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Uncovering Green Bonds: Pricing and its Determinants

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Abstract

This paper investigates the pricing implications of corporate green bonds in the primary and secondary markets. Our results confirm the existence of a green bond premium for both markets, suggesting that green bonds have lower yields than their traditional counterparties. We further study what influences the greenium by analyzing regional effects, ESG rating, external certification and experience of issuing green bonds. We find that the magnitude of the green bond premium is marginally higher for bond issuers in the EU relative to ones based in the US. Additionally, we conclude that experience in issuing green bonds affects their yields in primary market, while ESG ratings influence the green bond yields in the secondary market. We attribute our findings to differences in legislative landscapes for sustainable investments, as well as market participants' sentiment about the credibility and integrity of the developing green bond market.

Key words: sustainable finance, green bond market, green bond premium, PSM.

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1.Introduction

The recent move to sustainable development has been provoked by the growing concerns of climate change. Due to the carbon footprint of humankind activities, the temperature is expected to increase by 1.5 degrees Celsius in the coming decades. Limiting global warming at this level requires about 2.4 trillion USD (about 2.5% of the world's GDP) of annual investments (IPCC, 2021). Therefore, the role of financial markets to mobilize capital for environmentally-protective initiatives is crucial.

One of the modern ways to fund environmentally beneficial initiatives is through green bonds. They are issued for financing the projects with a positive impact on the environment, such as development of renewable energy, sustainable agriculture and clean transportation. Green financing is expanding exponentially with the yearly issuance of green bonds worth 0.8 billion dollars in 2007 up to 487 billion dollars in 2022 (CBI, 2023). Since the first inception of a $600 million climate-awareness bond by the European Investment Bank, corporations have also become active players in mobilizing green funds.

According to Flammer (2020), issuing green instruments signals about borrowers' environment-caring attitude and long-term outlook that attract a diverse and responsible base of investors. For investors, besides the ethical considerations of commitment to sustainable growth, green bonds can be a source of portfolio risk diversification, or simply a source of better financial performance (Han and Li, 2022). Nevertheless, there are some ongoing challenges in the green bond market, such as the supply-demand mismatch, insufficient regulation as well as ambiguous risk profile, which elevates greenwashing, illiquidity and regulatory risks (Cochu, 2016).

As claimed by the Efficient Market Hypothesis (Fama, 1970), conventional and green bonds should be priced equally, as financial markets incorporate all of the available information into prices immediately, including their environmental benefits. However, given the above mentioned considerations and market imperfections, we can suspect inefficiencies in the form of a pricing difference between conventional and green bonds. Previous research on the existence of a pricing differential between plain-vanilla and green bonds is inconclusive, but still in its infancy stage. The existence of negative green bond premiums in both primary and secondary markets is mainly driven by the excessive demand and investors' willingness to receive lower yields in return for their environmental contribution (Preclaw and Bakshi, 2015; Zerbib, 2019). On the other hand, research that finds positive green bond premiums deny the power of the "environmental impact", since investors have lower trust of these novel fixed-income instruments (Karpf and Mandel, 2018). In addition, there are further instances where identical pricing for green and conventional bonds is also observed (CBI, 2017; HSBC, 2016).

The (non-)existence and heterogeneity of a greenium can also depend on several determinants. To begin with, the development of sustainable investing, particularly through green bonds, varies for different regions due to their regulatory landscape. For example, the EU is actively implementing regulations about CSR, ESG and green bonds on the governmental level. Hence, policymakers raise the awareness and promote sustainable and green investments among corporations and investors, which results in a lower cost of debt (Eliwa et al., 2019). Meanwhile, the US does not establish and develop mandatory ESG and/or green bonds regulations for corporations, therefore local investors are facing higher greenwashing risks, requiring higher yields for their environmental commitment (Han and Li, 2022).

Furthermore, since the green bonds market still lacks stringent and universal standardization, as well as reporting and regulation, it is inclined to information asymmetry (Hu et. al., 2022). Thus, the availability of external certification for green bonds can signal about their credibility and integrity, which can increase their greenium (Flammer, 2020; Bachelet et al., 2019; Dorfleitner et al., 2020). Similarly, issuers' ESG rating disclosure assure investors about the purpose and quality of green instruments, which can subsequently lower their financing costs (Hachenberg and Schiereck, 2018). The better ESG risks and opportunities are managed by the issuing company, the higher the green premium can be (Immel et al., 2021; Hachenberg and Schiereck, 2018). Lastly, the experience of green instruments issuance matters. Repetitive issuers may enjoy economies of scale and scope, have more expertise and overall be more reputable in the eyes of investors, which can boost the green premium (Fatica et al., 2021).

Given the increasing importance of sustainable investment opportunities and emergence of the green bond market as a way to fight environmental problems, this paper will study the topic of the pricing differential between green and conventional corporate bonds and its determinants. It is essential to obtain reliable findings that can be used by investors, issuers, policymakers and society for the sake of environmental protection and climate change resolution.

Hence, the main research question of this paper is as follows:

Is there a yield differential between green and conventional bonds and what factors can influence it?

In order to study this, we gathered a sample of 5000 conventional and 718 green bonds alongside their bond and issuer-specific characteristics through the Bloomberg and Eikon databases. In order to extract price differential between green and conventional bonds, we use

Propensity Score Matching (PSM), similarly to treatment effects studies by Gianfrate and Peri (2019) and Hu et. al. (2022). We expand on previous research by analyzing both primary and secondary markets. Primary market yields reflect the cost of debt at issuance, while in the secondary market, they represent "investors' revised evaluation of green bonds" (Hu et. al., 2022). Furthermore, we improve the matching methodology by partially controlling for unobserved characteristics and restrict the matching to be 1-to-1. For the primary market, we do this by matching pairs of bonds that are from the same industry and issuance year. For the secondary market we match for bonds that are from the same industry and observed month. In the second part of study, we study the determinants of the green bond premium by using fixed-effect OLS regressions. We are, the first to our knowledge, to investigate how the magnitude of the greenium depends on the issuance region. Additionally, we study how ESG rating, external certification and experience in issuing green bonds can affect greenium.

The results suggest that there is a significantly negative premium for green bonds relative to their traditional counterparty, equal to 41 bps and 61 bps for the primary and secondary markets respectively. This can be primarily explained by the investors' perceptions of green financing as a contribution to the long-term sustainability and environmental protection. Additionally, it appears that the greenium in the EU is much more pronounced than in the US, where we again observe a higher green bond premium in the secondary market. We attribute this to the more extensive development in the legislation system of green financing in the EU. Notably, the effect is even more persistent in the years when the major directives and guidelines regarding environmental investment were passed. Next, the ESG rating appears to be an important determinant for the greenium for secondary market, although is not significant in primary market. Primarily, the availability of ESG rating increases the investors' sentiments about the true environmental purpose of bonds by rated issuers, that results in lower risks of greenwashing. Additionally, we find mixed results for the ESG score overall, and it does not have a marginally significant effect on the greenium. Furthermore, external certification has a similar mixed outcome, therefore in general we do not conclude that it has any influence on the yield differential. Lastly, experience in issuing green bonds appears to be an important determinant for greenium in the primary market for both markets. This supports the assumption that green bonds issued by experienced issuers appear are perceived to be more credible.

This work contributes to the literature by providing further evidence of the existence of a green bond premium, which is of benefit to investors, issuers and policy makers. For example, investors can be attracted to green bonds not only because of non-pecuniary motives, but also due to their financial prospects, i.e. higher returns, risk diversification etc. Additionally, this result has implications for legislators on the acceleration of sustainable investment development. Specifically, they can consider incentivizing borrowers to issue more green bonds by, for instance, expanding fiscal benefits. As an additional contribution, the extended analysis on the heterogeneity of the greenium due to regional differences, availability of external certification, issuer's ESG ratings and experience in green bonds issuance provide valuable insights on the determinants of green bonds pricing. In result, borrowers, investors and decision-makers can make better choices that stimulate green bond market growth and advance environmental viability.

The remainder of this paper is organized as follows. Section 2 discusses the literature on the green bonds, their pricing and factors that can influence them, Sections 3 and 4 describe the collected data and variables as well as the applied methodology respectively. Section 5 presents the results and their discussion. Finally, Section 6 concludes the paper.

2. Literature review

This section discusses the literature on the green bonds, their pricing and determinants. In particular, we summarize the previous findings for the (non)-existence of the green bond premium and what can influence it. As a result, we make the hypotheses to study the research question of this paper.

2.1 Green bonds

Green bonds are comparatively new financial instruments holding the features of conventional bonds, except for the fact that they are issued to finance projects, aiming at protecting the environment and developing alternative energy resources (Flammer, 2020).

The popularity of green financing has increased exponentially since its first inception in 2007 with an issuance of a $600 million climate-awareness bond by the European Investment Bank (Kaminker, 2015). At the beginning, the green bonds were used quite modestly by supranational and international organizations. With the passage of time, corporations and financial institutions have also embraced the importance of green initiatives and become active players in the green market (CBI, 2022). The issuance of green bonds signals not only about a company's intentions to raise financing but also their commitment to protection of the environment. This is important for modern investors, which are more environmentally conscious and long-term oriented (Tang and Zhang, 2020; Flammer, 2020).

However, despite such a noble purpose and hot interest among investors, the continuing growth of the green bond market faces some challenges. First and foremost, there are no commonly accepted classification and standardization systems for green bonds. Therefore, the definition, reporting and standardization of green bonds vary worldwide. Currently, the Green Bonds Principles (GBP) and the Climate Bonds Standards (CBS) are the main international voluntary frameworks used to identify green bonds. However, they grant either no or limited legal and actionable rights to green bond investors (CBI, 2022; GBI, 2018). In result, the issuers of the green instruments may make misleading claims about the company's commitment to the environment, fail to comply with the stated principles and use the proceeds for non-green projects (Wulandari et al., 2018). All of this entails the risk of greenwashing, where the sustainability claims for issuing the bond are marketing ploys. This information asymmetry affects the confidence of investors in determining whether green bonds are sustainable instruments and hence provoke reputational risks to the market as a whole (Flammer, 2020). In order to solve the above mentioned, the investors can employ due diligence agents to assure the issuer's integrity with the green instruments and prevent adverse selection issues in the market (Lin et al., 2012). However, this is always extremely costly and time-consuming. Hence, additional transaction costs in issuing green bonds render them less attractive as well promote their illiquidity issues.

Secondly, the enormous demand by investors for green fixed income instruments cannot be equalized to its supply, since the availability of green projects is low (Kaminker, 2015). This occurs due to the gap in development of a universal classification system for green bonds. In result, this makes it difficult for issuers to properly develop green bonds, which can be later challenged as being "non-green", and thus they will be penalized by investors that would not receive "green returns" (Cochu et al., 2016). Issuers can overcome this by using external reviewers to ensure the green bonds alignment, however their costs are high. Therefore, issuers may be reluctant to issue green bonds, but rather stick to traditional fixed-income instruments. Additionally, there is a lack of tax incentives and subsidies for launching green investment projects, even though they usually require high up-front investments for technologies and specialists' expertise (CBI, 2022).

Next, Cochu et al. (2016) state that the green investment risk profile is ambiguous and cannot disclose enough information about its performance and growth opportunities. This stems from the fact that this is a novel market, which lacks historical pricing data, reporting transparency, but also possesses liquidity risks due to a small pool of buyers and sellers. For instance, most green bonds are backed by their issuers' financial performance, not by the underlying green investment itself. Therefore, its credit quality and rating would be based on the issuing company too, which might be misleading. For example, green bonds issued by investment-grade companies will be regarded as stable and value-adding investments, while the riskiness of those issued by new companies without rating history can be hard to assess. Although, given the current agility of young companies to respond to green economy challenges, this might be a mistake as it can be more valuable to invest in green projects initiated by start-up projects.

2.2 Pricing of green bonds

Environmental, Social, and Governance (ESG) and Corporate Social Responsibility (CSR) topics have been widely investigated by researchers for many decades. The majority of studies confirm the positive association between corporate environmental, social, governance responsibility and financial performance. For example, Ge and Liu (2015) claim a positive relationship between CSR performance and companies' credit ratings that result in lower yield spreads for bond issuances.

The research on green bonds and its pricing is still in minority, but having revised the available literature, we have found 2 main strands for the discussion. Firstly, the authors conduct event studies that evaluate the issuer company's stock prices on the announcement day of green bond issuance. Any positive or negative abnormal deviations from the normal stock price signal about investors' perceptions regarding the value of green bonds. According to the findings, there are positive cumulative abnormal returns around the announcement date, which indicates that green bonds issuance enhances the company's value (Wang et al., 2020; Hoepner et al., 2020). The investors' positive reaction occurs due to decrease in exposure to negative CSR events and its associated costs, when engaging in green financing. Additionally, Flammer (2020), who finds similar results, explains that a company's devotion to sustainable development translates to improvements in firm long-term value and operating results, better environmental performance and green innovations.

Secondly, authors focus on the pricing of green bonds. Primarily, they use the matching and regression methods to investigate whether investors are willing to pay more for green investment or not. The studies find mixed results, although most of them suggest a positive or negative greenium, meaning that there is a yield difference between green and traditional bonds. For example, Preclaw and Bakshi (2015) investigate the yield differential between green and conventional bonds in the primary market with regression analysis for global samples. They confirm a negative green bond premium of approximately 18 bps, indicating that the demand for green bonds exceeds its supply and this drives their prices up. Similarly, Zerbib (2019) also confirms a small, but significant 2 bps greenium in the secondary market. By using the matching method followed by regression analysis, he attributes this negative premium to the "investor's pro-environmental preferences". Additionally, Gianfrate and Peri (2019) used a PSM method for both primary and secondary markets, which estimates the causal effect and control for confounding variables. They found the greenium to be present with 20 bps in the primary market and 12 bps for secondary market results, despite high issuance costs for green bonds.

On the other hand, when Karpf and Mandel (2018) studied the secondary sample of US municipal bonds with regression analysis, they found a positive premium of 25 bps for green bonds. They indicate investors' lower trust and awareness about green bonds as investment solutions, which make them riskier and lower priced than brown bonds. Additionally, they mention additional expenses for certification and reporting of green bonds that increases the cost of green projects. Similarly, the paper by Kapraun et al. (2019) discovered the green discount of 6 bps for the secondary market results. Although they found that green bonds were traded at a negative premium of about 12 bps in the primary market.

Furthermore, there are studies that claim the same yields for green and conventional bonds. For example, CBI (2017) and HSBC (2016) reports do not find any pricing difference between green and conventional bonds. Even though the studies highlight the lower default risk of green bonds, which can lead to lower yields in the long run. However, the limitations of these studies are their low samples with 14 and 30 green bonds respectively. On the other hand, Larcker and Watts (2020) used a more considerable sample of 640 pairs of municipal green and brown bonds together with a matching method to extract yield difference for the primary market. Their findings also suggest that green and brown bonds are viewed as identical by the investors.

Based on the aforementioned, we can produce the first hypothesis regarding the greenium.

Hypothesis 1: There is a yield differential between green and conventional bonds

Under our hypothesis 1, there is a difference between green and conventional bonds pricing. However, we cannot specify the sign of the yield difference due to mixed previous findings. The reasons for pricing differential could be due to investors' willingness to pay for the environmental contribution, the low supply in the green market, but also additional costs for the issuers related to their certification and reporting as well as risks of greenwashing because of weak regulation.

2.3 Green premium drivers

Having discussed the literature findings regarding the (non-)existence of green premium, we next focus on potential determinants of the greenium. While a vast number of the studies investigate whether there is any premium for green bonds relative to their traditional counterparties, there are no papers focusing on green bonds pricing differences across countries. Although, CSR and ESG standards, policies, certifications and reporting vary from region to region and this can affect the green bond yields.

The European Union has been actively implementing voluntary and mandatory stringent policy and regulations for CSR on the governmental level. The most important documents that they are using for promoting sustainability practices in companies' operations are renewed strategy for CSR, United Nations (UN) guiding principles on business and human rights, UN 2030 agenda for sustainable development. With the CSR promotion, EU authorities aim to encourage companies and investors to cooperate for sustainable goals despite the initial economic tradeoffs. According to Lin et al. (2012), the costs of issuance of green bonds was proportionally decreasing for companies engaging in more CSR activities. Consequently, the long-term influence of the substantial investments into CSR is positive, not only with non-pecuniary motives, but also financial returns.

The EU is also at the forefront of development of ESG regulation for business, which is substantiated by some directives. For instance, in October 2014, the Non-Financial Reporting Directive was introduced and requires companies to disclose their ESG-related information, such as risks and opportunities related to social and environmental issues in their activities, as well as the effects of their operations on people and the environment (Welling-Steffens et al., 2021). In addition to it, the Corporate Sustainability Reporting Directive was legalized in 2022 with extended rules and responsibilities on disclosing information for sustainable and environmental activities (EC, 2022). According to Eliwa et al. (2019), the companies publicly disclosing ESG information and scoring high on sustainable performance are rewarded with lower cost of debt for green bonds lending. Furthermore, there is Taxonomy Regulation, presented in 2021, that outlines whether an economic activity is considered to be "environmentally sustainable" or not (EC, 2020). This is one of the first and long-awaited documents in the EU as it can help the investors to ensure that the economic activity they want to invest aligns with environment-protection principles. With this, the EU expects to transition to a low-carbon economy, including the promotion of green bond financing, faster and more efficiently. In addition, the European green bond standard was created in 2019 in order to see whether the bond lies under the “green” classification (EC, 2019). With such a great advancement of transparency, legitimacy and comparability of the green financial instruments, the EU tries to reduce the risks associated with greenwashing and attract more investors to this market (EC, 2022).

Meanwhile, the US is not as advanced as the EU in establishing regulations for the disclosure of sustainable activities, since companies are not obliged legally to reveal this on a mandatory basis. In result, S&P 500 firms are claimed to score low on disclosing their environmental data (Tamimi and Sebastianelli, 2017). Similarly, there is no strict classification of green bonds in the US. According to Han and Li (2022), due to the lack of transparency and disclosure, the US green bonds can be used for funding projects that are not for environmental-protective measures. This results in increased greenwashing risks for investors, which makes them less reluctant to finance such initiatives. Additionally, there is a higher probability of downside potential for US green bonds than in the EU (Han and Li, 2022).

In result, there is a second set of hypotheses, which is related to greenium differences between US and EU:

$H2_a$: The negative premium of green bonds is more pronounced in the EU than US

$H2_b$: The negative premium of EU green bonds is most negative in the years when sustainability-linked legislative documents were published

The first hypothesis is based on the higher level of legitimacy, transparency and standardization development of the green bonds in the EU and therefore serving as a “safety pillow” for the investors against funding risks. This implies lower yields of green bonds compared to those in the US. For the second one, we hypothesize that EU green bonds yields will be different in the years where the major documents about green bonds regulation, certification and reporting are issued.

In addition to discussing the possible regional difference, we will outline the additional determinants that can affect the pricing of green bonds. From the general bond research, the authors find that yields can be influenced by duration, maturity, issuance size, liquidity, credit quality and rating, optionality such as callability, putability, or convertibility etc. (Chen et al., 2007). Similarly, the range of environmental, regulatory, economic factors as well as issuer and bond-specific features could influence the green bond premium (MacAskill et al., 2021). Given the nature and risks of green debt instruments, we discuss how features specific to this market, such as their external certification, ESG rating and experience, can affect the green pricing.

The availability of external verification for green bonds, as providers of environmental impact, is deemed to be an important factor for their yields. Specifically, the verification of green bonds by external parties signal about their credibility and integrity (Flammer, 2020). According to the findings of Bachelet et al. (2019) on 89 pairs of bonds, non-certified green bonds had a significant green discount of 10 bps relative to certified bonds. They explain that certification generates trust of investors and lower financing costs. Meanwhile, a lack of verificatio is concerning because of the potential of greenwashing. In the study by Dorfleitner et al. (2020), with 250 matched pairs, they also find that externally verified green bonds can exhibit significantly higher negative premiums of 5 bps due to reduced information asymmetry.

The following hypothesis tests on the effect of external certification on green bond premium. Although the research on this scope of green bonds studies is relatively scarce, we suspect externally certified green bonds enjoy higher premiums than their non-certified counterparties due to the existence of information asymmetry in the green market. The availability of external verification signals investors about the credibility of green bonds and lowers its costs. We state the hypothesis as follows:

H3: Externally verified green bonds exhibit a higher premium than non-externally verified green bonds

Another factor that can affect greenium is the ESG rating of the issuer. Given the greenwashing risks associated with the green market, the availability of this rating provides investors with enhanced assurance about the issued green instrument and reputation of the issuer. The higher ESG rating means that the company is more sustainable and responsible in its operating as well as manages ESG risks and opportunities, which can generate higher long-term value for investors (Flammer, 2020).

According to the findings by Immel et al. (2021) there is a relationship between ESG scoring and green bond premium. Specifically, they find that the availability of issuer's ESG rating leads to significantly higher green premium of between -9 and -19 bps. Furthermore, they state that the improvement of ESG score can increase this further by 6-13 bps. All in all, reduced information asymmetry and greenwashing risks make investors sacrifice higher yields in favor of more sustainable issuers. The similar result is also suggested by Hachenberg and Schiereck (2018), since higher ESG scores are awarded with the application of an extremely strict set of criteria by credible reviewers. Therefore, the green bonds by such issuers should not have any regulatory and greenwashing risks, and are in high demand. This contributes to a higher green premium.

Based on the abovementioned, we will test the following hypotheses:

H4$_a$: The green bond premium increases for green bonds whose issuers have ESG rating relative to those without ESG rating

H4$_b$: The higher ESG score is associated with a higher greenium

Next, the availability of experience in issuing green bonds can affect the green bond premium. According to Fatica et al. (2021), an experienced borrower that issued green bonds for more than 2 times, can enjoy an additional premium of about 44 bps. With experience, the issuer can more effectively use the proceeds and develop economies of scale and scope for their green initiatives, which boosts investors' confidence. Additionally, issuer's reputation is important for investors for building up their professional image. Therefore, these considerations can make investors more reluctant to finance the products by the experienced issues, especially for such novel debt instruments.

Given the abovementioned, we can come up with the following hypothesis:

H5: There is a higher greenium for issuers that have prior experience in issuing green bonds than those without prior experience

We will study the outlined hypotheses in both the primary and secondary corporate bond market, since a limited amount of authors revised them simultaneously. Although the primary market study can reflect pricing dynamics of green bonds. Meanwhile, the secondary market findings can reveal implications on "investors' revised evaluation of green bonds" (Hu et. al., 2022).

3. Data

This chapter describes the data used in this study to investigate the main research question. Specifically, we outline the process of data selection and transformation as well as discuss the final dataset used for the analysis.

3.1 Data selection and transformation

In order to conduct the research, this paper uses two sources of data, namely Bloomberg Terminal and Refinitiv Eikon. To begin with, the relevant samples of conventional and green bonds were retrieved from Bloomberg Terminal, widely used as a data source for other green bond-related studies as well, such as by Zerbib (2019) and Flammer (2020). This is a popular choice by researchers since Bloomberg labels bonds as "green" only if they are aligned with GBP. Therefore, unlabeled climate-aligned bonds are excluded from the search and the risk of greenwashing is minimized (Wulandari et al., 2018).

For choosing the bonds into the research sample, several filters were applied. First, we include bonds that are issued only by public companies in order to ensure the accessibility and quality of their financial and trading data. Second, the minimum issuance size is set at $200 million to reduce the noise in the data as well as confirm the minimum level of bond liquidity. Third, we filter for the bonds with fixed coupons for pricing standardization across the sample. Additionally, we exclude the bonds that have a rating of default. Lastly, we use the bonds issued between January 2014 and February 2023. The application of this criteria results in 5000 conventional and 714 green bonds.

Afterwards, we use Eikon to download data on the variables of interest for this research. For the primary market, we download the yield at issuance for each bond. For the secondary market, we retrieve the data on each bond’s monthly yields to maturity since their issuance till January 2023. Additionally, we also retrieve data on bond and issuer characteristics, such as coupon rate, issue and maturity dates, credit rating of the issuer, country of incorporation, currency, amount issued, industry, maturity type and debt type for all conventional and green bonds. Furthermore, we gather data on issuer’s ESG score at bond issuance and throughout the bonds’ outstanding years, number of green issuances by issuer and availability of green certification for green bonds.

As a starting point in filtering the data, outliers should be accounted for. Hence, we removed the bonds whose yields at issuance/to maturity and amount issued lie outside of 5th and 95th percentiles. Next, we also exclude the bonds that have unique characteristics either for traditional or green bonds, such as irregular maturity types, currencies and countries. Additionally, we removed the bonds with missing data on yields and other characteristic variables. In result, there are 657 green bonds and 4823 conventional bonds in the final sample in the period between 2014 and 2023. From Table 1, we can notice that more than 50% of green bonds in our sample are from 2021 and 2022.

Table 1: Green bonds sample distribution by year

This table shows the distribution of green bonds' issuance years within our sample and their statistics, such as frequency, percentage and corresponding average amount issued in 100 millions of US dollars.

Year	Obs.	%	Avg. Amt issued ($100mln)
2014	9	1.37	888.18
2015	5	0.76	1066.18
2016	13	1.98	828.45
2017	21	3.20	678.68
2018	25	3.81	635.46
2019	55	8.37	557.12
2020	84	12.79	571.70
2021	184	28.01	618.06
2022	243	36.99	746.86
2023	18	2.74	752.24
Total	657	100.00	672.22

3.2 Sample description

The descriptive statistics of the main variables for green and conventional bonds can be found in Table 2 below. It is noticeable that yields at issuance and to maturity of green bonds are lower than its plain-vanilla counterparties in the given sample. The amount issued for green bonds is lower because green projects are still in minority, which diminishes the amount of money that can be raised via green instruments. Furthermore, the standard deviation of amount issued for green bonds seems to be lower compared to those for conventional bonds. Last but not least, the longevity of green bonds is higher due to the substantial lifespan of green projects, such as developing alternative sources of energy and environmental pollution reduction.

Table 2: Descriptive statistics of the green and conventional bonds samples

The table presents descriptive statistics on the main variables of the samples for green and conventional bonds. The mean, median, maximum, minimum, standard deviation of the following variables are reported – yield at issuance, yield to maturity and coupon of bonds in percent, size of the issuance in 100 millions of US dollars, number of years before maturity.

	Green bonds					
	Obs.	Mean	Median	Std.Dev	Max	Min
Yield at issue (%)	657	2.85	2.81	1.66	10	0.04
Amount issued ($100mln)	657	672.22	556.95	573.15	7589.05	200
Tenor	657	7.87	5.55	8.16	101.15	0.43
Yield to maturity (%)	15,389	3.12	3.02	2.11	14.87	-4.37
Coupon (%)	657	2.80	2.75	1.66	10	0.05
	Conventional bonds					
	Obs.	Mean	Median	Std.Dev	Max	Min
Yield at issue (%)	4,832	3.52	3.47	1.72	12.01	0.005
Amount issued ($100mln)	4,832	997.61	750	809.48	17530.96	200
Tenor	4,832	6.91	4.24	8.39	99.72	0.12
Yield to maturity (%)	229,487	3.62	3.28	2.15	14.99	-2.1
Coupon (%)	4,832	3.48	3.44	1.72	12	0.005

For these descriptive statistics, we can compare them with similar studies that also investigate the greenium globally in the primary and secondary markets in recent years (Kapraun et al., 2019; Loffler et al., 2021; Zerbib, 2019). We find that the variables' statistics of this paper are similar to previous studies, but with varying magnitudes, which can be attributed to differences in the period and range of gathered datasets. Specifically, Loffler et al. (2021) and Zerbib (2019) suggest that green bonds' yields, coupons and amount issued are lower than those of traditional bonds, which also holds for our sample. On the other hand, Kapraun et al. (2019) report coupon rates and yields that are slightly higher, while tenor is shorter for green bonds compared to plain-vanilla bonds.

Next, we will review the data distribution for other bond and issuer-specific features in the gathered sample. From Table 3, we can see that the North American and European countries have the most of the green and conventional bonds in our sample, making up approximately 80% and 88% of the worldwide issuance respectively. Although, we notice that the percentage and average amount issued of green bonds are slightly higher for Europe by about 2% and $4mln as compared to North American green bonds issuance. Furthermore, it is noticeable that Asia is rapidly picking the trend of green investment with having 15% and $500mln issuance of green bonds and making the third-biggest continent in issuing green bonds in our sample.

Similarly, the distribution of issued bonds currencies in Apppendix A1, shows that about 88% of green and 94% of conventional bonds are denominated in EUR and USD respectively.

Table 3: Green and conventional bonds sample distribution by continents

This table shows the distribution of green and conventional bonds in our sample across geographical continents. It lists frequency, percentage and corresponding average amount issued in 100 millions of US dollars for bonds by continent.

	Green bonds			Conventional bonds		
	Obs.	%	Avg. amt issued ($100mln)	Obs.	%	Avg. amt issued ($100mln)
North America	255	38.81	711.62	3,096	64.07	1054.82
Europe	269	40.94	715.99	1,169	24.19	916.12
South America	10	1.52	531.50	140	2.90	683.60
Asia	105	15.98	501.34	330	6.83	897.77
Australia and Oceania	11	1.67	478.91	20	0.41	1384.25
Africa	7	1.07	622.73	77	1.59	832.64
Total	657	100.00	672.22	4,832	100.00	997.61

Next, Table 4 shows a breakdown of green and conventional bonds by industries according to BICS Level 1 in Bloomberg. The most frequent issuances are issued by financial institutions with 38% and 27% for green and traditional bonds correspondingly. The leadership of green bonds in this industry can be attributed to the increase of financial sector exposure to climate change and pollution risks. Hence, the development of green projects' investment can be a way to hedge them (Fatica et al., 2021). The second most popular industry for issuing green bonds is Utilities, where the environmental risks are at the core of their operations. The increased number of green projects need sufficient financing, therefore green bonds come as handy instruments for raising capital.

Table 4: Green and conventional bonds sample distribution by industry

This table shows the distribution of green and conventional bonds per industry in our sample. It lists the statistics, such as frequency, percentage and corresponding average amount issued in 100 millions of US dollars for the industry distribution. Industries are classified according to Bloomberg BICS Level 1.

	Green bonds			Conventional bonds		
BICS Level 1	Obs.	%	Avg. amt issued ($100mln)	Obs.	%	Avg. amt issued ($100mln)
Communications	15	2.28	851.31	400	8.28	1129.41
Consumer Dis.	35	5.33	674.57	667	13.80	810.36
Consumer Stap.	9	1.37	894.50	317	6.56	998.93
Energy	14	2.13	426.35	477	9.87	1046.21
Financials	252	38.36	584.46	1,309	27.09	954.04
Government	45	6.85	1524.17	129	2.67	2224.18
Health Care	4	0.61	718.75	317	6.56	1202.12
Industrials	28	4.26	416.82	348	7.20	851.39
Materials	28	4.26	599.37	345	7.14	743.08
Technology	15	2.28	733.01	264	5.46	1258.21
Utilities	212	32.27	627.61	259	5.36	814.01
Total	657	100.00	672.22	4,832	100.00	997.61

Then, Table 5 shows the distribution of issuers' S&P credit rating. Similarly to Flammer (2020), we categorized the gathered data on ratings by several scales, such as Prime (AAA), High (AA+, AA, AA-), Upper-medium (A+,A, A-), Lower-medium (BBB+, BBB, BBB-), Non-investment (not lower than CCC in our sample). Approximately, 90% of green and 80% of brown bonds have the investment-grade rating, which can be explained by the prior removal of outliers from the sample. Also, a high proportion of green bonds being of investment grade suggests the credibility of their issuers' for raising green financing.

Table 5: Green and conventional bonds sample distribution by issuers' credit rating scale

This table shows the distribution of green and conventional bonds in our sample according to the issuers' S&P credit rating. It lists frequency, percentage and corresponding average amount issued in 100 millions of US dollars for each category of issuer rating.

	Green bonds			Conventional bonds		
Issuer rating	Obs.	%	Avg. amt issued ($100mln)	Obs.	%	Avg. amt issued ($100mln)
Prime	82	12.48	1120.12	374	7.74	1502.46
High	91	13.85	532.48	492	10.18	1131.16
Upper-medium	205	31.20	649.42	1,434	29.68	1043.36
Lower-medium	218	33.18	616.97	1,537	31.81	949.10
Non-investment	61	9.28	552.62	995	20.59	750.80
Total	657	100.00	672.22	4,832	100.00	997.61

Table 6 represents the distribution of maturity types for the gathered bonds. About 60% of green bonds and 70% of non-green bonds are callable, meaning that the issuer can call the bond before its maturity. This can be advantageous for the issuer in case of the change in market conditions, such as lower interest rates or appearance of urgent funding needs. Given that green bonds have longer financing periods for environmental projects than traditional bonds, a callable option is useful for their issuers too.

Table 6: Green and conventional bonds sample distribution by maturity type

This table shows the distribution of green and conventional bonds in our sample per their maturity type. It lists frequency, percentage and corresponding average amount issued in 100 millions of US dollars for the bond-maturity type distribution.

	Green Bonds			Conventional Bonds		
Mty Type	Obs.	%	Avg. amt issued ($100mln)	Obs.	%	Avg. amt issued ($100mln)
At maturity	244	37.14	753.88	1,382	28.60	1123.15
Call/sink	14	2.13	547.83	29	0.60	954.36
Callable	393	59.82	630.22	3,370	69.74	948.59
Sinkable	6	0.91	392.42	51	1.06	859.36
Total	657	100.00	672.22	4,832	100.00	997.61

Table 7 presents the statistics on the debt type of bonds, such as secured and unsecured bonds. It shows that approximately 81% and 91% of green and brown bonds are unsecured, meaning that issuers do not pledge collateral for bondholders to secure them. The results are comparable with Loffler et al. (2021), where they find 86% green and 94% conventional bonds being unsecured. Given the aforementioned discussion on the industry and credit ratings, we can elaborate on our sample being overweight with unsecured bonds. Firstly, the majority of the companies in our sample operate in the industries with great access to capital markets and low physical assets, such as Financials, Governments, Technology, Communications. Secondly, issuers having high credit ratings have increased "faith and trust" of investors, therefore unsecured debt should not pose any problem for them. Additionally, the majority of green bonds can be unsecured due to the lack of collateral assets in environmentally-friendly projects, but also due to investors' appreciation of the benefits of green projects, not prioritizing the availability of collateral.

Table 7: Green and conventional bonds sample distribution by debt type

This table shows the distribution of green and conventional bonds in our sample by debt type. It lists frequency, percentage and corresponding average amount issued in 100 millions of US dollars for the bond-debt type distribution.

	Green Bonds			Conventional Bonds		
Seniority	Obs.	%	Avg. amt issued ($100mln)	Obs.	%	Avg. amt issued ($100mln)
Secured	124	18.87	619.68	437	9.04	817.70
Unsecured	533	81.13	684.44	4,395	90.96	1015.50
Total	657	100.00	672.22	4,832	100.00	997.61

Followingly, in the Appendix A2 and Appendix A3 we include the data distribution on variables relevant for green bonds analysis only. Overall, around 53% of the green bonds from our sample were externally verified as “green ones”. This percentage can be compared to Flammer (2020), which has 65% of green bonds certified by third parties. Next, 58% of all green bonds from our sample were issued by companies already having prior experience issuing these green instruments.

Moving forward, Appendix A4 shows that 55% of the issuers of green bonds in our sample have an ESG score, while it was 50% in Hachenberg and Schiereck (2018). Table 8 describes the ESG scores statistics of the green bonds issuers for the primary and secondary market. Specifically, the average ESG score of the borrower at the issuance was about 69 out of 100, which is comparable to the average score of 66 in Kapraun et al. (2019). Notably, the average bond volume was about $3mln higher for issuers that had ESG ratings. For the secondary market, the table displays the data on issuers’ ESG scores for the green bonds issued throughout the years. The average issuers’ ESG scores for the past 9 years vary from approximately 69 to 74. In the first years of the green bonds issuance, there were a few green bonds, consequently, a limited amount of issuers with ESG rating is reported for our sample. Nevertheless, the average ESG was quite high at that time. In the most recent years, the availability of issuers’ ESG ratings for the green bonds in our sample improves with the slight increase in the average ESG grade. Although, we can notice much lower minimum issuers’ ESG scores, which might be related to a higher amount of companies issuing green bonds, but also more stringent criteria and regulation around ESG scoring.

Table 8: Descriptive Statistics on the green bond issuers' ESG scores in primary and secondary market

The table presents descriptive statistics of issuers' ESG scores for green bonds in our sample for primary and secondary markets. The mean, median, maximum, minimum, standard deviation of the ESG score at issuance (primary market) and ESG scores between 2014 and 2022 (secondary market) are reported**.**

Variables	Obs	Mean	Std. Dev.	Median	Min	Max
			ESG score at primary market			
ESG score at issuance	210	68.93	14.99	72.75	16.98	95.44
			ESG score at secondary market			
	Obs	Mean	Std. Dev.	Median	Min	Max
ESG score 2014	4	72.66	12.26	68.03	64.11	90.48
ESG score 2015	6	74.07	11.59	71.56	60.26	89.04
ESG score 2016	11	69.8	11.74	70.51	46.87	85.69
ESG score 2017	18	69.16	10.16	69.10	50.54	89.98
ESG score 2018	21	72.43	8.06	72.74	53.81	88.73
ESG score 2019	37	71.74	13.17	73.41	17.44	91.98
ESG score 2020	37	74.08	11.93	73.91	26.74	90.77
ESG score 2021	112	72.72	11.61	74.44	34.25	95.448
ESG score 2022	364	74.02	20.74	80.87	10.43	95.46

4. Methodology

This part outlines the methodology that studies whether there is a green bond premium and what can possibly influence it. In detail, we use propensity score matching to determine the greenium and panel OLS regressions to extract its determinants.

4.1 Propensity Score Matching

To investigate the existence of a green bond premium, we cannot observe two identical bonds issued at the same time with one of them being green and the other being conventional. Therefore, we need to create factual and counterfactual groups with the usage of observational data. In order to ensure that the constructed treatment and control groups are comparable and we can isolate the "green label" effect, we use a matching method. Precisely, we employ PSM, which is often applied in similar research (Gianfrate and Peri, 2019; Hu et. al., 2022). Its practicality lies in the ability to construct balanced pairs between different groups and reduce their confounding bias (Burden et. al., 2017).

In the previous section we outline the structural differences between the green and conventional bonds in our dataset, such as amount issued, geography, currency, debt and maturity type, currency, industry and credit rating. Thus, matching conventional and green bonds based on their comparable traits will result in finding pairs with similar properties. By classifying green and conventional bonds as the treatment and control group respectively, the first step of PSM is to calculate a propensity score, which is the conditional probability of receiving the treatment based on implied control characteristics. The second step is to pair green and conventional bonds based on their estimated propensity score (Gianfrate and Peri, 2019). Lastly, an average treatment effect (ATE) is determined, which is the weighted difference between the matched green and conventional bonds.

According to Gianfrate and Peri (2019), several conditions need to be satisfied for PSM to work properly. First, the conditional independence assumption should be met, meaning that bond yields are independent of treatment being conditional on the propensity score. To ensure it, all features that affect the bonds yields and bond type must be observable. Second, the common support assumption should be ensured. This means that the sample should contain pairs of green and conventional bonds that have similar propensity scores. Third, similar propensity scores should be calculated from comparable observable characteristics. In other words, green and conventional bonds characteristics should not deviate too much from each other, i.e investment-grade and junk bonds should not have close propensity scores. The biggest constraint of PSM mainly concerns the first assumption, since it is impossible to fully remove bias relating to unobservable characteristics affecting the bonds yields.

In order to partially reduce the bias of matched pairs, we apply restrictions to the sample before implementing PSM. Specifically, we could restrict matching across each separate time interval and cross-sectional observation to limit the unobservable characteristics that can affect the bond yields in the panel dataset. In result, we could control for differences related to the market environment in a given period and unobservable firm characteristics, i.e. different investment strategies (Flammer, 2020). However, given the low number of observations of green bonds in the primary market, we decide to restrict matching over bonds issued both in the same industry and year, not issuer and year. Precisely, there are only 74 unique green bond observations across each issuer and year, which limits the analysis on the determinants of a potential green bond premium. Using OLS regressions with such a low number of observations can produce unreliable estimators and lead to biased results (Wooldridge, 2006). Additionally, even though matching by issuer is a more superior way to reduce the possibility of unobservable firm and issuer characteristics, there is a trade-off between the number and accuracy of matches. Increasing the observations with industry matching can avoid this problem and still be a good alternative for issuer matching.

Specifically, issuers in the same industry are likely to face similar economic and market impacts, regulatory requirements, have similar business structures, competition and creditworthiness, which partially controls for unobserved characteristics. For instance, according to Schwaab et. al (2017), about 31% of credit risk variation for corporations is explained by their industry characteristics. Furthermore, Zhou and Cui (2019) mention that issuance of green instruments for companies from the same industry is not random. For example, companies from the utilities sector naturally issue green bonds for funding green initiatives, while in communications they may be driven by regulatory and reputational risks as well as investors' demand. Hence, industry matching can account for such differences and reduce heterogeneity bias. Additionally, Wu et al. (2019) note that companies in their decision-making follow peer enterprises, including financial decisions. Their study concludes that companies issuing green bonds stimulate their industry peers to do the same, which decreases the green bond financing costs for the whole industry. For consistency and comparability of results, we perform the matching in the secondary market for bonds in both the same industry and month, but with a larger number of available monthly yield-to-maturity observations.

With these conditions in place, we employ a logit model that estimates the conditional probability of a bond being classified as green, based on a set of different observable characteristics. In line with previous research (Gianfrate and Peri, 2019; Loffler et al., 2021; Flammer, 2020; Zerbib, 2019), the control variables that represent these characteristics are the tenor, amount issued (in natural logarithm), issuer credit rating, maturity type and seniority of the bonds. As such, the probabilistic model is run on a dummy variable, which is equal to 1 if the issued bond is green and 0 if it is conventional, over variables that classify the different abovementioned matching characteristics. The resulting coefficients from the regression are the propensity scores that we use for the matching procedure.

There are several viable matching algorithms, but since the pre-matching criteria ensure that the bonds are compared in their respective industry and time period, for simplicity we will focus on using one matching approach, namely radius[1]. Radius matches the treatment group to the control group if their propensity score is within a certain predefined range (Gianfrate and Peri, 2019). By decreasing the radius on which bonds are matched, the quality of matching improves. For example, for the primary market we use a radius of 0.1, meaning that we match the green and conventional bonds if they have propensity scores within 0.1 of a difference from

[1] We used the "gmatch" package in Stata, which sets 1-to-1 matching more easily than other packages. However, for PSM it only uses radius approach.

each other. For the secondary market, we implement a radius of 0.001, since a higher number of observations with similar propensity scores allows for setting a more stringent criteria. With the final matched pairs, we estimate the ATE. The resulting variable determines whether the difference in yields is statistically significant and whether it is negative, showing an indication of the green bond premium. Furthermore, we will use the matched pairs for the regression analysis that studies what influences the outcome of the matching.

4.2 Regression analysis

In addition to studying the pricing of green bonds, this paper analyzes how other issuer and bond-specific features, such as region, ESG rating, experience in green bonds issuance as well as external certification, can affect the price differential between green and conventional bonds. Previously, we have outlined how the pairs of matched bonds with PSM are set. This results in a panel of paired bonds that vary across time and issuer. From this, we construct a panel dataset, determined by the yield differential ($\Delta\tilde{y}_{i,t}$), which subtracts the yields of the matched green ($y_{i,t}^{GB}$) and conventional bonds ($y_{i,t}^{CB}$) as follows:

$$\Delta\tilde{y}_{i,t} = y_{i,t}^{GB} - y_{i,t}^{CB}, \qquad (2),$$

where $y_{i,t}$ refers to bond's yield at issue for the primary market and yield-to-maturity for the secondary market analysis. A negative (positive) yield differential means that the green bond is priced at premium (discount) compared to its matched brown counterparty.

After determining the yield differential for the matched pairs' sample, we will use it as the dependent variable in regression analysis for every hypothesis. In detail, we will carry out the panel regressions using fixed effects, as it can control for factors that vary both across time and cross-sectionally (Wooldridge, 2006). Specifically, where possible, we will use fixed effects in the primary market to control for the issuer and issuance year. For the secondary market, we will use fixed effects to control for the issuer and month due to the availability of monthly yield observations.

For the research questions, the variables that are potential determinants of the yield differential and will be used in the regressions are described in Appendix B1.

Additionally, we include a set of control variables consisting of issuer and bond characteristics in order to account for potential heterogeneity across the bonds and reduce omitted variable bias (Hu et al., 2022). The control variables consist of tenor, amount issued (in natural log), issuer rating, maturity type and seniority of the bonds, similar to what was used in the matching process.

Starting with the second hypothesis, in order to determine the regional impact on green bond premium, as well as the combination of time-varying and region-specific effects, we estimate the following fixed-effects regression models:

$$\Delta\tilde{y}_{i,t} = \beta_0 + \beta_1 EU_{i,t} + \gamma Controls_{i,t} + \lambda_t + \varepsilon_{i,t} \quad (3),$$

$$\Delta\tilde{y}_{i,t} = \beta_0 + \beta_1 EU\_14_{i,t} + \beta_2 EU\_15_{i,t} + \beta_3 EU\_16_{i,t} + \beta_4 EU\_17_{i,t} + \beta_5 EU\_18_{i,t} + \beta_6 EU\_19_{i,t} + \beta_7 EU\_20_{i,t} + \beta_8 EU\_21_{i,t} + \beta_9 EU\_22_{i,t} + \gamma Controls_{i,t} + \lambda_t + \varepsilon_{i,t} \quad (4),$$

where in equation 3, EU is a dummy variable equal to 1 if an issuer is based in a EU country or 0 if in the US, and Controls contain the set of above mentioned control variables. In equation 4, the variables EU_Year consist of the EU dummy variable multiplied by a dummy variable for the respective year. The variable $\lambda_t$in both equations is the time-fixed-effects indicator, which involves year and month as time fixed effects for the primary and secondary markets respectively. We do not use cross-sectional fixed effects for testing this hypothesis, because they allow for the intercept to vary across entities and not over time (Wooldridge, 2006). Since the region of the issuer is constant across time, the dummies would be omitted.

For the third hypothesis, we use the following regression to study the effects of external certification on the yield differential:

$$\Delta\tilde{y}_{i,t} = \beta_0 + \beta_1 \, External\ Certification_{i,t} + \gamma Controls_{i,t} + \lambda_t + \mu_i + \varepsilon_{i,t} \quad (5),$$

where Certification is a dummy variable equal to 1 if the issued bond has received an external certification at the given period and 0 otherwise for equation 5. In this instance, both time and issuer fixed effects can be used, as bond certification can vary across time and issuer.

For the fourth hypothesis, the following regressions will be run in order to study the effects of issuer's ESG rating and their scores on the yield differential:

$$\Delta\tilde{y}_{i,t} = \beta_0 + \beta_1 ESGRating_{i,t} + \gamma Controls_{i,t} + \lambda_t + \varepsilon_{i,t} \quad (6),$$

$$\Delta\tilde{y}_{i,t} = \beta_0 + \beta_1 ESGScore_{i,t} + \gamma Controls_{i,t} + \lambda_t + \mu_i + \varepsilon_{i,t} \quad (7),$$

where in equation 6, ESG Rating is a dummy variable equal to 1 if the issuer has an ESG rating and 0 otherwise. For this regression, we will only use time fixed effects for both primary and secondary markets, for the same reason as in equations 3 and 4. In equation 7, ESG Score represents the ESG Score of an issuer, where available, and ranges from 0 to 100. For the primary market, this variable is based on the issuer's ESG score at bond issuance, so we use time fixed effects for the same reason as in equation (3). Meanwhile, this score can vary yearly, which is why use both issuer and time fixed effects for the secondary market analysis, For the fifth hypothesis, in order to determine whether experience in green bond issuance has an effect on the yield differential, we use the following regression:

$$\Delta\tilde{y}_{i,t} = \beta_0 + \beta_1 Experience_{i,t} + \gamma Controls_{i,t} + \lambda_t + \varepsilon_{i,t} \quad (8)$$

where Experience is a dummy variable equal to 1 if the issuer has issued a green bond prior to the observed issuance and 0 if it is the first green issuance. We only use time fixed effects in the primary market, since after the issuer's first green bond issuance, the dummy variable will be equal to 1 for the rest of the observations in the data, so issuer fixed effects are irrelevant. However, we argue that joint (time and issuer) fixed effects can present a more realistic picture for the secondary market yield differentials. The availability of monthly time series, controlling for both a given period of time and issuer, would provide a slightly higher variability in our dummy variable, because there are more unique observations that are accounted for in the coefficient estimate.

Lastly, the results section will provide separate, as well as joint outcomes of the time and issuer fixed effects where available for both primary and secondary markets. To increase the validity of our results, we will use robust standard errors for our regression results.

5. Results and Discussions

This section outlines the findings of the conducted research according to the steps described above. First, we will elaborate on the question whether there is a "greenium" effect for the green bonds as compared to traditional bonds. Second, we will discuss how the region, ESG ratings, external verification and experience of green bond issuance can affect the green bond premium.

5.1 Greenium

In order to obtain matching results, we firstly estimate the propensity scores of control variables by using a logit model, as discussed in the methodology. Table 9 reports the results for both primary (a) and secondary (b) markets. In both markets, a larger issued amount indicates a lower likelihood of a bond being classified as green, while tenor has a negative but close to 0 influence. Additionally, it is more likely for green bonds to have Prime (AAA)-rated issuers relative to other ratings for both markets. Lastly, callable bonds are less likely to be issued as green and there is a high probability of issuing secured green bonds over unsecured ones. Overall, although we use a logit model for the purpose of propensity score estimation, at this stage it also suggests the factors associated with the green bonds issuance.

Table 9: Estimation of the probability of the treatment effects

This table shows the regression results of the logit regression on the probability of the bond being green for primary and secondary markets analysis. The dependent variable is a dummy, where 1 is green bond and 0 otherwise. Independent variables - natural logarithm of Amount issued, Tenor, Secured is a dummy if the bond is backed with collateral, Prime, High and Upper Medium are dummies if the bond's issuer has High, Prime and Upper Medium S&P credit rating respectively, Callable is the dummy if the bond is callable, 0 if not. Standard errors are reported in the parentheses. The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively.

	Primary market	Secondary market
	(a)	(b)
Tenor	0.021***	0.014***
	(0.005)	(0.001)
Amount issued ($100mln)	-1.222***	-1.208***
	(0.081)	(0.016)
Prime	0.649***	0.702***
	(0.139)	(0.029)
High	0.983***	1.326***
	(0.150)	(0.027)
Upper-medium	0.429***	0.399***
	(0.103)	(0.021)
Callable	-0.393***	-0.131***
	(0.094)	(0.018)
Secured	0.829***	1.083***
	(0.116)	(0.023)
Constant	22.539***	21.388***
	(1.634)	(0.319)
Observations	5,480	244,876

After determining the propensity scores, we implement the PSM method in combination with the pre-matching characteristics, so that matching is performed on bonds from the same industry and year for the primary market, and bonds from the same industry and month for the secondary market. Table 10 shows the descriptive statistics for the matching results in both markets. The primary market findings show a negative and significant ATE of -41 bps for 446 pairs of matches, suggesting a negative green bond premium on the yield at issuance. Similarly, we find a negative and significant ATE of -61 bps with a total of 11,320 matches for the secondary market, which implies a negative green bond premium for the monthly yields-to-maturity. There is a noticeable difference between the number of matched pairs in both markets, despite the use of a more stringent radius of 0.001 in the secondary market sample versus 0.1 in the primary one. The difference between both matching outcomes is reasonable, considering that the total number of monthly observations in our secondary market sample is at 250,000.

Table 10: Results of Propensity Score Matching between green and conventional bonds

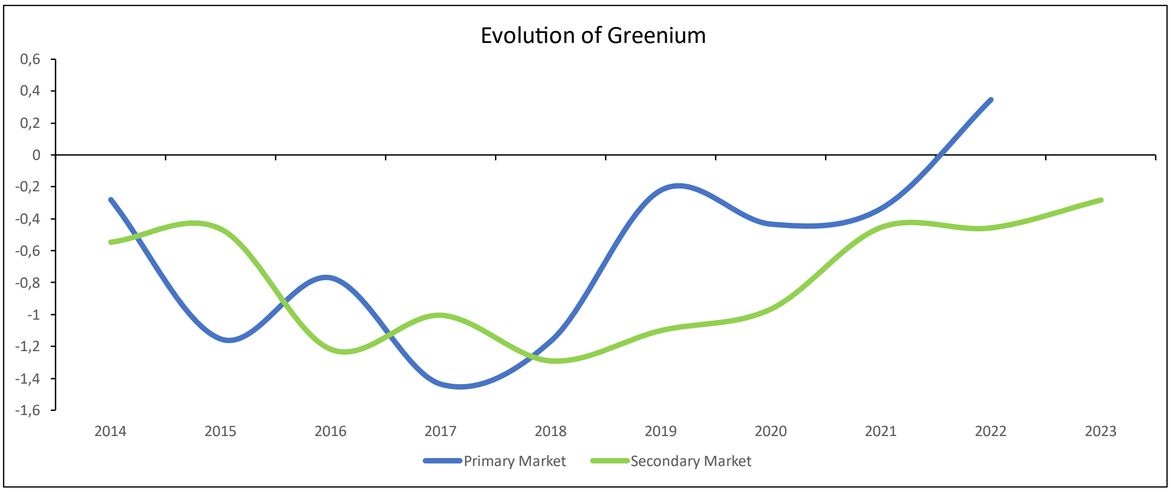
This table reports the results of the PSM for primary (a) and secondary (b) markets. We employ the radius matching approach of 0.1 and 0.001 for the primary and secondary markets respectively. ATE is the average treatment effect, which is the the weighted difference between the matched green and conventional bonds.The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively.

	Primary Market (a)	Secondary Market (b)
ATE	-0.41***	-0.61***
Standard Error	0.13	0.03
Number of matches	446	11,320

To further study the price differential, we plot the evolution of the greenium over time for both primary and secondary markets in Figure 1. We see a negative green bond premium with similar magnitude in both markets, reaching levels close to -150 bps for the period from 2014 to 2018. The explanation of the negative premium may lie in the investors' persistent demand and commitment for responsible and sustainable financing (Zerbib, 2019). Given this, they are accepting the costs of their environmental preferences with lower yields of green bonds compared to their traditional counterparties. However, there is a noticeable shift in the results after 2020, where the primary market yield differentials reach even positive values, while in the secondary market, they approximate close to 0 but still remain negative, partially explaining the 20 bp difference between the ATEs from Table 10.

Figure 1: The evolution of the green bond premium in the primary and secondary markets

This graphs represents the evolution of green bond premium between 2014 and 2022 for our primary (blue) and between 2014 and 2023 for secondary (green) sample. For this, we use ATEs produced by PSM to depict the difference between green and conventional bonds in a given year. If the difference is below 0, then green bonds are traded at premium compared to conventional bonds.



When comparing the outcomes in both markets with previous research, we find mixed results. Gianfrate and Peri (2019) show a negative premium in both primary and secondary markets with -20 bps and -12 bps respectively, which is opposite to our comparison. Loffler et. al. (2021) observe similar differences, but point out that the greenium in the secondary market is significant and highly negative for samples after 2017. On the other hand, Hu et al. (2022) find a -19 bps and -28 bps greenium in both primary and secondary markets respectively. Although green bond research is still in its infancy, these recent papers provide some evidence leading to a higher greenium in secondary markets. Furthermore, our findings can be attributed to the irregular market conditions caused by the COVID-19 pandemic, leading to severe price distortions in the corporate bond market (Yang, 2021). In addition, different developments in recent years contribute to changes in the green bond market. Namely, the relative increase of green bond issuance throughout the years, rise in demand and variety of market participants across wider ranges of sectors, as well as more dispersed credit ratings of borrowers and green instruments themselves can impact the magnitude of the greenium between primary and secondary markets (Bigley et al., 2022; CBI, 2022; Duguid, 2022).

Lastly for our matching, we perform a balance check to see if the observable characteristics of our green and conventional bonds have no systematic differences after matching, according to the third assumption of the PSM method as described in the methodology (Gianfrate and Peri, 2019). In Appendix C1 and C2 show the balancing tests for both primary and secondary markets' results. For the former one, the majority of our control variables are not significant after matching, hence the means between the green and conventional bonds are not statistically different than 0. This is not the case for the variables of tenor, amount and the upper-medium rating classifier. Since they are significant, it would suggest that the means between their coefficients for green and conventional bonds are statistically different, so these controls were not effective in the matching process. Nevertheless, Rubin's B is at 23.9, lower than 25% and inside the range of 0.5 and 2, which would suggest that the overall balancing property is satisfied. As for the secondary market results, we have similar results, except that here Seniority is also statistically significant after matching. However, Rubin's B is at 24.2, suggesting that the overall balancing property is still satisfied. In conclusion, the balancing tests for both samples show that in general a good balancing property.

With these results in mind, we can progress to study the determinants of the greenium that we observe in both primary and secondary markets.

5.2 Determinants of the greenium

In this section, we will study how regional-effects, external certification, issuer's ESG ratings and experience of issuing green bonds can influence the green bond premium. As outlined in the methodology, we will use fixed-effects OLS regressions for the matched sample, where the yield differential between green and conventional bonds will be regressed on the above mentioned determinants. Additionally, we use control variables representing bond and issuer characteristics for each regression. Notably, we drop bond observations that are issued by the same issuer in a given time period in our panel dataset, so that there are duplicates per period, otherwise it would not allow us to use fixed effects properly.

First, we begin our analysis for regional effects in line with Hypothesis 2a, where we compare the greenium between EU and US bonds. Table 11 presents the results, where we estimate the fixed-effects OLS panel regression of bonds' yield differential on EU, a dummy variable equal to 1 if the bond is issued in the EU and 0 if it is issued in the US. The dependent variable is the yield differential based on the yield at issue or the monthly yield to maturity for the primary (a) and secondary (b) markets respectively. As explained in the methodology, we use time fixed effects only for this regression. Notably in Table 11, we report the set of issuer and bond characteristics that we control for in all further regressions.

Table 11: Fixed-effects OLS regressions of EU- versus US-regional influence on the yield differential of green and conventional bonds

The table presents results of fixed-effects OLS regressions of the yield differential of green and conventional bonds on the region. The dependent variable is yield differential for primary market (a) and secondary market (b). For the independent variables - variable EU is a dummy which takes value of 1 if the bond was issued in the EU or in the US; Control variable - natural logarithm of Amount issued, Tenor, Secured is a dummy if the bond is backed with collateral, Prime, High and Upper Medium are dummies if the bond's issuer has High, Prime and Upper Medium S&P credit rating respectively, Callable is the dummy if the bond is callable, 0 if not. Time fixed effects are yearly for the primary market and monthly for the secondary market. The use of time, issuer or both fixed effects as well as standard errors are reported in the parentheses. The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively.

	Primary market (a)	Secondary market (b)
EU	-0.495*	-0.730***
	(0.253)	(0.077)
Tenor	-0.006	0.055***
	(0.022)	(0.004)
Amount issued ($100mln)	-0.279	-0.642***
	(0.215)	(0.076)
Secured	0.827**	0.554***
	(0.333)	(0.122)
Callable	0.665**	0.682***
	(0.312)	(0.099)
High	-0.487	-1.019***
	(0.312)	(0.093)
Upper_medium	-0.454	-0.366***
	(0.335)	(0.083)
Constant	5.772	14.082***
	(4.481)	(1.565)
Issuer FE	No	No
Time FE	Yes	Yes
Observations	295	6,174
R-squared	0.237	0.164

Note: Prime ratings were dropped due to collinearity.

Describing the results, the EU coefficient is negative at -0.495 and statistically significant at the 10% level for primary market, indicating that by controlling for a given year across all issuers, EU-issued bonds exhibit greenium, which is 49.5 bps higher than those issued in the US. As for the secondary market findings in column (b), the EU coefficient is negative at -0.73 and statistically significant at the 1%. Thus, controlling for a given year across all issuers, bonds issued in the EU have a 73 bps higher greenium than their US counterparty. According to these two regressions, the secondary market sample has more statistically significant results due to considerably lower standard errors, which can be attributed to the higher number of observations. However, the R-squared in the secondary market is 0.164, while it is 0.237 in the primary market, meaning that the model does better to explain the variation in the yield differential for the latter. Indeed, a higher number of observations would need a better specified model to explain the variation in the yields of the secondary market. Based on the abovementioned results, we reject the null hypothesis and conclude that there is a difference between the greenium of EU and US-based bonds.

There could be several explanations for the green bond premium differential between 2 regions. Firstly, it can be related to the economic patterns of the US and EU, such as long-term interest rates, inflation, market volatilities etc. Secondly, more developed legalization, verification, regulation and promotion of green financing instruments in the EU comes with enhanced issuers' transparency and investors' confidence, which lowers the borrowing costs (Eliwa et al., 2019). Lastly, cultural aspects may influence the yield differential. According to Hinsche (2021), European investors have higher altruism levels than US investors, which makes them more willing to obtain green bonds even with lower yields, but for the purpose of preserving the environment and fighting global climate change.

Moving to Hypothesis 2b, we further study whether there are time-effects on the greenium for EU-based bonds due to introduction of sustainability and green financing legislative documents. Table 12 shows the regression results for both primary (a) and secondary (b) markets, where we regress the same yield differentials on the independent variables ranging from EU_2014 through EU_2023, which are dummies equal to 1 if a bond is issued both in the EU and in the respectively indicated year and 0 if it is issued either in the US, or in a different year than indicated, or both. In the primary market, most of the coefficients are negative, suggesting that the European green bonds have a higher premium than US ones. However, they are not statistically significant, except for EU_2022, which equals to -1.473 and is statistically significant at the 1%. This suggests that European bonds issued in 2022 have a greenium that is 147.3 bps higher than their US counterparty. The results for the primary market are misleading due to the inflated standard errors before 2022, where we still observe high coefficients. This can be attributed to the increased dimensionality of our model by including the above mentioned dummy variables and a lower number of observations results in extremely high standard errors.

For the secondary market findings, we find that all coefficients are highly negative and statistically significant, except for EU_2023. Furthermore, the values of the coefficients are distinct from each other, where in earlier years we observe variations in the greenium, slowly increasing and reaching their peak in 2018. Particularly, the greenium of European bonds are on average 238.7 bps higher than their US counterparty in 2018. On the other hand, in recent years the greenium for European bonds decreases, such as a drop of around 50 bps from 2021 to 2022. This behavior is in line with the observed decreasing greenium in Figure 1 for the secondary market in general, which provides further evidence that European bonds are mainly driving the greenium.

Table 12: Fixed-effects OLS regressions on the EU green bond premium through 2014-2023

The table presents results of fixed-effects OLS regressions of yield differential between green and conventional bonds on the EU greenium. The dependent variable is yield differential for primary market (a) and secondary market (b). For the independent variables - variable EU_year is a dummy which takes value of 1 if the bond was issued in the EU and in certain year, and 0 if the bond was either issued in the US, or in a different year, or both; Control variables are the same as in Table 11. Time fixed effects are yearly for the primary market and monthly for the secondary market. The use of time, issuer or both fixed effects as well as standard errors are reported in the parentheses. The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively.

	Primary market (a)	Secondary market (b)
EU_2014	-0.413	-0.519**
	(1.228)	(0.251)
EU_2015	-0.993	-1.751***
	(1.654)	(0.199)
EU_2016	0.413	-0.798**
	(1.278)	(0.346)
EU_2017	-0.933	-1.213***
	(0.710)	(0.217)
EU_2018	0.111	-2.387***
	(0.838)	(0.189)
EU_2019	0.275	-1.915***
	(1.021)	(0.156)
EU_2020	-0.398	-0.719***
	(0.597)	(0.177)
EU_2021	-0.590	-0.802***
	(0.383)	(0.139)
EU_2022	-1.473***	-0.289**
	(0.549)	(0.114)
EU_2023		-0.156
		(0.329)
Constant	6.183	11.685***
	(4.499)	(1.578)
Controls	Yes	Yes
Issuer FE	No	No
Time FE	Yes	Yes
Observations	295	6,174
R-squared	0.240	0.154

Note: EU_2023 gets omitted in primary market analysis.

The high greeniums in certain years can be attributed to the different legislative developments in the EU. Firstly, the Non-Financial Reporting Directive that guidelines companies on the disclosure of their ESG-related information was issued at the end of 2014. Therefore, the issuing companies become more transparent in their environmental-protective activities. As a result, EU investors can easily make judgments of environmental impact of green bonds by such issuers, which make their funding less risky and can lower the yields. We can link this explanation to a jump in the EU greenium in 2015 as a lagging effect considering the period at which the Directive was issued. Similarly, we can explain the high magnitude of the greenium in 2018. Guidelines on non-financial reporting, as an amendment to the Directive, were implemented by the European Commission in 2017 in order to disclose ESG data in a more enhanced and comparable way (EC, 2017). The active and consistent ESG disclosure by companies was spread to investors, which increased their positive sentiments about green bonds. Furthermore, the coefficient for the EU in 2019 is also significantly high, at -191.5 bps relative to its US counterparty. The European green bond standard was created in 2019 in order to provide transparency and reliability for green investing tools. Hence, we acknowledge its influence for the high greenium at that time. Lastly, we see that the coefficient for the EU in 2021 suggests a green bond premium that is 80 bps higher than in the US, which is the opposite to Figure 1, where we already see a large decrease in the secondary market greenium. This can be associated with the Taxonomy Regulation that was introduced in 2021 and aims to outline which company's activity is sustainable and environmentally-friendly. This document helps investors to determine whether the activity they want to finance aligns with environment-protection principles. Additionally, its ultimate goal is to increase green financing in the EU. Therefore, this can contribute to the significantly lower yields of EU green bonds in 2021 and consequently higher green bond premium.

Considering our results for the regional effects on the greenium, we can proceed with the additional determinants by first studying the effect of external certification on the green bond premium, which is in line with our third hypothesis. Table 13 below shows the fixed-effects OLS panel regressions of bonds' yield differential for primary (Panel A) and secondary (Panel B) markets on Certification, a dummy variable equal to 1 if the bond was externally reviewed for the given period and equal to 0 otherwise. We perform fixed effects both across time and cross-sectionally separately and jointly, which allows us to determine whether the availability of external certification has an effect over the green bond yields for a given period and issuer.

Table 13: Fixed-effects OLS regressions of the external certification influence on the green bond premium

The table presents results of fixed-effects OLS regressions of the yield differential of green and conventional bonds on the availability of external classification. The dependent variable is yield differential for primary market (Panel A) and secondary market (Panel B). For the independent variables - variable Certification is a dummy which takes value of 1 if the bond was externally verified as being green and 0 otherwise; Control variables are the same as in Table 11. Time fixed effects are yearly for the primary market and monthly for the secondary market. The use of time, issuer or both fixed effects as well as standard errors are reported in the parentheses. The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively.

Panel A: Primary Market			
Certification	-0.476	-0.098	0.555
	(0.298)	(0.868)	(0.816)
Constant	-1.382*	3.625**	1.318
	(0.770)	(1.522)	(1.448)
Observations	381	381	381
R-squared	0.266	0.042	0.327
Controls	Yes	Yes	Yes
Issuer FE	No	Yes	Yes
Time FE	Yes	No	No
Panel B: Secondary Market			
Certification	-0.142*	0.840	0.798
	(0.086)	(0.735)	(0.729)
Constant	-1.930***	-1.487**	8.158
	(0.145)	(0.640)	(9.937)
Observations	8,033	8,033	8,033
R-squared	0.114	0.017	0.067
Controls	Yes	Yes	Yes
Issuer FE	No	Yes	Yes
Time FE	Yes	No	No

From the primary market results (Panel A), the Certification coefficient is negative when considering time and issuer fixed effects. Furthermore, it is positive when controlling both for time and issuer heterogeneity. However, these coefficients are not statistically significant, suggesting that the yield differentials of externally certified bonds are not significantly different relative to regular bonds. On the other hand we observe negative and significant results only when controlling for time in the secondary market (Panel B). This implies that by controlling for a given month across all issuers, externally certified bonds have a greenium that is 14.2 bps higher than for non-certified bonds. For this case, we reject the null hypothesis and conclude that external certification has a significant effect on the greenium. However, issuer and joint fixed effects lead to positive results, suggesting the opposite, despite that they are not statistically significant. In conclusion, excluding the case where we control for time in the secondary market, our results cannot support our hypothesis.

Despite the differences between both markets, our results have similarities with previous literature, however, it is worthwhile to mention that these studies are not fully comparable due to the use of different samples and methodologies. For the primary market, Fatica et. al. (2021) find further evidence that in general, institutions do not place higher premiums on certified green bonds. However, when they divided the sample for financial and non-financial institutions, the latter ones exhibited higher premiums. Bachelet et al. (2019) found in the secondary market that certified green bonds have a higher premium that non-certified ones. In line with our results for time fixed effects, this can be explained by investor sentiment derived from enhanced credibility of bonds' environmental proceeds in secondary market trading. This leads to the increased investors' demand and therefore attribution of higher premiums on certified bonds. On the other hand, a lack of certification can be concerning for investors due to lower transparency and the potential of greenwashing.

Next, we study the effect of ESG ratings on the green bond premium, in line with hypothesis 4a and 4b. Table 14 below shows the fixed-effects OLS panel regressions of bonds' yield differential for primary (a) and secondary (b) markets on ESG_Rating, a dummy variable equal to 1 if the issuer has an ESG rating and 0 otherwise. In this instance we use time fixed effects for the regressions, as described in the methodology. We can see that the coefficients are negative, suggesting that the yield differential for bonds with ESG ratings have higher green premiums. However, since the results are not significant for the primary market sample, we fail to reject the null hypothesis. The results for the secondary market sample are significant, suggesting that when controlling for time, bonds with issuer's ESG ratings have greeniums that are 15 bps higher than those issued by borrowers without a rating. We find some similarities with the results in the literature. In general, the availability of issuer's ESG ratings generally leads to a higher green bond premium, as it signals about the credibility of the issuers, which reduces information asymmetry and risks of greenwashing (Hachenberg and Schiereck, 2018).

Table 14: Fixed-effects OLS regressions of the issuer's ESG rating influence on the green bond premium

The table presents results of fixed-effects OLS regressions of the yield differential of green and conventional bonds on the availability of issuer's ESG rating. The dependent variable is yield differential for primary market (a) and secondary market (b). For the independent variables - variable ESG_Rating is a dummy which takes value of 1 if the bond's issuer has ESG rating and 0 if not; Control variables are the same as in Table 11. Time fixed effects are yearly for the primary market and monthly for the secondary market. The use of time, issuer or both fixed effects as well as standard errors are reported in the parentheses. The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively.

	Primary market (a)	Secondary market (b)
ESG_Rating	-0.260	-0.151**
	(0.227)	(0.063)
Constant	0.659	7.930***
	(4.438)	(1.476)
Issuer FE	No	No
Time FE	Yes	Yes
Observations	381	8,033
R-squared	0.237	0.189

Proceeding with hypothesis 4b, Table 15 below shows the fixed-effects OLS panel regressions of bonds' yield differential for primary (a) and secondary (b, c, d) markets on ESG_Score, a variable that ranges from 0 to 100 indicating the ESG score of an issuer. This variable is the issuer's ESG score at bond issuance for the primary market analysis, while for the secondary market we use the ESG scores that vary for the bond over the years for a given issuer. As outlined in our methodology, we apply time fixed effects for the primary market sample, while we simultaneously use time, issuer and joint fixed effects for the secondary market. Overall, we can see that the ESG score coefficients are very low in both markets. Notably, the coefficient is positive in the primary market, although it is not statistically significant.

Meanwhile, the results are mixed in the secondary market. When we control for a given period across all issuers, if the issuer's ESG score goes up by 1, this leads to a significant 0.4 bp increase in the green bond premium. However, when we control for a given issuer across all periods, an increase in the issuer's ESG score of 1 implies a significant 1 bp decrease in the greenium. For joint fixed effects, the score coefficient is positive, but not statistically significant. Considering these results, the effect of ESG scores on the greenium is inconclusive and we cannot support our hypothesis. In the literature, Immel et al. (2021) find that higher ESG scores lead to significantly higher greeniums between 6-13 bps, contributing to a rise in demand for green bond trading due to higher credibility of their issuers. Since we only see similar results in one instance of our regressions, we cannot argue that higher ESG scores contribute to a reduction in information asymmetry.

Table 15: Fixed-effects OLS regressions of the issuer's ESG score influence on the green bond premium

The table presents results of fixed-effects OLS regressions of the yield differential of green and conventional bonds on the issuer's ESG score. The dependent variable is yield differential for primary market (a) and secondary market (b, c, d). For the independent variables - ESG_Score is the issuer's ESG score between 0 and 100; Control variables are the same as in Table 11. Time fixed effects are yearly for the primary market and monthly for the secondary market. The use of time, issuer or both fixed effects as well as standard errors are reported in the parentheses. The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively.

	Primary market (a)	Secondary market (b)	Secondary market (c)	Secondary market (d)
ESG_Score	0.007	-0.004***	0.010***	0.005
	(0.011)	(0.001)	(0.003)	(0.003)
Constant	6.074	18.722***	8.918	14.019
	(6.760)	(1.481)	(9.172)	(9.906)
Issuer FE	No	No	Yes	Yes
Time FE	Yes	Yes	No	Yes
Observations	210	8,033	8,033	8,033
R-squared	0.224	0.108	0.026	0.049

Lastly, we analyze how experience in issuing green instruments, that is a first or repetitive issuance, can influence the green bond premium in both primary and secondary markets. We estimate the fixed effects OLS panel regression of bonds' yield differential on Experience, a dummy variable equal to 1 if it is the issuer's green bond issuance and 0 if there were prior issuances. The dependent variable is the yield at issue or the monthly yield-to-maturity in the primary and secondary market respectively. We conduct these regressions with time fixed effects for the primary market and joint fixed effects for the secondary sample, as outlined in the methodology. Table 16 presents the results.

Table 16: The fixed-effects OLS regression of the experience of issuing green bonds on green premium

The table presents results of fixed-effects OLS regressions of the yield differential of green and conventional bonds on issuer's experience in issuing green bonds. The dependent variable is yield differential for primary market (a) and secondary market (b). For the independent variables - Experience is a dummy variable which takes value of 1 if the bond's issuer had prior green issuances and 0 if not; Control variables are the same as in Table 11. Time fixed effects are yearly for the primary market and monthly for the secondary market. The use of time, issuer or both fixed effects as well as standard errors are reported in the parentheses. The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively.

	Primary market (a)	Secondary market (b)
Experience	-0.576**	-0.004***
	(0.222)	(0.000)
Constant	-0.284	14.998
	(0.584)	(9.405)
Issuer FE	No	Yes
Time FE	Yes	Yes
Observations	381	8,033
R-squared	0.237	0.056

The primary market findings suggest that issuing multiple green bonds can be associated with lower yields of green bonds. Specifically, the Experience coefficient is -0.576 and statistically significant at the 1% level, which means that by controlling for each year across all issuers, the repetitive issuance of green bonds increases the greenium by about 58 bps. This result can be compared to Fatica et al. (2021), where they find that green bonds issued by experienced borrowers significantly increase yield differential in the primary market by 44 bps. This premium can be a result of reputational effects. By issuing multiple green bonds, issuers are perceived to be more reliable and transparent by investors in terms of alignment of their products with environmental purposes. Additionally, borrowers can negotiate better terms of issuance with underwriting institutions, which lower the costs.

Meanwhile, in the secondary market, we can see that the Experience coefficient is equal to -0.004, however it is still significant at the 1% level. Given the structure of our secondary market data and the classification of this dummy variable, we would not expect a large deviation in our results. Based on this, we can deduce that by controlling for a given month and issuer, the repetitive issuance of green bonds increases the green bond premium by about 0.4 bps. The difference between both samples can also be attributed to the fact that in the primary market, the issuer has more information about the green bond, its risks and use of proceeds, than investors. Therefore, availability of prior issuer's experience is more valuable for investors to ensure the integrity of green instruments. On the other hand, since in the secondary market investors can access more information regarding green bonds, the effect of experience on greenium is negligible.

In summary, our results provide valuable insights on the existence of the greenium and its determinants. We observe significant differences between the greeniums in the EU compared to the US, partially explained by the more developed regulatory frameworks that support sustainable investing in the EU. Next, the findings on the effect of external certification provide mixed results that are not significant, except for the instance of using time fixed effects in the secondary market sample, where we observe a positive effect on the greenium for externally certified bonds. However, when we control for both issuers and time, we find a negative influence, although it is not significant. Therefore, the relationship between external certification and the greenium is ambiguous. Furthermore, ESG ratings positively affect the greenium, but they are only significant for the secondary market sample. On the other hand, ESG scores provide mixed results that are not of marginal effect. Lastly, experience in green bond issuance leads to a positive effect on the greenium, which has a high influence in the primary market, but has a negligible impact in the secondary market.

6. Conclusion

Environmental issues have become an integral part of financial decision-making. Since governments alone cannot support initiatives at protecting the environment and battle climate change, the role of corporations cannot be overestimated. Green bonds have become one of the financial tools to fund such projects with the exponentially increasing interest from investors. Although, given their infancy and novelty, the economic benefits of green bonds compared to traditional ones are still questionable. The academic research about the existence of a greenium is mixed. Due to this ambiguity, but growing interest in green financial instruments, we have decided to continue the line of existing research that can be beneficial for investors, issues, policymakers and society.

With a sample of 5000 conventional and 657 green bond observations between 2014 and 2023, we isolate the greenium by using the PSM method and create matched samples. Our findings have shown strong evidence of greenium existence in primary and secondary markets. Hence, we can say that green bonds enjoy lower yields rather than their conventional counterparties and trade at premium. We can associate this with the environmental benefits and growing popularity of green bonds, therefore investors are willing to sacrifice higher yields for noble reasons.

Additionally, we study the determinants for green bond premium, such as region, ESG rating, external verification and experience in issuing green bonds. Firstly, green bonds in the EU trade at higher negative premiums than in the US, which we associate with a more developed EU legislative landscape, as well as higher levels of altruism. Moreover, we show that there are time-varying effects for secondary market green bond premiums in the EU, where higher greeniums are partially linked to periods in which documents related to environmental policy were published.

Secondly, external certification appears to not influence the greenium, except when controlling for the effects of time in the secondary market where we see a negative impact. Hence, we cannot conclude that the review given by non-affiliated parties can help in increasing trust, leading to lower yields. Next, the availability of ESG rating in the secondary market is seen to positively influence the greenium, which can be related to positive investor sentiment driven by issuers' credibility in the environmental use of proceeds. Furthermore, we find that ESG scores have a mixed and marginally low impact on the greenium and we conclude that higher scores do not contribute to more pronounced green premiums. Lastly, the experience of issuing green bonds positively influences the greenium, particularly for primary markets. The build-up of the reputation of such issuers make them more reliable for investors, therefore they can forgo yields in perceptions of lower risk.

This thesis has contributed to the green bonds research in several ways. We have improved on the PSM method used by previous literature with setting stringent pre-matching criteria. Additionally, we have revised the existence of green bond premiums for both primary and secondary markets simultaneously. Our conclusion on the existence of greenium for both markets suggests that green bonds are a valuable financial instrument for environmental purposes, not simply a marketing gimmick. Furthermore, to our knowledge, this is the first study to document the influence of the issuer's region on the greenium, which we attribute to the level of development for regulation and legislation of sustainable financing in the countries, or even altruism motives. Lastly, we contribute to the growing literature by studying how several potential determinants can influence the green bond premium.

There are certain limitations of this paper, primarily related to the sample imperfections and methodological inefficiencies. Firstly, although green bonds are becoming more popular among investors, they are still in the minority. Further application of stringent criteria to green bonds for matching lowers their amount even more. This makes the results prone to bias both in both matching and regression analyses. Additionally, given the quasi-experimental nature of

PSM, it has drawbacks. Future research can improve on the matching procedure by using more modern and robust algorithms, such as coarsened exact matching (Loffler et al., 2020).

Given the novelty of green bonds as financial instruments, there are implications for further research. Since more data becomes available, the results should be timely revised by using more extensive samples and stringent matching methods. Studies on a variety of regions can be undertaken with a more in-depth analysis, by focusing on the underlying drivers for the potential regional differences in the greenium. Furthermore, more sophisticated and greater choice proxies for bond classification, reporting and certification should be included in future research to validate their effect on the greenium. Lastly, due to the developing green bonds market with a widening base of investors and issuers, liquidity risks become another factor to affect green bond premium. Hence, they should be addressed with liquidity proxies that are able to capture specific features and risks of green bonds.

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Appendix A - Descriptive Statistics

Table A1 : Green and conventional bonds sample distribution by currency

This table shows the distribution of green and conventional bonds according to their currencies in our sample. It lists the statistics, such as frequency, percentage and corresponding average amount issued in 100 millions of US dollars for the currency distribution.

	Green Bonds			Conventional Bonds		
Currency	Obs.	%	Avg. amt issued ($100mln)	Obs.	%	Avg. amt issued ($100mln))
AUD	12	1.83	650.82	37	0.77	562.44
CAD	26	3.96	396.54	114	2.36	863.37
CHF	18	2.74	267.67	25	0.52	526.48
EUR	242	36.83	854.60	816	16.89	901.93
GBP	15	2.28	473.83	88	1.82	810.03
SGD	2	0.30	290.85	9	0.19	449.56
USD	342	52.05	597.10	3,743	77.46	1035.73
Total	657	100.00	672.22	4,832	100.00	997.61

Table A2: Green bonds sample distribution by external certification

This table shows the distribution of the external certification availability for green bonds in our sample. It lists frequency, percentage and corresponding average amount issued in 100 millions of US dollars for certified and non-certified green bonds.

Certification	Obs.	%	Avg. amt issued ($100mln)
No	304	46.27	640.34
Yes	353	53.73	699.67
Total	657	100.00	672.22

Table A3: Green bonds sample distribution by issuers' experience

This table shows the distribution of green bonds in our sample based on the availability of issuers' prior experience in issuing green bonds. It lists frequency, percentage and corresponding average amount issued in 100 millions of US dollars for the green bonds issued by previously experienced and non-experienced issuers.

Experience	Obs.	%	Avg. amt issued ($100mln)
No	272	41.40	544.31
Yes	385	58.60	762.59
Total	657	100.00	672.22

Table A4: Green bonds sample distribution by issuers' ESG score availability

This table shows the distribution of green bonds in our sample based on the availability of their issuers' ESG score. It lists frequency, percentage and corresponding average amount issued in 100 millions of US dollars for the green bonds issued by ESG- or non-ESG-rated issuers.

ESG score	Obs.	%	Avg. amt issued ($100mln)
No	293	44.60	670.48
Yes	364	55.40	673.61
Total	657	100.00	672.22

Appendix B – Variables information

Table B1: Variables for green bond premium determinants

This table contains the variables used for the green bond premium determinants analysis and their explanations.

Variable	Description
EU	1 if the green bond was issued in the EU, 0 if it was issued in US
EU_Year	1 if the green bond was issued in the EU in a given year, 0 if it was either from the US, or issued ina different year than indicated, or both
Certification	1 if the green bond was externally verified as being “green”, 0 if it was not externally verified
ESG_Rating	1 if the green bond issuer is ESG rated, 0 if not
ESG_Score	The score of the ESG-rated green bond issuer
Experience	1 if the green bond issuer previously issued green bond(s), 0 if it is the first green bond issued by the borrower

Appendix C – Additional Results

Table C1: Balancing test of PSM for the primary market

This table shows the balancing statistics on the control variables that were used for radius matching on the green and conventional bonds in the primary market. U shows unmatched treated and control groups. M stands for matched treated and control groups. Mean shows the average of variables for control and treatment groups. p > |t| is the indicator for the significance of differences in characteristics between control and treatment groups. We use all control variables as for matching except industry and year as they were already accounted for. The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively. If B>25%, R outside [0.5; 2].

Panel A : Balancing Test Statistics for the unmatched and matched sample

Variable	Unmatched	Mean			% reduction	t-test	
	Matched	Treated	Control	%bias	|bias|	t	p> |t|
Tenor	U	7.950	6.893	12.70		3.06	0.002
	M	7.950	7.083	10.40	18.00	3.33	0.001
Amount issued ($100mln)	U	20.153	20.519	-64.60		-14.9	0.000
	M	20.153	20.252	-17.50	73.00	-4.58	0.000
Callable	U	0.590	0.696	-22.40		-5.58	0.000
	M	0.590	0.588	0.40	98.40	0.09	0.926
Prime	U	0.143	0.102	12.40		3.21	0.001
	M	0.143	0.162	-5.90	52.40	-1.36	0.173
High	U	0.125	0.077	15.90		4.22	0.000
	M	0.125	0.132	-2.30	85.70	-0.52	0.602
Upper-Medium	U	0.311	0.298	2.70		0.67	0.502
	M	0.311	0.279	6.80	-147.90	1.81	0.071
Secured	U	0.190	0.090	29.10		8.08	0.000
	M	0.190	0.174	5.60	80.70	1.10	0.210

Panel B : Balancing Test Statistics for Matching Results

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R
Unmatched	0.094	384.44	0.000	22.8	15.9	81.5*	1.10
Matched	0.005	41.59	0.000	6.9	5.9	23.9	1.15

Table C1: Balancing test of PSM for the secondary market

This table shows the balancing statistics on the control variables that were used for radius matching on the green and conventional bonds in the secondary market. U shows unmatched treated and control groups. M stands for matched treated and control groups. Mean shows the average of variables for control and treatment groups. p > |t| is the indicator for the significance of differences in characteristics between control and treatment groups. We use all control variables as for matching except industry and year as they were already accounted for. The significance levels of 1%, 5%, 10% are marked with ***, **, * respectively. If B>25%, R outside [0.5; 2].

Panel A : Balancing Test Statistics for the unmatched and matched sample

Variable	Unmatched Matched	Mean Treated	 Control	 %bias	% reduction |bias|	t-test t	 p> |t|
Tenor	U	7.354	6.370	11.90		13.72	0.000
	M	7.354	6.454	10.90	8.5	14.77	0.000
Amount issued	U	20.167	20.547	-66.70		-74.60	0.000
($100mln)	M	20.167	20.289	-21.60	67.70	-29.54	0.000
Callable	U	0.587	0.644	-11.70		-14.25	0.000
	M	0.587	0.601	-3.40	70.90	-2.50	0.120
Prime	U	0.119	0.095	7.80		9.77	0.000
	M	0.119	0.112	2.10	73.40	1.50	0.187
High	U	0.160	0.079	20.20		20.14	0.000
	M	0.160	0.154	1.20	94.00	0.90	0.266
Upper-Medium	U	0.301	0.313	-2.60		-3.12	0.002
	M	0.301	0.287	3.00	-14.50	3.79	0.000
Secured	U	0.192	0.073	35.80		53.18	0.000
	M	0.192	0.126	20.00	44.30	24.92	0.000

Panel B : Balancing Test Statistics for Matching Results

Sample	Ps R2	LR chi2	p>chi2	Mean Bias	MedBias	B	R
Unmatched	0.091	10455.37	0.000	22.4	11.9	86.1*	1.10
Matched	0.010	4012.22	0.000	8.9	3.4	24.2	1.20