Green Bonds			Corporate Bonds		
	Number of tranches	**Total value [$ Million]**	**Percent of total value**	**Number of tranches**	**Total value [$ Million]**	**Percent of total value**
Metal & Steel	25	14 152	2,39%	816	317 840	0,91%
Telecommunications	16	11 607	1,96%	2 797	3 026 626	8,63%
Professional Services	4	683	0,12%	1 358	418 242	1,19%
Oil & Gas	4	1 608	0,27%	3 504	2 813 391	8,02%
Real Estate/Property	388	107 975	18,20%	5 290	1 441 190	4,11%
Utility & Energy	484	266 257	44,88%	6 378	2 374 220	6,77%
Insurance	29	16 690	2,81%	1 787	952 903	2,72%
Transportation	90	27 427	4,62%	3 493	1 354 130	3,86%
Retail	6	3 159	0,53%	1 660	1 472 131	4,20%
Food & Beverage	21	11 514	1,94%	3 011	2 405 832	6,86%
Computers & Electronics	46	37 268	6,28%	5 043	5 703 730	16,25%
Holding Companies	7	2 130	0,36%	853	340 601	0,97%
Healthcare	7	6 149	1,04%	5 317	5 667 235	16,15%
Construction/Building	44	18 610	3,14%	3 274	916 617	2,61%
Leisure & Recreation	1	77	0,01%	1 032	791 195	2,25%
Auto/Truck	59	43 572	7,34%	1 875	1 206 933	3,44%
Chemicals	21	12 867	2,17%	1 534	835 330	2,38%
Consumer Products	8	4 490	0,76%	1 483	1 138 568	3,24%
Machinery	9	2 659	0,45%	927	459 806	1,31%
Mining	14	2 409	0,41%	681	294 373	0,84%
Aerospace	1	200	0,03%	825	862 958	2,46%
Dining & Lodging	5	1 804	0,30%	607	274 968	0,78%
Textile	0	0	0,00%	93	21 931	0,06%
Agribusiness	2	972	0,16%	124	15 489	0,04%
Forestry & Paper	25	9 764	1,65%	339	140 592	0,40%
Total	**1 316**	**593 305**	**100%**	**54 101**	**35 090 751**	**100%**

Panel C: Top originators/issuers

Green Bonds	By value of deals	By number of deals	Corporate Bonds	By value of deals	By number of deals
TenneT Holding BV	8,60%	2,85%	Apple Inc	2,15%	0,36%
ENGIE SA	3,73%	1,37%	Verizon Communications Inc	1,36%	0,23%
Volkswagen International Finance NV	1,31%	0,46%	CVS Health Corp	1,42%	0,11%
China Three Gorges Corp	0,15%	0,23%	Oracle Corp	1,38%	0,14%
E.ON SE	2,40%	1,03%	Comcast Corp	1,37%	0,21%
Apple Inc	2,15%	0,23%	Amazon.com Inc	1,36%	0,14%
Societe du Grand Paris	2,15%	0,57%	AbbVie Inc	1,36%	0,11%
Electricite de France SA-EDF	1,60%	0,34%	Microsoft Corp	1,17%	0,10%
Ardagh Metal Packaging Finance plc	1,96%	0,57%	Anheuser-Busch InBev Finance Inc	0,98%	0,05%
Suez SA	1,90%	0,57%	Exxon Mobil Corp	0,96%	0,15%

Panel D: Bonds by year

Year	Green Bonds			Corporate Bonds		
	Number of tranches	Total value [$ Million]	Percent of total value	Number of tranches	Total value [$ Million]	Percent of total value
2014	19	11 340	1,88%	5 757	3 031 680	8,6%
2015	28	13 913	2,30%	6 664	4 006 301	11,4%
2016	36	22 848	3,78%	5 909	4 052 573	11,5%
2017	61	28 686	4,75%	6 820	3 865 378	11,0%
2018	77	22 110	3,66%	6 334	4 259 625	12,1%
2019	151	49 606	8,21%	6 161	4 123 452	11,7%
2020	147	67 846	11,23%	7 269	5 354 494	15,2%
2021	388	196 285	32,50%	5 507	3 949 879	11,2%
2022	409	191 407	31,69%	3 680	2 603 452	7,4%
Total	**1 316**	**604 042**	**100%**	**54 101**	**35 246 833**	**100%**

Panel E: Purpose Of Funding

Purpose Of Funding	Green Bonds			Traditional Bonds		
	Number of Deals	Total Value [$ Million]	% of Total Value	Number of Deals	Total Value [$ Million]	% of Total Value
Corporate Control (CC)	5	4 137	0,7%	2 111	9 159 351	26,0%
Capital Structure (CS)	121	72 476	12,0%	9 712	8 466 494	24,0%
Fixed Asset Based (FAB)	20	9 538	1,6%	380	169 984	0,5%
General Corporate Purpose (GCP)	732	517 891	85,7%	15 533	17 451 004	49,5%
Total	**878**	**604 042**	**100%**	**27 736**	**35 246 833**	**100%**

Chapter 3
Methodology and univariate analysis

3.1 Model and variables

To teste our hypotheses, we make use of equation (1), where the subscripts refer to bond tranche i at time t. The bond spread is our dependent variable having both credit rating, contractual characteristics, and macroeconomic factors as the independent variables. $Spread_{i,t}$ is expressed in basis points and is an indicator of the economic cost per tranche of a bond at the time of issuance. It represents the difference between the bond yield and a benchmark rate, such as a government bond yield (F. Kanda et al., 2022).

(1)

$$Spread_{i,t} = \alpha_0 + \beta_1 Green\ Bond_{i,t} + \beta_2 Rated_{i,t} \beta_3 Rating_{i,t} + \beta_4 Rating\ discordance_{i,t} + \gamma\ Contractual\ Characterisitics_{i,t} + \varphi\ Macroecnomic\ factors_t + \varepsilon_{i,t}$$

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. Appendix A has a full description of all model variables as well as the expectation of their impact on the dependent variable.

3.1.1 Credit Rating

To analyze the credit rating of the bonds, we started by creating a dummy variable that assumes 1 when the tranche is rated, and 0 otherwise. When buying a bond, investors mainly expose themselves to the default risk of the asset and the underlying company. This leads the market to have more confidence on rated bonds due to the transparency and decreased levels of risk that the rate provides (Gabbi and Sironi 2005). As so, *rated* is expected to affect negatively the bond spread.

For those that were rated, tranche ratings were obtained from both Moody's, S&P and Fitch, with all tranches having at least one rating assigned to them by one of these institutions. Due to the ratings being non-numeric the following conversion system was implemented: AAA=Aaa=1, AA+=Aa1=2, and so on until D=21. When a tranche has more than one rating assigned, we assumed the average. As it is perceptively above, the higher the number of the rating the worse that rating is, with bonds with a high rating number having a higher spread.

In addition, a dummy variable was created to control for the existence of two different ratings for the same tranche. Assuming the value of 1 when this occurs, the variable allows us to understand if the existence of rating discordance has any statistically significant effect on its spread. The expectation is that tranches with *rating discordance* have a higher spread.

To control for issuing firms' characteristics, we use the issuer credit rating. The system used to convert the ratings into a discrete numeric value was the same abovementioned. As so, we used *company rating* which assume the numeric value of the rating, and *company rated* the dummy that classified as 1 if the company was rated, and 0 otherwise.

3.1.2 Contractual Characteristics

From the extant literature, (Long et al., 2007; Marques and Pinto 2020; Bae and Goyal 2009), we borrow the following variables: *(i) maturity*, *(ii) deal size*, *(iii) number of banks* and *(iv) tranches*, *(v) currency risk*, *(vi) subordination level* (*vii) switcher, (viii) country risk,* and *(ix) callable*.

We expect that an increase in the *maturity* of the bond will lead to an increase of the risk, and therefore of the spread. A subordinated bond or a bond with *currency risk* or a *call option* have higher spreads (Fabozzi and Vink 2012; Samet and Obay 2014). *Country risk* accounts for the issuer's country creditworthiness. Therefore, we expect a positive relationship between this variable and the bond spread. The ratings were considered from Moody's and then turned into a numerical scale where Aaa=1, …, and D=21.

The *deal size* of the bond, on the contrary, is projected to have an inverse relation with the spread, as the increase in size is often associated with higher liquidity and lower uncertainty (Sorge and B. Gadanecz 2008; Vink and A. Thibeault 2008). Bank involvement, measured by *number of banks*, is expected to impact negatively the spread due to the increased support in the transaction (Sufi 2007). Following the literature, *number of tranches* and *switcher* are also variables expected to have an inverse relationship (Cumming et al., 2019; Marques and Pinto 2020). *Switcher* represents a dummy variable that accounts for 1 when a company has issued both green and traditional corporate bonds during the sampling period.

3.1.3 Macroeconomic Factors

To consider for the possible implication of macroeconomic factors in the pricing of the bonds, both yield curve slope and market volatility are considered. The slope of the yield curve is calculated by the difference between the five-year Euro swap rate and the 3-month Libor rate, while market volatility is measured by the Chicago Board Options Exchange Volatility Index. The literature once again points towards a possible negative impact on spreads from the yield curve slope, while the opposite is expected for volatility (Campbell and Taksler 2003; Marques and Pinto 2020).

3.2 Univariate Analysis

Analyzing table 2 we find that the average credit spread for green bonds (173,4 bps) is 24,1 bps lower than the mean spread for corporate bonds (197,5 bps). This discrepancy, however, does not follow suit when we look at the maturity of the securities. Both Green bonds (9,3 years) and corporate bonds (9,5 years) have similar maturities. Tranche Rating, on the other hand, presents a modest difference between green and corporate bonds. Green bonds mean tranche rating (5.4|A1) is slightly superior to the rating average for corporate bonds (5.8|A2). Similarly, when comparing the company ratings, green bond average company rating (4.9|A1) is marginally lower and hence better than the mean rating of corporate bond companies (5.5|A2).

We can find more significant differences when we turn our attention to the deal value. Green bond average deal value (688 $M) is significantly lower than that of conventional bonds (1 270 $M). The average number of banks involved in a green bond (5,9) is also significantly lower than that of corporate bonds (8). This may suggest that banks see the need to increase monitoring and risk-sharing in the traditional bond market, which in turn can be explained by the higher deal value that traditional bonds market entail. To complement this observation, brown bonds also present a higher number of tranches per deal (1.95), when compared to green assets (1,5).

When addressing our dummies variables, we find little discrepancies. Green bonds have 69,8% of their tranches rated, on par with the 67,9% presented within brown bonds. The same scenario happens for rated companies, both green (62,8%) and brown bonds (63,2%) see identical percentages. The trend continuous when looking at currency risk, green bonds (20,8%) and brown bonds (18,7%) share similar percentages. Regarding rating discordance green bonds register as 21,6% discordance while traditional securities record 27,8%, a difference of 6,2 bp. The observed difference in ratings between green and brown bonds is noteworthy as rating discordance can have a substantial effect on bond pricing. It is possible that brown bonds may have a wider spread compared to green bonds due to the higher risk associated with the variable. Green bonds (3,1%) also express a more significant share of subordinated debt when compared with traditional assets (0,9%) as well as a higher percentage of callable options, 61,4% and 55,4%, respectively for green and brown bonds. On appendix more detailed summary statistics can be found.

Table 2 - Descripetive statistics

Variable of interest	Green Bonds	Traditional bonds	Variable of interest	Green Bonds	Traditional bonds
Univariate analysis - continuous variables					
Credit spread (bps)			**Maturity (years)**		
Number	878	27 736	Number	878	27 736
Mean	173.41	197.48 ***	Mean	9.34	9.5
Median	130	146	Median	7.02	7
Deal Value ($ Million)			**Tranche Rating [1-22 weak]**		
Number	878	27 736	Number	564	17 648
Mean	687.97	1270.8 ***	Mean	5.39	5.8 ***
Median	450	500	Median	7	6
Number of Banks			**Country Risk**		
Number	878	27 736	Number	878	27 736
Mean	5.9	8 ***	Mean	2.52	2.56 ***
Median	4	6	Median	1	1
Number of tranches			**Company Rating [1-22 weak]**		
Number	878	27 736	Number	878	27 736
Mean	1.49	1.95 ***	Mean	4.88	5.47 ***
Median	1	1	Median	6	6
Univariate analysis - dummy variables					
Tranche Rated			**Currency risk**		
Nr. of tranches	878	27 736	Nr. of tranches	878	27 736
Nr. of tranches with d=1	613	18 830 ***	Nr. of tranches with d=1	183	5 199
% of total	69.8%	67.9%	% of total	20.8%	18.7%
Tranche Rating Discordance			**Collateralized**		
Nr. of tranches	878	27 736	Nr. of tranches	878	27 736
Nr. of tranches with d=1	190	7 703 ***	Nr. of tranches with d=1	63	3 037
% of total	21.6%	27.8%	% of total	7.2%	10.9%
Callable			**Subordinated**		
Nr. of tranches	878	27 736	Nr. of tranches	878	27 736
Nr. of tranches with d=1	539	15 352	Nr. of tranches with d=1	27	256 ***
% of total	61.4%	55.4%	% of total	3.1%	0.9%
Companies Rated			**Switcher**		
Nr. of tranches	878	27 736	Nr. of tranches	878	27 736
Nr. of tranches with d=1	551	17 526 ***	Nr. of tranches with d=1	624	2 469
% of total	62.8%	63.2%	% of total	71.1%	8.9%

Notes: We test for similar distributions in contractual characteristics using the Wilcoxon rank-sum test for continuous variables and the Fisher's exact test for discrete ones. (***) indicates significant difference at the 1% level. (**) indicates significant difference between the 1% level and the 5% level. (*) indicates significant difference at the 10%.

Chapter 4
Results

4.1 Greenium

We start by examining if green bonds have a lower spread than brown bonds [H1]. Table 3 highlights the results of the regression equation (1) presented in section 4 using the described sample in section 3. All regressions are run with fixed effects by year and industry to consider possible sources of heterogeneity in the fixed income markets.

To understand the validity of the in-question hypothesis we consider model [1] and model [2]. Both models were estimated with the incorporation of a dummy variable that assumed 1 if a bond was deemed green and 0 for non-green bonds. In Model [2] we control for issuing firms credit rating.

We find that in fact exists a statistically significant difference between the spreads of the two asset classes. According to Model [1], green bonds have, on average, a 7.47 bps lower credit spread than brown bonds. Similarly, Model [2] shows a spread difference of 8,46 bps between the two securities. We therefore accept[H1], confirming the existence of greenium in the market.

Furthermore, these findings are suggestive of several implications regarding bond pricing that warrant further examination. As expected, *rated* bonds have significantly lower spreads, while the increase in credit risk determined by a lower *rating* will lead to increases in spreads. Both Model [1] and Model [2] underwent recalculation using only these two metrics as dependent variables. This yielded adjusted R-squared values of 0.456 and 0.462, respectively, indicating a marginal difference of 0.11 and 0.106 when compared to the values derived from the complete model. As so, it is possible to conclude that although credit ratings explain the majority of bond pricing, investors also take in consideration other metrics in their assessment.

Table 3 - Regression analysis

Dependent variable: Credit spread (bps)	[1] Full Sample	[2] Full Sample with company variables	[3] Grenn bonds sample	[4] Green bonds sample with company variables	[5] Corporate bond ssample	[6] Corporate bond ssample with company variables
Independent variables:						
Intercept	203.679 ***	201.621 ***	220.149 ***	225.457 ***	206,00 ***	203.733 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Green Bond	-7.47 *	-8.46 **				
	(0.0638)	(0.0353)				
Rated	-304.87 ***	-293.83 ***	-188.297 ***	-226.868 ***	-307.661 ***	-302.587 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Rating	35.25 ***	35.86 ***	20.47 ***	27.142 ***	35.61 ***	36.53 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Rating discordance	28.17 ***	29.49 ***	29,00 ***	34.88 ***	28.41 ***	36.09 ***
	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.000)
Maturity	0.4 ***	0.4 ***	-0.719	-0.609	0.461 ***	0.45 ***
	(0.000)	(0.000)	(0.1978)	(0.2745)	(0.000)	(0.000)
Log deal size	-22.43 ***	-21.51 ***	-36.88 ***	-36.301 ***	-22.13 ***	-21.19 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Callable	74.39 ***	75.29 ***	109.59 ***	113.42 ***	72.81 ***	73.67 ***
	(0.0000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Switcher	1.58	2.3	-34.9 ***	-33.49 ***	3.83	4.5 *
	(0.4982)	(0.3207)	(0.000)	(0.000)	(0.112)	(0.0621)
Subordinated	57.33 ***	55.35 ***	65,00 **	47.79	60.51 ***	58.6 ***
	(0.000)	(0.000)	(0.0321)	(0.1183)	(0.000)	(0.000)
Currency risk	22.88 ***	22.554 ***	24.66 ***	25.38 ***	22.63 ***	22.33 ***
	(0.000)	(0.000)	(0.009)	(0.007)	(0.000)	(0.000)
Number of tranches	9.66 ***	9.37 ***	5.41	4.82	0.81 ***	9.52 ***
	(0.000)	(0.000)	(0.3943)	(0.3062)	(0.000)	(0.000)
Number of banks	-2.13 ***	-2.04 ***	0.744	0.774	-2.16 ***	-2.07 ***
	(0.000)	(0.000)	(0.394)	(0.373)	(0.000)	(0.000)
Country risk	1.47 ***	1.35 ***	-0.338	-0.338	1.622 ***	1.48 ***
	(0.000)	(0.035)	(0.835)	(0.8327)	(0.000)	(0.000)
Collateralized	77.57 ***	75.37 ***	33.95 **	36.78 **	78.33 ***	76.06 ***
	(0.000)	(0.000)	(0.019)	(0.012)	(0.000)	(0.000)
Volatility	2.57 ***	2.56 ***	2.32 ***	2.31 ***	2.58 ***	2.58 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EUSA5y-Libor3M	-0.01	-0.012	-0.06	-0.0674	-0.01	-0.011
	(0.327)	(0.269)	(0.268)	(0.226)	(0.366)	(0.315)
Company Rated		-15.37 ***		55.19		-17.08 ***
		(0.001)		(0.110)		(0.000)
Company Rating		-1.04 **		-9.76 ***		-0.85 *
		(0.0224)		(0.007)		(0.0640)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	28 614	28 614	878	878	27 736	27 736
Adjusted R^2	0.566	0.568	0.433	0.44	0.571	0.573
Rated and rating dummies as independent variables only						
Adjusted R^2	0.456	0.462	0.21	0.216	0.462	0.468
Differences in adjusted R^2	0.11	0.106	0.223	0.224	0.109	0.105

Notes: Standard errors in parathesis. *** denote p-values <0.01, ** denote p-values <0.05, and * denotes p-values <0.10. FE = Fixed effects.

Rating discordance comes out as a positive and significant variable indicating that divergences in the attributed ratings between both S&P and Moody's create a sense of increased risk in the security. *Maturity* goes in line with the current literature and indicates that spreads tend to increase 0,40 bp for each added year. *Subordination* and *callable* should be highlighted as important determinants of bond pricing as they have significant and positive coefficients - 57,33 and 74,39 bps considering model [1]; and a 55,35 and 75,29 bps in model [2].

The findings support the expectation that investors perceive increased credit risk as subordination level rises, given their lower priority for repayment in the event of default, thus prompting a premium to be sought. It is also possible to corroborate existent literature (Samet and Obay 2014; Qiu and Yu 2010), indicating that callable bonds have a positive call spread.

The influence of the *deal size* is negative and significant for both models, meaning that an increase in the size of the issue may lead to lower spreads. This indicates a positive price liquidity effect related to the transaction size as highlighted by (Marques and Pinto 2020). The *number of banks* included in the deal also show a negative effect on spreads indicating that increased monitorization is perceived by the market as a reducing risk factor.

The *collateralized* dummy variable behaves as expected: we show a positive and significant impact on bond spreads. As for our macroeconomic variables, *volatility* is positive and significant for both models. On the contrary, *EUSA5y-Libor3M* is insignificant for both model [1] and [2].

Looking at model [2] our findings document that the company's variables allow a very small increase in the adjusted R-squared value when compared to model [1], therefore implying that the firm's proxies do not provide relevant amounts of increased information. However, it should be worth noting that with the addition of company's variables, the *green bond* dummy became more significant. While it is only significant at the 10% level for model [1], model [2] presents a significance level of 5%.

Looking at the in-question variables, we see that *company rated* behaves similarly to the *rated* dummy. As expected, a company that is rated is able to have better funding conditions on the market. According to our model there is a 15,37-bps reduction of bond spreads. On the other hand, *company rating* shows a very small although negative impact on the dependent variable. The results suggest that a worse rating quality will decrease the spread by 1,04-bps. This goes against with what both models have presented with the *rating* dummy and to what is expected.

A possible explanation may be that investors are indeed worry about credit risk but make their assessment based on the bond credit risk rating which already takes into consideration the creditworthiness of the company, rather the company rating by itself. This may suggest that the market by only looking at the credit rating of the bond may be neglecting the underlying credit rating of the company leading to worse rated companies benefiting from reduced market spreads.

4.2 The Pricing of GB versus CB

Following the methodology of (Marques and Pinto 2020), the study employs a Chow test for a structural break to scrutinize whether common pricing characteristics differently influence the credit spreads associated with green and brown bonds. The fundamental aim is to determine the significance of pricing characteristics for both bond typologies and to verify, in the event of their significance, whether they exhibit identical coefficient values. In view that the Chow test statistics is of 7,85 for GB versus CB we can conclude that green and traditional bonds are influenced differently by common factors. Therefore, we will be examining the spreads determinants for each bond separately. This will allow us to respond to our [H2] and to identify if liquidity has a stronger impact on GB spreads vis-à-vis those for brown bonds, permitting us to also answer [H3].

Still looking at table 3 we will make use of models [3] to [6] to answer the above-mentioned hypothesis. Models [3] and [4] were estimated using only the green bond sample, with model [4] including the company credit rating variables as additional controls. Model [5] and [6] follow the same rational but in this case the sample is solely composed of corporate bonds. Results show, as in our analyses for the full sample, that both bonds' typologies show reduced spreads whenever they are rated. Also, in line with what was expected both debt instruments will see increased spreads as their rating deteriorates.

It is however relevant to mention that even though the direction of the impact is the same, the magnitude is not. Green bonds appear to be less sensitive to the variables, showing: a 188,3 bps reduction when the tranche is *rated*, which contrasts with the 307,66 bps reduction for corporate bonds; and a 20,47 bps increase of spreads for each unit increase in *rating* while corporate bonds increase by 35,61 bps. The incorporation of firms' credit rating controls does not change these results.

Maturity while positive and statistically significant for both models of corporate bonds, comes out statistically insignificant as a pricing variable for green bonds. We can see the same happening when we consider the *number of tranches*, *number of banks,* and *country risk*. Although, this might be explained by the low sample of green bonds, it is also an indicative that green bonds are indeed differently priced than their brown counterpart.

Switcher on the opposite side, comes out negative, as expected, and significant at the 1% level for green bonds, while for corporate bonds the variable is only significant (at the 10% level) when we include proxies for issuing firms' credit ratings. These results also contrast with the ones observed on the full sample models, indicating again that green bonds respond differently to common pricing variables. *Subordinated* despite not being significant for model [4], it presents similar coefficients for both assets.

Regarding the macroeconomic variables, *volatility* presents a similar impact on both assets while *EUSA5y-Livor3M* is always not significant. *Company rated* is significant and negative, as expected, for corporate bonds, while it is insignificant in the green bond sample. In line to what had already been observed in the full sample, *company rating*, against expectations, shows negative coefficients in both models, particularly in the green bond sample, with a coefficient of -9,76 bps at the 1% significance level, contrasting with the -0,85 bps (at the 10% level) coefficient of the corporate bond model.

Overall, our findings showed that both green and corporate bonds react differently to common pricing variables, leading us to accept [H2].

4.3 Liquidity

To examine if the results validate [H3], we focus on *log deal size* variable. Our expectation, as previously mentioned, is that an increase in transaction size will increase liquidity, leading to a reduction of the liquidity premium present on spreads. Green bonds as a more illiquid asset are therefore expected to be more impacted.

Looking at the results, both models [3] and [4] present higher coefficients than their corporate bonds counterpart: green bonds show a reduction in spread between 73.76 and 72.6 bps for each 100 million increase in the deal size while for corporate bonds the coefficient ranges between 44.26 and 42.38 bps. Hence, we are able to find support in the findings towards our expectations and accept [H3].

4.4 Robustness tests

In table 4 we present robustness checks that aim to validate our primary findings using alternative econometric regression methods. In particular we aim to check if the abovementioned baseline results are robust across different sub-samples. In models [7] through [10] we investigate whether the deal type of the bond matters for the existence and the magnitude of the greenium, specifically we make the distinction between investment grade and high-yield bonds.

Overall, the models suggest that the baseline results are mainly driven by investment grade bonds, since they make most of the full sample observations. High-Yield debt although points towards an existence of greenium by having the green bond dummy variable negative, these coefficients are not statistically significant. These results can be mainly explained by the low number of both total, and more importantly, green bonds observations.

Table 4 - Robustness analysis

Dependent variable: Credit spread (bps)	[7] Investment Grade		[7] Investment Grade With company variables		[8] High Yield		[8] High Yield With company variables	
Independent variables:								
Intercept	151.29	***	148.29	***	405.85	***	408.92	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Green Bond	-6.59	***	-7.07	**	-4.58		-10.64	
	(0.044)		(0.031)		(0.766)		(0.488)	
Rated	-155.1	***	-126.71	***	-702.91	***	-639.48	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Rating	17.06	***	14.52	***	48.86	***	46.12	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Rating discordance	16.71	***	15.99	***	23.16	***	-10.64	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Maturity	1.18		1.17	***	-7.73	***	-7.55	**
	(0.000)		(0.000)		(0.000)		(0.000)	
Log deal size	-16.63	***	-15.73	***	-10.51	***	-8.44	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Callable	51.45	***	51.32	***	55.96	***	56.23	***
	(0.0000)		(0.000)		(0.0000)		(0.000)	
Switcher	-5.4	***	-4.2	**	-59.89	***	-57.93	***
	(0.003)		(0.023)		(0.000)		(0.000)	
Subordinated	75.73	***	79.38	***	19.31		15.71	
	(0.000)		(0.000)		(0.503)		(0.583)	
Currency risk	22.66	***	22.81	***	24.82	***	22.43	***
	(0.000)		(0.000)		(0.000)		(0.00)	
Number of tranches	8.95	***	8.83	***	-2.08		-4.87	***
	(0.000)		(0.000)		(0.595)		(0.000)	
Number of banks	-0.94	***	-0.91	***	-1.65	***	-1.4	***
	(0.000)		(0.000)		(0.006)		(0.003)	
Country risk	5.57	***	5.39	***	-2.25	**	-2.58	***
	(0.000)		(0.000)		(0.016)		(0.006)	
Collateralized	19.82	***	17.43	***	77.59	***	70.14	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Volatility	2.26	***	2.27	***	6.2	***	6.24	***
	(0.000)		(0.000)		(0.000)		(0.000)	
EUSA5y-Libor3M	-0.02	**	-0.0239	***	-0.09	**	-0.1	***
	(0.010)		(0.009)		(0.012)		(0.002)	
Company Rated			-39.28	***			-91.61	***
			(0.000)				(0.000)	
Company Rating			3.25	***			3.54	***
			(0.000)				(0.07)	
Industry fixed effects	Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes	
Number of observations	23 773		23 773		4 841		4 841	
Green Bonds	779		779		99		99	
Corporate Bonds	22 994		22 994		4 742		4 742	
Adjusted R^2	0.291		0.2945		0.426		0.428	

Notes: Standard errors in parathesis. *** denote p-values <0.01, ** denote p-values <0.05, and * denotes p-values <0.10. FE = Fixed effects

Conclusion

Our study examines the motivations behind the most recent "green bond boom". To understand this phenomenon, we hypothesize the following: H1: Green bonds have lower spreads than similarly rated bonds; H2: Green bonds and similarly rated brown bonds are affected differently by common pricing variables; H3: Liquidity has a stronger impact on green bond spreads vis-à-vis brown bond spreads. We use a sample of 28,614 bonds, of which 878 are green bonds and 27,736 are corporate bonds, issued in the 2014-2022 period.

Our findings, in accordance with Gianfrate and Peri (2019) and Zerbib (2019), are supportive of H1, suggesting that green bonds have statistically significant lower spreads, between 7.47 bps (and 8.48 bps if controlling for issuing firms' credit risk), than similarly rated bonds, confirming the existence of a greenium in the bond market. This lends support to the idea that investors are willing to forgo financial benefits on socially responsible assets. The empirical evidence from robustness tests, corroborates the base line results and points out that they are mainly driven by investment-grade bonds.

We also confirm that green and corporate bonds are differently affected by common pricing variables such as rated, rating, number of tranches, number of banks, and country risk. Finally, using log-deal size as a proxy for liquidity, we identify that while green bonds have a 73.76 bps (and 72.6 bps when controlling for issuing firms' credit risk) for each 100 million added to the transaction, corporate bonds spreads are only affected between 44.26 and 42.38 bps. As so, our results are also able to corroborate expectations that liquidity has a stronger impact on GB spreads vis-à-vis brown bonds.

The dissertation provides insightful information regarding the pricing dynamics of a rapidly growing green debt market. There is, however, room to further explore this field. Subsequent studies would be queen in addressing the same questions but should be looking to use bigger samples and different methodologies. It would also be interesting to understand if the reported price dynamics are replicable using specific sample regions, such as China or the EU and how those dynamics may differ for different industries.

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Appendices

Appendix A: Variable Defenitions

Variable name	Variable definition	Source	Expected impact on credit spread	
			GB	CB
Dependent variable:				
Credit spread	Margin yielded by the security at issue above a corresponding currency treasury benchmark with a comparable maturity (OAS).	DCM Analytics		
Independent variables:				
Contratual characterstics				
Rated (Tranche)	Dummy equal to 1 if the tranche has a credit rating from S&P, Moody's or Fitch, and 0 otherwise.	DCM Analytics	-	-
Rating (Tranche)	Tranche rating based on the S&P's, Moody's and Fitch rating at the time of bond issuance. The rating is converted as follows: AAA=Aaa=1, AA+=Aa1=2, and so on until D=22. Moody's or Fitch, and 0 otherwise.	DCM Analytics	+	+
Tranche Rating discordance	Dummy equal to 1 if S&P, Moody or Fitch assign a different credit rating for the same tranche, and 0 otherwise.	DCM Analytics	+	+
Maturity	Maturity of bonds, in years.	DCM Analytics	+	+
Log deal value	Log deal transaction size. Transaction size is converted into US Dollars.	DCM Analytics	-	-
Subordianted	Dummy equal to 1 for tranches that are subordinated, and 0 otherwise.	DCM Analytics	+	+
Number of tranches	The number of tranches per transaction.	DCM Analytics	-	-
Number of banks	The number of financial institutions participating in bond issuance, as bookrunners, underwriters or servicers.	DCM Analytics	-	-
Currency risk	Dummy equal to 1 for bonds that are denominated in a currency different from the currency in the deal's nationality, and 0 otherwise.	DCM Analytics	+	+
Switcher	Dummy variable that takes the value of 1 if the switcher has issued both Green bonds and Corporate Bonds in the same year.	DCM Analytics	-	-
Collaterized	Dummy equal to 1 if the tranches are backed by fixed assets, and 0 if, instead, they are backed by current assets.	DCM Analytics	+	+
Green Bond	Dummy variable that takes the value of 1 if the bond is considered Green, and 0 otherwise	DCM Analytics	-	-
Callable	Dummy equal to 1 if the bond has a call option, and 0 otherwise.	DCM Analytics	+	+
Macroeconomic factors				
Volatility	The Chicago Board Options Exchange Volatility Index (VIX). VIX reflects a market estimate of future volatility	Datastream	+	+
EUSA5y-Libor3M	The slope of the Euro swap curve. Obtained as the difference between the five-year Euro swap rate and the 3-month Libor rate.	Datastream	-	-
Country Risk	Each country has a number regarding the risk, from 1 (AAA) to 21 (C).	DCM Analytics	+	+
Firm's proxy				
Company Rated	Dummy equal to 1 if the company has a credit rating from S&P, Moody's or Fitch, and 0 otherwise.	Datastream	-	-
Company Rating	Company rating based on the S&P's, Moody's and Fitch rating at the time of bond issuance. The rating is converted as follows: AAA=Aaa=1, AA+=Aa1=2, and so on until D=22.	Datastream	+	+

Appendix B: Summary Statistics

Panel A : Continuous Variables

	Green Bonds						Corporate Bonds					
	Number	**Mean**	**Median**	**Std. Dev.**	**Min**	**Max**	**Number**	**Mean**	**Median**	**Std. Dev.**	**Min**	**Max**
Contractual characteristics												
Tranche spread to benchmark (bp)	878	173,41	130	141,58	-23	1154	27736	197,48	146	166,31	-195	1419
Deal Value [M$]	878	687,97	450	856,27	6,025	46000	27736	1270	500	2627	0,625	46000
Tranche Rating	613	5,39	7	4,17	1	17	17648	5,8	6	4,9	1	19
Number of Banks	878	5,96	4	5,18	1	32	27736	8,07	6	6,55	1	50
Number of Tranches	878	1,49	1	0,88	1	9	27736	1,95	1	1,65	1	20
Maturity	878	9,34	7,02	9,03	1,49	62	27736	9,5	7,01	8,58	0,53	100,74
Macroeconomic factors												
Volatility	878	20,8	19,44	7,55	9,14	72	27736	17,84	15,27	8,14	9,14	82,69
EUSA5y-Libor3M	878	71,79	76,4	62,96	-68,2	221,2	27736	85,98	87,3	60,89	-69,8	221
Country Risk	878	2,52	1	2,41	1	20	27736	2,56	1	2,22	1	19
Firm's proxy												
Company rating	878	4,88	6	4,25	1	17	27736	5,47	6	4,91	1	22

Panel B : Dummy Variables

	Green Bonds			Corporate Bonds		
	Number	**% Total**	**SD. Dev.**	**Number**	**% Total**	**SD. Dev.**
Contractual characteristics						
Callable	878	61,4%	49%	27736	55,4%	48%
Subordinated	878	3,10%	17%	27736	0,9%	18%
Collaterized	878	7,2%	26%	27736	10,9%	34%
Company Rated	878	62,8%	48%	27736	63,2%	43%
Switcher	878	71,1%	45%	27736	8,9%	32%
Currency Risk	878	20,8%	41%	27736	18,7%	41%
Tranche Rating Discordance	878	21,6%	41%	27736	27,8%	44%
Tranche Rated	878	69,8%	46%	27736	67,9%	38%