DISSIPATING GREEN BOND PREMIUM

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ABSTRACT

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This study analyses pricing of 3,365 bonds, including 649 green bonds, issued in EUR and USD in the U.S. and European markets. First, the effect of green bond label on the price is determined by using propensity score matching for primary market data. The results provide weak evidence for the existence of greenium for the whole sample and EUR denominated bonds, while USD denominated bonds and issues by corporates are not affected by the green label based on the analysis. Non-corporate issuer (banks, sovereigns, supranational institutions, and agencies) green bonds trade at significant premiums compared to their conventional peers.

In the secondary market the premium is studied using a matched sample created by nearest neighbour matching. The greenium is only present for non-corporate issuers after controlling for liquidity and time to maturity. Examining the sample further shows that the effect is stronger for bank issues than for other non-corporate issuers. Finally, this study provides evidence for greenium disappearing from the markets with monthly green bond issuance market share reducing the green bond premium of bonds. Greenium fluctuating with increasing monthly volumes indicates that as the markets have experienced saturation, the green bond premium has dissipated from the market. However, the yield spreads of green bonds issued by sovereigns, supranational institutions, and agencies (SSA) are unaffected by the increased market share supporting the notion of these green bonds being of highest quality.

Results argue that the bond premium is affected by issuer type and the currency it is denominated in. Non-corporate issuer bonds are favoured by the pro-environmental investors possibly due to their trustworthiness and reputation. The greenium exists for this issuer type both in primary and secondary market albeit the premium in secondary market is lower. Green bond premium decreasing as relative issuance volume has increased could imply that it is driven by scarcity. The demand seems to be most persistent for non-corporate issues especially for bonds by SSAs that could be seen as most impactful. Considering the great need for green investments to reach the goals set by the Paris Climate Agreement, dissipating green bond premium is not incentivizing further investments possibly causing the market to stagnate in future without policy support.

Key words
Green bond, green bond premium, green finance, bond market

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Tämä tutkimus analysoi 3,365 euroissa ja dollareissa noteerattujen joukkovelkakirjojen (jvk), mukaan lukien 649 vihreän jvk:n, hinnoittelua Yhdysvaltain ja Euroopan markkinoilla. Aluksi vihreän "leiman" vaikutusta hinnoitteluun tutkitaan hyödyntämällä propensity score matching -metodia primäärimarkkinadataan. Tulokset tarjoavat heikosti merkitsevää näyttöä viherpreemion olemassaolosta tarkastellessa koko otantaa ja euromääräisiä velkakirjoja, kun taas yhtiöiden ja dollareissa noteerattujen vihreiden jvk-lainojen hinnoissa ei esiinny preemiota. Muiden kuin yhtiöiden (valtiot, ylikansalliset organisaatiot, virastot ja pankit) liikkeelle laskemissa vihreissä jvk-lainoissa preemio on suuri ja merkitsevä.

Sekundäärimarkkinatutkimuksessa hyödynnetään nearest neighbour matching -metodilla luotuja jvk-pareja. Kontrolloidessa likviditeettiä ja juoksuaikaa, viherpreemio on merkitsevä ainoastaan muissa jvk-lainoissa, joissa pankkien liikkeellelaskuissa esiintyvä preemio on suurin. Tutkimus tarjoaa myös näyttöä siitä, että preemio on katoamassa markkinoilta. Kuukausittaisten vihreiden jvk-lainojen liikkeellelaskun kasvaessa suhteessa kaikkiin kuukausittaisiin liikkeellelaskuihin madaltaa viherpreemiota indikoiden, että volyymien kasvaessa preemiot katoavat markkinasaturaation seurauksena. Tätä efektiä ei kuitenkaan ole havaittavissa valtioiden, ylikansallisten organisaatioiden ja virastojen eli instituutioiden joukkovelkakirjoissa, mikä tukee käsitystä näiden vahvasta sijoittajakysynnästä.

Viherpreemioon näyttäisi vaikuttaa liikkeellelaskijan ominaisuudet sekä liikkeellelaskuvaluutta. Vastuulliset sijoittavat suosivat erityisesti instituutioita mahdollisesti niiden uskottavuuden ja luotettavuuden vuoksi. Niiden jvk:t nauttivat preemiosta niin primääri kuin sekundäärimarkkinoilla, vaikkakin preemio on pienempi sekundäärimarkkinoilla. Vihreiden jvk-lainojen liikkeellelaskun kasvun pienentävä vaikutus preemioon kertoo preemion syntyvän mahdollisesti vihreiden jvk-lainojen saatavuuden niukkuudesta. Kysyntä näyttäisi kohdistuvan muiden kuin yhtiöiden, erityisesti instituutioiden jvk-lainoihin, joilla on mahdollisesti suurin vaikutus ympäristön kannalta. Huomioiden suuret investointitarpeet, jotta Pariisin ilmastosopimuksen tavoitteissa pysyttäisiin, markkinoilta häviävä preemio ei kannusta vihreiden joukkovelkakirjojen liikkeellelaskuun, mikä voi aiheuttaa markkinoiden stagnaation ilman poliittista tukea.

Asiasanat
Vihreä joukkovelkakirja, vihreä joukkovelkakirjalaina preemio, vihreä rahoitus, jvk

Säilytyspaikka
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CONTENTS

1 INTRODUCTION

Transition to low-carbon economy is one of the most urgent issues facing the world today. Last decade was the warmest decade in history. The global average temperature was 1,1°C higher than pre-industrial levels in the end of 2019 (World Meteorological Organization, 2020). Constantly warming climate raises sea levels, causes heatwaves resulting in lethal wildfires, creates draughts and floods, and negatively affects food security especially in developing economies. The urgency for environmental actions is high but they are lacking. While there are regulation and subsidies for pro-environmental projects, these interventions alone are not enough evident from consistently rising carbon emissions.

In Paris Climate Agreement of 2015, 195 countries agreed to adopt a plan to reduce emissions and reduce global warming below 2°C. The emission growth stagnated for few years but have steadily grown ever since. As a result, the world is not on track to meet the Paris Agreement goal. According to UNFCCC (2022) report published before the COP 27 meeting, the nationally determined contributions as of now will increase emissions by 10,6 % by 2030 compared to 2010 levels and are forecasted to stagnate after 2030. While improvement from 2021 report of 13,7 %, the current trend will result in 2.5°C of warming by the end of the century. To reach the 1.5°C target by 2030, emissions would need to decrease by 40 % from the 2019 levels. Climate action plans need to strengthen which requires large influxes of capital and green bonds offer a solution for this issue.

The financial sector plays a crucial role in the transition to low-carbon economy by directing capital to where it is most needed. The Copenhagen Accord in 2009 underlined the importance of financial markets in fighting climate change. A decision plan presented during United Nations Climate Change Conference in 2022 (alias COP 27) highlighted that to meet the net zero emission target by 2050 would require at least 4 trillion USD investments yearly in renewable energy (UN Climate Change Conference, 2022). The urgency of transitioning to a low-carbon economy has led to the emergence of sustainable finance, which integrates environmental, social, and governance (ESG) factors into financial decision-making. While all ESG aspects are crucial, environmental issues have taken the front stage in discussions at United Nations Conference of the Parties (COP) meetings. Participants have agreed on plans to reduce emissions but often lack the necessary funds to implement these plans. The UN has highlighted green bonds as a key instrument to address the capital shortage for environmental initiatives. Green bonds are credit instruments used to raise capital to fund pro-environmental projects. The first green bond was issued by European Investment Bank in June 2007, IFC issued first $1 billion bond in March 2013, and in December 2020 the green bond market reached $1 trillion cumulative issuance milestone (Climate Bonds Initiative, 2023).

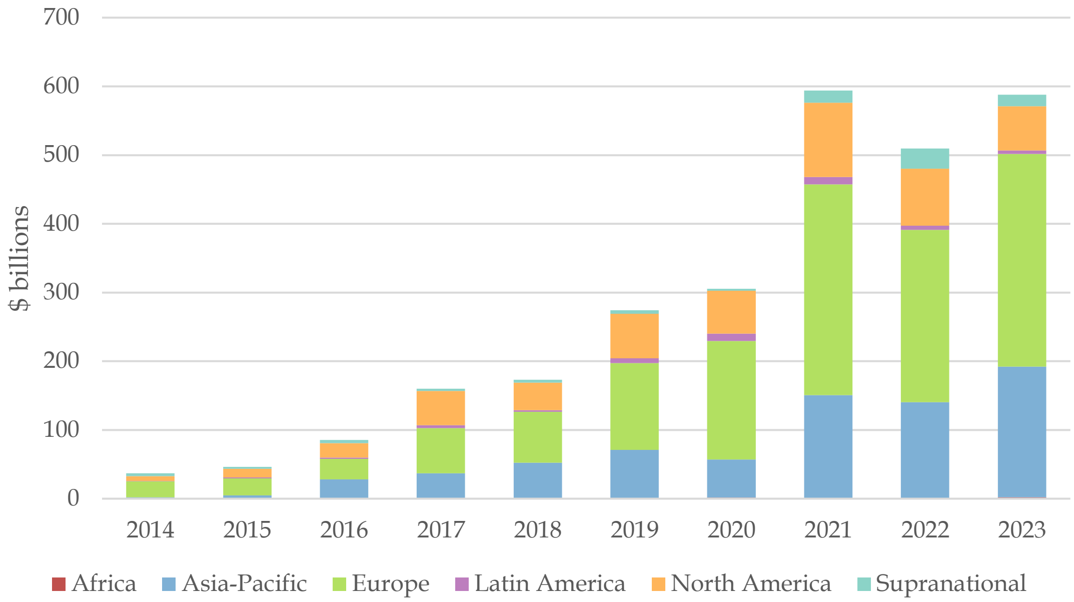

Figure 1 Green bond issuance from 2014 to 2023 in $ billion.
Source: Climate Bonds Initiative

Due to being a relatively new market with number of issues heavily clustered on the past five years, the literature on the subject is in infancy and somewhat conflicting on several topics, including arguably one of the most important topics of green bond pricing. Green bonds funds are required to be monitored and reported to investors for added transparency which creates additional costs for the issuing company. As the current literature is conflicting about green bond issues being rewarded by the market with lower yields, some companies are not willing to establish a framework to issue green bonds (Deschryver & Mariz, 2020), further accelerating the global warming trend toward a 2.5 °C increase in temperature. This thesis aims to contribute to the existing green bond avenue of research by studying the green bond premium (greenium) existence in U.S. and European markets, differences between the markets, and by introducing green bond issuance volume as one possible factor affecting the size of premium.

Given the fact that the green bond market growth has been strong despite issuers stating their unwillingness to issue bonds without factual premium (Deschryver & Mariz, 2020) and institutions not prepared to invest into bonds with premium (Flammer, 2021; Larcker & Watts, 2020), either party has bent their opinion. Companies are not mandated to issue green bonds therefore they can fund pro-environmental projects using conventional bonds with added benefit of being able to freely move the raised capital to other projects. Conversely institutions have seen a surge in customer demand for green assets warranting them to acquire green instruments, including bonds. To identify whether the market growth has been incentivized by lower capital costs, this study answers the following question:

1. *Does green bond premium exist in U.S. and Europe primary and secondary markets?*

European market is seen as the forerunner in sustainability policies, which might create differences between the two major markets. As is evident from Figure 1, the green bond market growth is mainly driven by Europe, while U.S. growth has been inconsistent. Additionally, investors could prefer different issuer types creating pricing differences. To account for these potentially different preferences, a comparison is made between EUR and USD denominated bonds and different issuer types.

2. *Are there pricing differences between EUR/USD bonds or different issuer types?*

The main contribution of this study is the attempt to capture the potential effect of increasing market share of green bonds to green bond premium. As the market has grown over the years, especially after 2021, pro-environmental investors have increasing number of options to invest into, thus allowing them to choose better yielding bonds while satisfying their environmental preferences. This could decrease the green bond premium over time. Confirmation of this effect could help partly explain the different results in prevailing literature.

3. *Has the green bond premium decreased as green bond issuances have become more frequent?*

2 THEORETICAL FRAMEWORK

Green bond premium or "greenium", refers to the pricing difference between green and conventional bonds, where green bonds are often priced higher than their conventional peers. The greenium has been hypothesized to exist primarily due to two factors; pro-environmental investor preferences for green bonds and the perceived lower riskiness of green bonds (Teti et al., 2022). Theoretically, investors who gain non-pecuniary utility from an instrument move the equilibrium prices of those instruments creating a premium (Fama & French, 2007). For example, green bonds might offer additional utility to environmentally conscious investors, thus these investors would be willing to accept lower returns, increasing the price of the green asset. However, studying the effect of non-pecuniary preferences empirically has been challenging because investment returns are often not known ex ante, complicating the isolation of preference effects. Green bonds provide a new opportunity to study investor preferences for green assets because their returns are known to the investor at the time of the investment decision.

Second potential factor, the lower riskiness of green bonds, arises from their monitoring and reporting requirements and the fact that issuing green bonds help issuers transition to low-emission operations which, reduces their exposure to climate risk. Taken together green bonds could have lower risk profile, which should warrant lower returns creating a notion of premium when comparing the bonds. This area of research is less explored in the green bond literature.

Demand for pro-environmental attributes has been a widely studied phenomenon. Preferences are apparent for example in electricity markets where consumers have the possibility to choose between different forms of energy productions. Several groups are prepared to pay more for their electricity if the production produces lower emissions, and even higher price if the fuel source is renewable (Roe et al., 2001). The findings hold also for investor decisions in capital markets. Socially responsible investing (SRI) has been gaining importance, and the investors of SRI funds has been shown to have lesser financial motives expecting lower returns for their investment (Riedl & Smeets, 2017). The notion of green assets providing lower returns than brown assets is also supported by Hong & Kacperzyk (2009) who examined the pricing of "sin stocks" i.e., companies producing tobacco, alcohol, or gambling services, and presented evidence for sin stocks trading at a discount therefore providing higher returns. Environmental preferences are also evident from the stock price action following a green bond issue announcement. Disclosures are often followed up by short term excess returns on the stock price of the issuer (Daubanes et al., 2021, Flammer, 2021; Tang & Zhang, 2020).

More recently the investor preferences for socially responsible stocks have been suggested to be time-varying, depending on the economic situation with highly rated SRI stocks outperforming during economic boom, and underperforming during a bust (Bansal et al., 2021). Furthermore, comparing green and brown energy stock at the times of high frequency of climate change news measured by climate policy uncertainty (CPU) index, green energy stocks are shown to enjoy higher demand leading to higher prices and lower volatility than their brown counterparts. The effect is significantly stronger when the news frequency reaches higher quantile of distribution (Bouri et al., 2021, 2022). In European equity market investors increase their ownership in green assets when policy changes give more credibility to low-carbon transition such as EU Green Deal and reduce ownership when prices of oil increase (Alessi et al., 2023).

Overall, comparing the flows of socially responsible investing funds show that the demand for SRI has been higher during more recent years (Białkowski & Starks, 2016). Additionally, these funds are less sensitive to performance further emphasizing the role of nonpecuniary motives. Given that SRI investors expect lower returns, are less sensitive, and SRI funds are able to ask higher commissions while demand is increasing (Riedl & Smeets, 2017), green bond investors might be willing to accept lower returns creating a premium in the market.

In credit markets, company's good corporate social performance has shown to be rewarded with lower yield spreads indicating a positive relationship between social and environmental policies and perceived credit quality (Oikonomou et al., 2014). Indeed, environmental concerns raise the cost of capital and lower credit rating (Bauer & Hann, 2010). Variation in perceived climate risk affects also corporate bonds. Corporate bonds with high beta with a climate change news index exhibit lower returns (Huynh & Xia, 2021). At the times of high perception of climate risk, investors seem to be willing to pay more for bonds issued by pro-environmental companies. Perhaps the most convincing argument for greenium was given by the twin sovereign bond issue by Germany in September 2020 where all bond characteristics were identical except other bond was labelled a green bond. The green bond traded at 2 bps lower yield to maturity than its counterpart in secondary market (Löffler et al., 2021).

Institutional investors believe that climate risks have started to materialize creating financial implications, which need to be combated with active risk management as reported in study by Krueger et al. (2020). Furthermore, most of the 439 respondents stated a belief that climate risk is underpriced in the market. Climate change creates direct costs to companies from weather anomalies or indirect exposure through policy and regulation changes such as carbon pricing aimed to reduce environmental damage. The policies incentivise new technological innovations that threaten traditional industries (Kruger et al., 2020). Consequently, green bonds have shown to offer investors diversification benefits during normal market conditions and market distress over conventional bonds (Karim et al., 2023). Especially during high levels of economic and climate policy uncertainty, green bonds perform better than conventional counterparts (Dong et al., 2023) making the instrument attractive for intertemporal hedging.

Baker et al. (2018) modelled green asset price discovery by building a model where there are two types of investors with one-period portfolio choice problem. These investors solve the following utility functions:

$$\text{Group 1: } max\, w_1' r - \tfrac{\gamma}{2} w_1' \Sigma\, w_1$$

$$\text{Group 2: } max\, w_2' r + w_2' e\; - \tfrac{\gamma}{2} w_2' \Sigma\, w_2$$

Both types have common expectations for risk **Σ**, returns **r**, and common risk aversion **γ**. These investors build a portfolio with weights **w** in each asset. What differentiates the types from each other is that Group 1 investors optimize mean-variance, while Group 2 incorporates nonpecuniary motives to their portfolio decision-making, such as assets positive perceived environmental scores **e** > 0, from which they gain additional utility. Per Baker et al. (2018) these investors have capital of a_1 and a_2. Therefore the market portfolio is defined as:

$$\frac{a_1}{a_1 + a_2} w_1 + \frac{a_2}{a_1 + a_2} w_2 = w_m$$

where $w_m$is the market portfolio, a vector of weights assigned to each security, proportional to its market value relative to the total market value of all assets. When all the capital is held by Group 1 investors, the authors note that for the market to clear the weights must be equal to market weights:

$$w_1 = \frac{1}{\gamma} \Sigma^{-1} \mathrm{r} = w_m$$

As there are no other investors, the resulting equation can be used to calculate the expected return of the market by substituting γ with Sharpe ratio equating to:

$$r = \frac{r_m}{\sigma_m^2} \Sigma w_m = \beta r_m$$

Baker et al. (2018) note that portfolio weights for Group 2 i.e., investors who gain nonpecuniary utility, are:

$$w_2 = \frac{1}{\gamma} \Sigma^{-1} (\mathrm{r} + \mathrm{e})$$

The authors assume with no loss of generality that the overall average e is zero. Therefore, same substitution for γ can be made resulting in a Capital Asset Pricing Model with an environmental addition:

$$r = \frac{r_m}{\sigma_m^2} \Sigma w_m = \beta r_m - \frac{a_2}{a_1 + a_2} e$$

Deriving from the model assets with positive environmental scores e.g., green bonds, should have lower expected returns thus trade at a premium. Moreover, larger the proportion of investor capital with taste for environmental assets, lower is the expected returns for green bonds.

3 LITERATURE REVIEW

Green bonds (GB) are a part of thematic bonds, instruments that raise financing for projects related to a certain theme. Green bonds lack a common definition but are typically identified as fixed-income securities nearly identical to conventional bonds, with one crucial difference. The funds raised through green bond issuance must be used to finance or refinance eligible green projects, such as renewable energy, clean transportation, or green housing. This capital is specifically earmarked for these projects, and its use is closely monitored and reported to investors (Kapraun et al., 2021). The green feature makes the bonds appealing for environmentally conscious investors who want to support green projects directly, and they offer diversification benefits for institutions who want to reduce their climate change related risks (Bachelet et al., 2019). While the funds received from green bonds are used for specific projects, they are backed by the issuer's balance sheet (Tang & Chang, 2020).

Green bonds did not achieve a running start following the first issues by EIB in 2007 and World Bank in 2008, and the following six years were quiet for green bond markets. The instrument started to draw attention in 2013 when first corporate green bond was issued by a Swedish property company Vasakronan, and at the end of 2015 the market reached $100 billion, coinciding with year of the Paris Agreement (Climate Bonds Initiative, 2023). Ultimately the market growth has been rapid with over 90 % average annual growth rate since inception to end of 2023, and it is becoming large enough to have an indisputable impact on the environment.

Concerned with current emissions developments central banks have started to explore options to further support green finance. Focused strategies would help accelerate the transition towards carbon-free economy. According to ECB (2022) press release the central bank is aiming to ease collateral requirements and adjusting its bond portfolio to favour green bonds. The bank is also working on its own minimum disclosure requirements and in discussion with rating agencies to improve theirs.

3.1 Green bond regulation

A major hurdle for green bonds is the fear of greenwashing. The term is used to describe the act of declaring a commitment to the environment while the company has no intention to follow up with the declaration. This attracts consumers and has positive short-term effect on the reputation of the company until the statements are revealed to be false. Most notorious example of this is the Volkswagen emission test scandal in 2015 where it was found that the cars were equipped with software that detected when emission test was being ran and adapted the performance to achieve lower reported emission levels. In fact, diesel cars' emissions were 40 times above the US limit and the revelation sent the stock price plummeting and caused severe reputational damage (Bachelet et al., 2019).

At first companies issued self-labelled green bonds but in 2011 Climate Bonds Initiative, a non-profit organization established following UN Biodiversity Conference COP15 two years earlier, launched Climate Bond Standards to improve integrity of the market and avoid greenwashing. As the market has grown, numerous other entities and countries have issued their own framework. For instance, China has introduced China Green Bond Principles, ASEAN Capital Markets Forum launched ASEAN Green Bond Standards, and EU High-Level Expert Group on Sustainable Finance proposed that EU should create its own principles (EU HLEG, 2018). EU followed the proposal and European green bond standard is currently waiting to be signed.

As there are multiple different standards to follow and none of them are mandatory for the issuer, there are equal number of different interpretations on what is an eligible green project. This has led to controversies, because the issuer can choose what framework to follow in the issuance to achieve the green bond status. For instance, in 2016 Mexico City Airport Trust issued a green bond to fund a new airport. Although the construction and resulting building were deemed green, the project supported one of the most polluting industries in the world, raising questions about the true environmental impact of such investments (Kapraun et al., 2021). Similarly, China's green bond framework allows "clean utilization of coal" which is not accepted by most other standards. Especially nuclear energy is highly debated topic amongst green bond authorities due to it being zero-emission clean energy source while simultaneously creating radioactive waste (Yeow & Ng, 2021).

The most important and widely used guidelines currently are Green Bond Principles (GBP) established by International Capital Market Association (ICMA) in 2014, which are being recognized on the international level (Bachelet et al., 2019). The GBP has four main components (ICMA, 2022):

1. *Use of proceeds:* All eligible green projects should produce clear environmental benefits. GBP does not specify which projects are eligible but provides a broad example of categories such as energy efficiency, pollution prevention and control and circular economy products. The first component recommends the issuer to report how the funds are used, and to assess and quantify the portion of the funds used to refinance previous projects.

2. *Process for Project Evaluation and Selection:* The issuer is required to disclose the sustainability objectives, the project process, and other environmental implications, including social and environmental risks, of the supported projects to all parties.

3. *Management of Proceeds:* The third component mandates that the proceeds should be stored in a separate account or be otherwise tracked by the issuer. The issuer can manage the proceeds per bond or on an aggregated basis and should report the intended placement of unallocated capital.

4. *Reporting:* Issuer should maintain a record of how the proceeds are used annually and provide additional information in case of material development. The annual report includes implemented allocation of funds and the amounts (in percentages in case of confidentiality agreements), brief description of projects, and expected impact of the projects. This section also emphasizes focus on transparency and accuracy of the information reported.

Green Bond Principles recommend the issuer to use a third-party to review and verify bonds alignment with GBP pre-issuance (ICMA, 2022). The review has few different forms. ESG provider can give a secondary party opinion about the issuers plans and the greenness of the project and possibly rate the overall sustainability of the bond (Eliet-Doillet & Maino, 2023). Furthermore, the third-party can give a legally binding assessment for more robust review or check the issue's compliance with stricter Climate Bonds Standards. Post-issuance an external auditor verifies the internal tracking and allocation of funds from the green bond proceeds. If the bond fails to follow the chosen principles, there are no legal consequences but in certified bonds the certification status can be revoked, and bond excluded from green bond market (Yeow & Ng, 2021). Paying for third-party review to increase transparency and trust is a popular practice especially in developed markets (Kapraun et al., 2021).

The accepted principles are subject to change as the market evolves and governments become more involved in the market. European Commission Technical Expert Group has suggested that companies should start to disclose their ratio of green bonds to total bonds amount outstanding to signal their commitment for green projects (European Commission, 2019) which could be included in the upcoming European green bond standard. As a leading green bond market, the new standard will have major implications for the future of the market. Naturally the monitoring, reporting, and optional verification requirements make green bonds costlier to issue compared to conventional bonds. Therefore, the issuing company expects to gain additional benefits to offset these higher costs.

3.2 Issuance benefits

3.2.1 Green bond premium

As the market has matured, several studies have examined the pricing of green bonds vis-à-vis conventional bonds. The earliest studies were conducted by industry professionals finding conflicting evidence on the existence of premium. Barclays (2015) reported a negative yield premium in secondary market, HSBC (2016) found no premium in primary and secondary markets, and Bloomberg (2017) highlighted a negative yield premium but for only euro denominated government bonds. Following these studies academic literature on green bond premium began to evolve.

Studying U.S. municipal bonds, Baker et al. (2018) found evidence for green bond premium existence in green municipal bonds, especially ones that were certified by an external reviewer. Smaller, highly graded green bonds exhibited lower liquidity indicating that buyers favoured selling conventional bonds over green bonds. The issued green bonds on average had higher credit rating and longer maturities. The greenium while small in aggregate, was three times larger for certified green bonds. However, a study released year before found municipal green bonds to be traded with higher yields in the secondary market (Karpf & Mandel, 2017). Building on earlier findings, a pioneering study by Zerbib (2019) examined the green bond premium in secondary market using a worldwide sample, where he discovered a small and significant greenium of 2 basis points. The premium was more pronounced for financial issuer bonds and issuances by lower credit rated companies. The author also noted that the issuance currency might influence the premium and the premium evolves over time.

In more recent years the existence of greenium is still under debate. Supporting the notion of currency affecting the premium, Teti et al. (2022) examined the relatively small and illiquid market of Italy in EU where environmental policies are currently being prioritized. In Italy, the premium anomaly was observed to be market-wide, with both corporate and financial issuers benefiting from the green bond premium with primary market premium reaching up to 40 basis points. However, the authors found that the greenium was larger for corporate issuers, conflicting with earlier findings that financial companies had larger premiums. As Teti et al. (2022) analysed secondary market pricing of bonds, they they presented an interesting finding that aligned with Zerbib (2019): during the period from June 2020 to June 2021, the green bond premium increased in size.

Kapraun et al. (2021) examined over 2000 green bonds and found no evidence of premium for the aggregate sample. However, when inspecting subsamples, the study reported that large corporate issues, bonds issued by governments and supranational entities, and euro dominated bonds were priced higher i.e., had lower yields than their conventional counterparts. Additionally, green bonds in countries with high Environmental Performance Index (EPI) scores, or those with third-party green certification, or issued by companies with high environmental ratings, benefited from a greenium. More evidence for the fact that not all green bond issuers are treated equally is provided by Fatica et al. (2021) paper where they argued that bonds issued by financial institutions do not exhibit a premium while corporate and supranational issues do. Return issuers enjoy larger premiums further providing an argument for the reputational effect. If the issuing bank has subscribed to the United Nations Environment Program Financial Initiative, their green bonds tend to exhibit a premium.

On the contrary, Bachelet et al. (2019) showed evidence for green bonds having higher yields, lower variance, and more liquidity in aggregate in a worldwide sample. Examining the bonds by issuer revealed differences. Private issuer bonds without green certificate had higher yields, higher variance, and lower liquidity, whereas institutional issuers had the opposite characteristics. Larcker and Watts (2020) studied green and conventional U.S. municipal bonds issued by the same issuer during same day. Their findings showed investors' unwillingness to forgo returns in favour of the environment evidenced by the near identical pricing of conventional and green bonds. Flammer (2021) and Tang & Zhang (2020) found no evidence of a green bond premium in corporate bonds, raising the question of why the number of green bond issuances is increasing if they are costlier to issue and offer no pricing advantage for the issuer. The summary of conflicting literature is listed under Appendix 1.

3.2.2 Signalling

Flammer (2021) hypothesized that there are three reasons why corporations issue green bonds. First, the company uses green funding as it is cheaper than conventional (capital argument), which has conflicting evidence based on the previous chapter on green bond premium. Second is to signal the markets that the company is taking action for the environment (signalling argument). Third, they make the claims to improve reputation but have no intention of following up on the pro-environmental projects (greenwashing argument).

Signalling argument has been supported by the existing literature. Tang & Chang (2020) studied the effects of green bond issuance announcement on the company's stock and found that the stock price, liquidity, and ownership increase after the announcement. Especially domestic institutions increase ownership in issuing companies. The findings indicate that the issuer can be rewarded for the issuance by other means than the greenium. Issuance brings more attention to the company giving a significant reputation boost. Interestingly the stock effect is not observed with financial companies emphasizing that investors value issues differently based on issuers sector or more likely firms conducting the green project directly are rewarded. Flammer (2021) study highlights similar results. Company stock reacts positively to green bond announcements, but the market reaction is restricted only to certified green bonds and is stronger for first time issuers. Furthermore, green, and long-term investors increase ownership in companies issuing green bonds.

For managers, green bonds offer a way to signal their expected project profitability to the market which in turn increases the stock price, therefore their compensation. Green bond funding used to decrease emissions reduces the capital needed to buy emission permits enhancing profitability (Daubanes et al., 2021).

3.2.3 Greenwashing

The possible green bond benefits for the issuer rises the problem of greenwashing. However, the greenwashing argument has been rejected by existing literature for certain issuances. Banks issuing green bonds tend to reduce lending to polluting sectors after the issuance (Fatica et al., 2021). The issuance is followed by reduction carbon emissions especially with entities situated in developed markets and countries with high climate change exposure (Al Mamun et al., 2022). Additionally, bonds that target decarbonization projects such as renewable energy or pollution control have the largest effect on CO_2, and the effect is more pronounced long term. Intuitively, the carbon reduction effect is more pronounced with certified green bonds (Flammer, 2021), which also improve the overall environmental performance of the company (Yeow & Ng, 2021).

Green bond issuance is not immediately followed by a significant improvement in the environmental performance of the issuer (Flammer, 2021), but the CO_2 emission reduction and environmental score improvement materializes three years after the issuance (Makpotche et al., 2024). Furthermore, the effect is more prevalent five years after the issuance, indicating that the underlying funded projects require time to produce environmentally positive output.

Greenwashing risk seems to persist in self-labelled bonds not certified by a third-party as the bonds do not affect the environmental performance of the issuer (Flammer, 2021). Considering that self-labelled green bonds can be used to fund any project deemed green by the issuer, the reporting does not follow any framework and is not monitored by an independent party, the greenwashing risk naturally remains high. Coincidentally these bonds are priced equally or lower to conventional bonds by the market (Baker et al., 2018; Bachelet et al., 2019; Kapraun et al., 2021). As long as there is no public governance and companies can self-label bonds, the risk of greenwashing persists (Flammer, 2021) and investors looking for environmental impact would probably be better off investing in green bonds following recognised frameworks.

3.3 Factors behind the possible premium and conflicting results

Existence of green bond premium in primary and secondary market is heavily debated topic in the literature with inconclusive results in primary market and majority of studies confirming a premium in secondary market (MacAskill et al., 2021). The results tend to vary based on used sample and empirical methods.

With significant portion of corporate issuers of green bonds operating in sectors like energy and industrials, which are notably more susceptible to environmental credit risk, investing in green bonds from issuers in these sectors could entail substantial exposure to environmental risks (Ehlers et al., 2017). Considering the riskiness, Bachelet et al. (2019) reported lower yield and variance for institutional investors, while Aloui et al. (2023) and Cicchiello et al. (2022) found that green bond prices reacted more aggressively during the COVID-19 crash indicating investor willingness to reduce ownership in green bonds over conventional bonds during market shock.

If non-pecuniary motives drive the green bond premium, bonds issued by polluting companies should present a larger premium than those issued by sustainable companies, as they have a greater potential effect on the climate. However, this assumption has not been supported in the literature. A potential explanation is that investors prefer green bonds issued by sustainable companies over those issued by polluting companies. According to findings by Kapraun et al. (2021), investors tend to use a top-down approach when deciding where to invest, favoring issuers with strong existing sustainability profile. However, the idea of time-sensitive premium by Teti et al. (2022) and Zerbib (2019) supports evolving non-pecuniary motives of investors.

Currently investors' trust in the issuer might be the main factor dictating the existence of the premium. Baker et al. (2018), Bachelet et al. (2019), and Kapraun et al. (2021) highlight the effect of certification on greenium indicating a possibility for private issuers to mend their lack of reputation by getting their bonds certified by a third party. Furthermore, greenium differences between government and corporate issues could also be explained by reputational discrepancy as governments are often seen as more trustworthy. Flammer (2021) and Larcker & Watts (2020) studies on U.S. market rejecting the notion of premium, while Teti et al. (2022) and Kapraun et al. (2021) report greenium in EUR nominated bonds provide evidence for differences between the markets. In pro-environmental EU trust in the green bond issues might be higher than in U.S., resulting in a premium.

However, while adhering to principals has been identified as one main driver for green bond premium. Baker et al. (2018) argued that the certification effect is difficult to interpret. If the bonds that were certified were already identified by the public to be green, then the certification effect in studies is overvalued. The idea behind the third-party certification is to attract concerned investors, therefore if the company pays for the rating agency's opinion, then the company must have feared that the reputation needs amending.

As the market matures further and additional requirements for reporting are introduced, possible information frictions dissolve. For example, bank issues not having a green bond premium might indicate that investors are not able to connect the funds to a green project causing the lack of premium (Fatica et al., 2021) which could be remedied with more thorough reporting. The size of the premium could also be affected by future policy interventions. European Central Bank's Monetary Policy Strategy Review in July 2021 announced an intended shift in monetary policy actions towards green bonds. Following the news, bonds eligible for the purchase program saw decreases in yield and the number of issues increased (Eliet-Doillet & Maino, 2023).

Additional studies and policy interventions might be needed to grow the market to a size where it will have a considerable effect on the transition to a low-carbon economy. Portfolio managers and traders interviewed by Larcker & Watts (2020) and Flammer (2021) stated no interest in green bonds if they were trading at a premium. On issuer side, some corporations are not issuing green bonds as the process is costlier and green bond premium has not been uniformly found by existing literature (Deschryver & Mariz, 2020). Furthermore, energy companies have been the lead issuer in the market contributing most to the growth, but the investment pipeline might be drying up and the market might stagnate in the future. However, with strengthened policy frameworks and incentives for green investments should motivate broader range of sectors to participate in the market, resulting in lower amounts raised per issuance but greater issuance numbers.

On the whole green bond investors seem to have time-varying environmental preferences (Bansal et al., 2021; Bouri et al., 2021, 2022; Dong et al., 2023; Huynh & Xia, 2021; Teti et al., 2022; Zerbib, 2019), are less sensitive to returns (Białkowski & Starks, 2016) but sell green bonds more aggressively during market distress (Aloui et al. 2023); Cicchiello et al., 2022). Their preferences might also depend on their country of residence and the issuer characteristics with trust in the issuer being a major factor (Baker et al., 2018; Fatica et al., 2021; Kapraun et al., 2021; Teti et al. 2022; Zerbib, 2019). This observation would explain why the studies find such conflicting results and cannot examine a premium in aggregate. Noticeably one factor has not been studied in earlier literature. The effect of green bond market maturing on green bond premium. Given that for pro-environmental investors there has been limited number of green bonds available, they could have accepted lower returns due to scarcity of green bonds. Now that the issuance volumes have greatly increased, these green bond investors do not need to forgo returns to support green projects.

4 DATA AND RESEARCH METHODS

To study whether there is evidence of green bond premium in primary and secondary market I use both conventional and green bond data. The dataset was retrieved from LSEG Workspace (previously Refinitiv) by first gathering bonds labelled green with issuance dates from 2007 till the end of 2023 from EU and U.S. markets. Bonds by municipalities were excluded due to their varying tax treatments that affect the yields. To avoid uncertainty on the issuance pricing, the data were filtered to only include bonds with fixed coupon payments and bonds denominated in euros and dollars. After collecting the green bond data, conventional bonds issued by the same issuers with identical criteria was collected. The starting sample consisted of 62,764 conventional bonds and 2,113 green bonds. All the bonds with issuance sizes lower than EUR 200 million were removed as per Gianfrate & Peri (2019) to have liquid bonds. Sizes more than EUR 30 billion and tenor over 50 years were also removed to create more equal samples as outliers could make following propensity score matching difficult due to the variables not being balanced between created groups. Additionally, junk bonds and non-rated bonds were removed to remove outliers and because credit rating is required for matching. Subsequently cleaning the data from missing ISIN codes and yield spreads left a total of 3,365 bonds in the dataset of which 649 are green bonds. Table 1 describes the final sample.

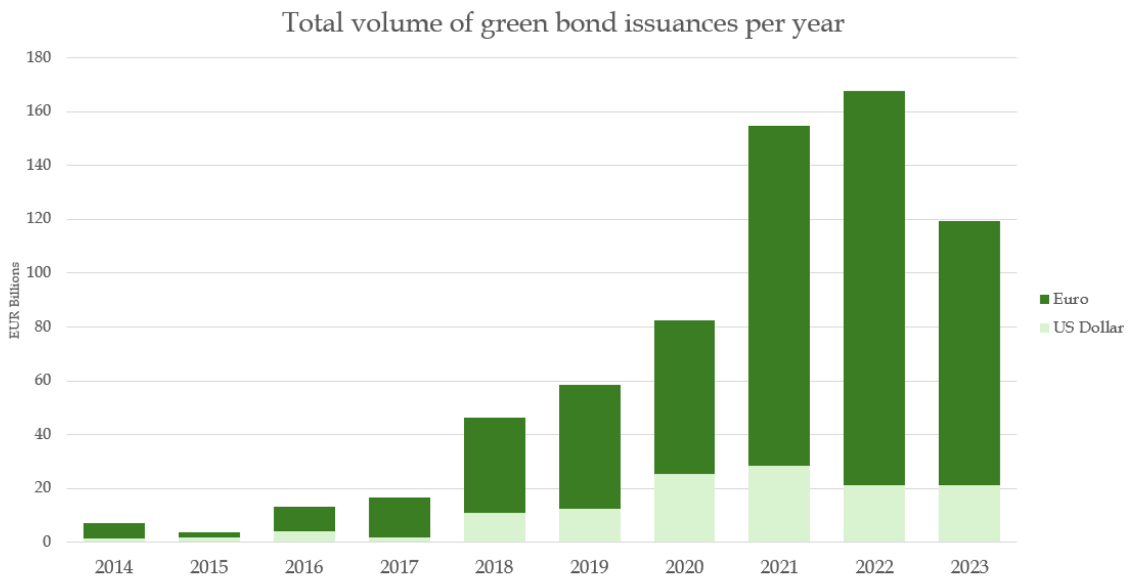

Figure 2 Volume of green bond issuances in EUR billion per year in sample.

While the number of observations was greatly reduced by missing data, especially due to credit rating data, the used sample covers a total volume of EUR 690,5 billion, presented per year in Figure 2. Lack of credit rated green bonds in early years of the market causes the sample to begin from 2014, which aligns with the establishment of Green Bond Principals during the same year. As with the whole green bond market, USD denominated bonds are in the minority in my sample. The overall volume trajectory of the sample mimics that of the whole green bond market.

Table 1
Descriptive statistics

Green Bond = 0

Variable (N = 2716)	Mean	St. dev.	Min	Max
Spread (bps)	115.037	76.137	-153	635
Coupon (%)	2.556	1.723	0	9.25
Coupon Frequency	1.489	0.500	1	2
Amount (M €)	1 617	3 195	228	24 810
Tenor (Years)	12.04	8.96	2	50
Rating	5.332	2.953	1	10
Covered	0.142	0.350	0	1
Guaranteed	0.182	0.386	0	1
Callable	0.402	0.490	0	1

Green Bond = 1

Variable (N = 649)	Mean	St. dev.	Min	Max
Spread (bps)	116.576	75.098	-1	492.8
Coupon (%)	2.308	1.702	0	7.5
Coupon Frequency	1.302	0.459	1	2
Amount (M €)	1 032	1 791	228	22 210
Tenor (Years)	10.46	7.13	2	50
Rating	5.755	2.984	1	10
Covered	0.080	0.272	0	1
Guaranteed	0.190	0.392	0	1
Callable	0.510	0.500	0	1

Notes: Spread denotes the yield spread over benchmark interest rate; Coupon (%) is the annual coupon rate; Coupon frequency is the annual frequency of the coupon payments (1 = Annual, 2 = Semiannual); Amount (M€) is the issuance volume converted to EUR millions; Tenor (Years) is the difference between maturity date and issue date in years; Rating is the S&P equivalent credit rating (AAA = 1, BBB- = 10); Covered, Guaranteed and Callable are dummy variables where Yes = 1 and No = 0.

According to the statistics, the mean green bond in the dataset has 1.5 basis points higher yield spread over the benchmark interest rate while having a lower coupon. Green bonds have noticeably lower volume, shorter time to maturity and worse credit rating than the conventional bonds in the sample.

4.1 Propensity score matching

To efficiently identify the impact of green bond label on a bond, the bonds are divided into two groups based on the green bond label: a treated group comprised of green bonds, and a control group including conventional bonds. The effect of the "treatment", i.e., bond being green, is analysed by comparing bonds from these two groups together. In ideal testing environment one could observe both outcomes at the same time but unfortunately, this is not possible with bonds as simultaneous issues of both green and conventional bonds are extremely rare. This problem results bonds having different characteristics within their groups apart from the treatment status. To overcome this issue, a matching method is used to construct the treatment and control groups. Taking all relevant observable bond characteristics X from treated group and using them to find a nearly identical control group avoids the selection bias of manually choosing bonds for treatment and control groups and gives an accurate estimation of the treatment effect. However, as the number of X characteristics increases, it becomes more difficult to find comparable observations (problem known as curse of dimensionality). In previous notorious studies, matching on multiple exact variables has greatly reduced the number of observations. For example, Flammer (2021) analyses 152 green bonds and Zerbid (2019) 135 green bonds.

One way to combat curse of dimensionality issue is to use single-index balancing score, which is a bundle of all characteristics X in a single variable introduced by Rosenbaum and Rubin (1983). The calculated single-index variable, also known as propensity score, can be used to find the treatment effect the same way as matching observations on all covariates. This propensity score (PS) matching method to estimate the average treatment effect on the treated (ATT) has been utilized before in green bond studies by Gianfrate & Peri (2019), Löffler et al. (2021), and Teti et al. (2022) to great effect, and will be the method of choice for this study.

Estimating the effect of a treatment using this method is a two-step process. First, Probit or Logit model is used to predict the probability of bond being a green bond given the observable pre-treatment characteristics. Second, the treated observations (green bonds) are matched with control observations (conventional bonds) using the propensity scores estimated in the first step. (Wamser, 2014) The ATT is the difference in outcome variable (Yield spread) between the matches and will be the focus of this study. In general, the estimator for ATT can be written as (Teti et al., 2022):

$$\tau_{ATT}^{PSM} = E(\tau | P(X), D = 1) = E[Y(1) | P(X), D = 1] - E[Y(0) | P(X), D = 0]$$

Where $P(X)$ is propensity score, a logit/probit model with D as dependent variable and X as independent variables, defined as $P(X) = P(D = 1 | X)$. The score is conditional probability of receiving treatment given pre-treatment characteristics X.

To use propensity score matching, few assumptions must hold. Conditional independence assumption (CIA) assumes that the outcome variable (Yield spread in this study) is independent of treatment conditional on the propensity score. All variables that affect the treatment and the outcome must be observable and included in the model. This assumption is strong and impossible to verify whether all relevant characteristics are controlled. Second assumption is that the treatment effect for an observation is not affected by the treatment status of another. Third condition is a requirement that the propensity scores of treated, and control groups overlap i.e., are on the common support. Final condition is that observations with similar propensity scores must have same observed characteristics i.e., the differences between variables in treatment and control groups within certain propensity scores are not statistically significant.

Using propensity score matching allows for multiple different matching methods to be used. This study will use three different methods. In nearest neighbour (NN) matching pairs are matched in terms of propensity score with treated observation matching with closest control observation. This can be done with replacement where same control unit can match with multiple treated units or without replacement i.e., control units can be used only once during the matching procedure. Without replacement method reduces the number of available observations, therefore it performs poorly with low observation numbers or if propensity scores do not overlap. The results also depend on the matching order and allowed score difference within pairs should be controlled to have better quality pairs. Nearest neighbour matching with replacement also allows for the treatment to be matched with multiple near control variables enhancing the quality of average matches but increasing the variance (Smith and Todd, 2005). Additionally, the method forces treated units to be matched with the set number of control units indifferent from the propensity score distance.

Radius matching enables to set a propensity score radius in which control units are matched per treated unit. Therefore, it combats the issue of NN matching with multiple matches by defining the range of propensity scores. Effect of used control units in range are weighted based on the distance from the treated unit. The downside of the method is the difficulty of estimating what radius is sufficient and if propensity scores are balanced, radius matching can create bad matches compared to NN.

Kernel matching uses all the observations for matching by giving weights based on the distance of propensity scores between treated and control units. This improves the matches for rare propensity scores within the common support and potentially reduces bias by not discarding control units. Disadvantages of this method are the lack of exact matches and possible biases at the start and end of the propensity score distribution.

4.2 Variable selection

Variables for the propensity score estimation model for this study can be chosen from three sets: all variables that affect the treatment assignment, all variables that affect the outcome or mix of both sets (Austin, 2011). Studying different PS models has shown that the optimal model includes variables affecting the outcome but not the treatment assignment (Brookhart et al., 2006). Furthermore, including these variables decrease the variance of treatment effect without increasing bias, while introducing exposure related variables only increase the variance. In this study's context the set of variables included in the model should be related to bond yield spread and not to sustainability-linked factors such as company's ESG score.

Green bond issuances are backed with by the issuers balance sheet, not by the project itself making the fundamental risk factors equal between conventional and green bonds (Löffler et al., 2021). With this in mind, adequate independent variables for the model should be factors that affect bond pricing. Prior green bond pricing study by Teti et al. (2022) where propensity score matching was used introduced factors such as volume, coupon, tenor, and rating to study Italian bond market. In addition, Gianfrate and Peri (2019) included controls for issuance year, sector, and covered bonds. Earlier yield spread literature suggests that bond callability (Duffee, 1998) and guarantees (Chen et al., 2020) could also affect bond pricing. Motivated by the literature the model used for propensity score in this study includes controls for coupon, coupon frequency, issuance volume, rating, currency, callability, and guarantees.

5 RESULTS

The results are structured as follows: In paragraph 5.1 I run a cross-sectional regression in primary market for the comprehensive sample and subsamples of corporate and non-corporate issuers i.e., governments, supranational institutions, agencies and banks, and euro and dollar denominated bonds. In paragraph 5.2 I analyse results given by the propensity score matching method on the samples using nearest matching without replacement, with replacement and with 3 matches for each green bond. Additionally, I will utilize radius matching with two different radiuses and kernel matching method. Finally, in paragraph 5.3 I use matched sample created by the nearest matching without replacement - method and analyse the existence of the green bond premium in secondary market where I can control for liquidity with bond bid-ask spread.

5.1 OLS regression

Table 2 presents the results from the cross-sectional regression on the yield spread at issuance for the whole sample and four subsamples. Green bond dummy variable is statistically significant at 1% level in the whole sample indicating -8.79 basis points lower yield spreads. Non-corporate and euro denominated subsamples show significant lower spreads of -13.39 and -11.39 respectively for green bonds. In dollar denominated and corporate samples the green bond label however does not affect yield spread.

Inspecting other variables reveals differences in characteristics affecting yield spread. Higher coupon frequency has a major effect on the spread in euro denominated bonds while it has no effect on bonds issued in dollars nor in bonds issued by corporates. Tenor is mostly insignificant across samples likely due to time to maturity being reflected in the coupon of the bond. Issue volume has a large positive effect in the corporate sample. The coefficient might be related to the smaller sizes of corporate issues as in the sample average size of corporate issues is 679 million EUR compared to 2,160 million EUR in non-corporate subsample. Nonetheless, basic OLS regression with a green dummy is not enough to determine whether the green bond premium exists within the sample. To address selection bias and control for confounding variables, the bonds are matched to properly identify the effect of green bond label.

Table 2
Cross-sectional regression - Primary market

	Dependent variable: Yield Spread at issuance (bps)				
	Whole sample	Corporate	Non-Corporate	Euro	Dollar
Green Bond	-8.684 ***	-2.136	-12.655 ***	-11.972 ***	-1.709
	(2.109)	(2.995)	(2.970)	(2.599)	(3.272)
Coupon	24.908 ***	29.305 ***	21.791 ***	25.013 ***	24.066 ***
	(0.823)	(1.557)	(0.896)	(1.021)	(1.380)
Coupon Frequency	-56.550 ***	61.199	-59.188 ***	-122.137 ***	9.161
	(12.076)	(214.846)	(12.068)	(12.776)	(9.147)
Tenor	-0.030	-0.004	0.003	-0.660 ***	0.247
	(0.110)	(0.154)	(0.183)	(0.169)	(0.159)
Rating	12.915 ***	10.491 ***	13.779 ***	11.933 ***	14.981 ***
	(0.402)	(0.727)	(0.555)	(0.552)	(0.630)
Amount (B €)	-3.042 ***	17.167 ***	-3.083 ***	-2.244 ***	5.543 **
	(0.428)	(4.394)	(0.440)	(0.439)	(2.480)
Currency	-4.732	123.619	-15.324		
	(12.102)	(214.870)	(12.073)		
Covered	6.778 ***		9.538 ***	1.818	52.684 ***
	(2.326)		(2.395)	(2.433)	(19.471)
Guaranteed	-1.163	4.225	-8.378 ***	0.555	-2.890
	(2.097)	(3.457)	(2.629)	(2.507)	(3.615)
Callable	-1.310	1.406	17.864 **	0.116	-5.934
	(2.465)	(5.211)	(8.777)	(3.651)	(3.859)
Constant	74.176 ***	-181.306	88.664 ***	146.387 ***	-74.572 ***
	(23.522)	(429.725)	(23.288)	(11.060)	(17.199)
Observations	3 365	1 490	1 875	1 842	1 523
R^2	0.589	0.430	0.640	0.652	0.539

Notes: Coupon (%) is the annual coupon rate; Coupon frequency is the annual frequency of the coupon payments (1 = Annual, 2 = Semiannual); Amount (M€) is the issuance volume converted to EUR millions; Tenor (Years) is the difference between maturity date and issue date in years; Rating is the S&P equivalent credit rating (AAA = 1, BBB- = 10); Covered, Guaranteed and Callable are dummy variables where Yes = 1 and No = 0. Robust standard errors. Standard errors in brackets. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels. Covered dummy omitted from corporate subsample due to insufficient observations.

5.2 Propensity score estimation

First step of the matching process requires the calculation of propensity scores based on set of variables as described in chapter 4. The scores will be estimated using a probit model. After the estimation, the common support condition is satisfied by discarding extreme propensity scores until treatment and control groups overlap. Finally, the propensity scores are divided into blocks with similar scores. If a block is not balanced, it will be divided into smaller blocks until the scores are balanced. Additionally, when the propensity scores have been balanced, the variable balance between treatment and control group within blocks is tested. If the differences are significant, the model must be re-specified with different variables.

The variable balancing condition caused multiple issues for this study as there are no specific guidelines to follow on how to achieve balance. I tested several different sets of variables and different variable transformations until arriving at a model that was balanced. The final probit model used, and coefficients are shown in Table 3.

Table 3
Estimation of propensity score - Probit regression

Log likelihood = - 1525.88				
Green Bond	Coefficient	Std. err.	z	P>|z|
Coupon	0.014	0.019	0.74	0.458
Coupon Frequency	0.228	0.258	0.89	0.375
Tenor Group	-0.037	0.049	-0.76	0.448
Rating	-0.029	0.012	2.46	0.014
Amount (Ln)	-0.410	0.042	-9.77	0.000
Currency	1.000	0.262	3.81	0.000
Covered Bond	-0.870	0.105	-8.32	0.000
Guaranteed Bond	-0.036	0.067	-0.54	0.592
_cons	6.936	0.897	7.73	0.000

Note: Tenor group is a categorical variable based on the maturity (short-term 2-3 y, medium-term 4 – 10 y, and long-term over 10 y). Amount (Ln) is the natural logarithm of volume. Currency is a dummy variable where 0 = Dollar and 1 = Euro.

Based on the probit coefficients coupon, coupon frequency, and currency are positively associated with green bonds. Tenor, rating, volume, covered, and guaranteed bonds are negatively associated with being green. The coefficient directions are in-line with previous literature which has found that green bonds tend to be issued by less creditworthy issuers, the volumes are lower, and time-to-maturity shorter than with conventional bonds. Positive currency coefficient can be attributed to the euro areas leading position in green finance and action against climate change.

The lowest maximum propensity score and highest minimum score act as range for the matching. The region of common support for the estimated propensity scores is [0.019; 0.468]. As matches are restricted to be only based on the common range of propensity scores they are made only within these scores. The median PS is 0.159 which signifies that half of the bonds in the sample have a lower likelihood of being green. Further description of the common support region is available in Appendix 2. Ultimately, the units are divided into 8 blocks based on propensity scores. Number of observations per block and inferior bound of propensity score is shown in Table 4. A total of 2.711 conventional bonds are within common support indicating that 5 conventional bonds lie outside the range and are excluded from the analysis.

Table 4
Inferior bound

Inferior of block of pscore	Green		
	0	1	Total
.0190016	285	11	296
.0714286	984	134	1 118
.1428571	932	196	1 128
.2857143	307	152	459
.3571429	83	38	121
.375	55	44	99
.3928571	38	51	89
.4285714	27	23	50
Total	2 711	649	3 360

An additional balancing property test for nearest matching without replacement is highlighted in Table 5. Null hypothesis for the tests is that the means are equal between control and treatment groups. Unmatched refers to the sample before matching and matched after matching and the results indicate that matching reduces biases drastically. Percentage bias for all variables is below the 10 % threshold after matching. Rubin's B which measures the absolute standardised difference of the means of propensity scores in unmatched and matched is 12.5, below the suggested value of 25 (Rubin, 2001). Furthermore, Rubin's R, measuring the ratio of treated to control variances of propensity scores is between 0.5 and 2. Based on the test the balancing property is satisfied and comparing the groups within matched sample should give robust evidence whether the green bond premium exists in the sample.

Now after all conditions for propensity score matching have been satisfied, I can begin to observe the average treatment effect on the treated being the yield spread differences between green and conventional bonds.

Table 5
Pstest - balancing property

Variable	Unmatched / Matched	Mean Treated	Mean Control	% Bias	% Reduction Bias	t-test t	t-test |p|>t
Coupon	U	2.308	2.557	-14.5		-3.31	0.001
	M	2.308	2.322	-0.8	94.4	-0.15	0.881
Coupon Frequency	U	1.302	1.489	-39.0		-8.71	0.000
	M	1.302	1.305	-0.6	98.4	-0.12	0.904
Tenor Group	U	2.193	2.217	-4.5		-0.99	0.323
	M	2.193	2.191	-0.6	93.6	0.05	0.956
Rating	U	5.755	5.336	14.2		3.27	0.001
	M	5.755	5.618	4.6	67.5	0.86	0.392
Amount (Ln)	U	20.396	20.625	-30.4		-6.47	0.000
	M	20.396	20.36	4.8	84.3	1.05	0.294
Currency	U	0.698	0.511	38.9		8.67	0.000
	M	0.698	0.695	0.6	98.3	0.12	0.294
Covered Bonds	U	0.080	0.142	-19.9		-4.25	0.000
	M	0.080	0.100	-6.4	67.9	-1.26	0.904
Guaranteed	U	0.190	0.182	1.9		0.43	0.668
	M	0.190	0.159	7.9	-323.9	1.46	0.143

Sample	Ps R^2	LR X^2	$p > X^2$	MeanBias	MedBias	B	R
Unmatched	0.075	248.33	0.000	20.4	17.2	70.9*	1.01
Matched	0.003	5.09	0.748	3.3	2.7	12.5	1.07

* if B>25%, R outside [0.5; 2]

Notes: Ps R^2 is the pseudo R^2 from probit estimation of the conditional treatment probability on all variables. LR X^2 is the likelihood-ratio test of joint insignificance of all regressors. B and R are Rubin's B and R measures respectively.

5.3 Primary market analysis

Table 6
Primary market treatment effects (bps)

Whole sample

Spread at Issuance	NN no rep	NN with rep	NN N = 3	Radius 0.001	Radius 0.0005	Kernel
ATT	-5.361	-5.943	-6.342	-6.684 *	-8.494 **	-7.614 **
Std. Err.	3.966	4.601	3.940	3.773	3.932	3.474
n. treat	649	649	649	638	610	649
n. contr.	649	449	1 082	2 358	1 955	2 716

Notes: NN no rep = Nearest neighbour without replacement. NN with rep = Nearest neighbour with replacement. N.treat and n. contr. report the number of used treatment and control observations respectively. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels.

I begin the analysis by matching bonds from the whole sample. Nearest Neighbour (NN) matching with no replacement matches a treated unit with a single control unit, and control units can only be used once in the matching process. As a result, all 649 green bonds are matched with 649 conventional bonds. The resulting ATT although negative, is not statistically significant. With replacement matching reduces the number of control bonds to 449 and the ATT remains insignificant. Matching a green bond with three nearest conventional bonds does affect the outcome either. With radius and kernel matching however, the average treatment effect on the treated is significant and negative. Radius matching with 0.001 propensity score range results a -6.684 basis points effect on the spread at issuance for green bonds, significant at 10 % level. Narrowing the radius in half to 0.0005 increases the premium to -8.494 basis points which is significant at 5 % level. Kernel matching using all of the observations on the common support with weighting reports a -7.614 basis point lower spread at issuance for green bonds at 5 % significance level. These results are reported in Table 6. Overall, the findings are somewhat inconsistent for the whole sample with small evidence for the existence of the green bond premium.

Finding no evidence for the presence of premium is consistent with previous literature examining international primary market samples. Earlier studies from Fatica et al. (2021), Flammer (2021), Kapraun et al. (2021), and Tang & Chang (2020) did not find a premium when examining the whole sample, but the premium appeared when examining different issuer types or currencies.

Table 7
Primary market treatment effects (bps)

Subsample - Corporate issuers

Spread at Issuance	NN no rep	NN with rep	NN N = 3	Radius 0.001	Radius 0.0005	Kernel
ATT	-3.554	-2.329	-1.119	-0.986	-2.628	-1.285
Std. Err.	5.301	6.401	4.922	4.811	5.293	4.181
n. treat	352	352	352	332	292	352
n. contr.	352	254	593	917	685	1 065

Subsample - Non-corporate issuers

Spread at Issuance	NN no rep	NN with rep	NN N = 3	Radius 0.001	Radius 0.0005	Kernel
ATT	-9.337	-12.203 *	-12.870 **	-13.414 **	-13.668 **	-11.803 **
Std. Err.	5.857	6.620	5.521	5.320	5.922	4.919
n. treat	292	292	292	284	273	292
n. contr.	292	226	536	1 108	757	1 561

Notes: NN no rep = Nearest neighbour without matching. NN with rep = Nearest neighbour with replacement. N.treat and n. contr. report the number of used treatment and control observations respectively. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels.

I divide the sample into two based on issuer type to further analyse the yield spreads at issuance. First group holds corporate issuers and second non-corporate issuers including agencies, governments, supranational institutions, and banks. In terms of number of bonds, corporate subsample holds 352 green bonds and 1,138 conventional bonds, from which 1,065 conventional bonds are on common support after estimating the propensity scores. In the other sample there are

297 green bonds and 1,578 conventional bonds. After calculating propensity scores, 5 green bonds and 17 conventional bonds are off support.

Conducting matching within two different issuer types reveals differences. In bond issuances by corporates the green bond label has no effect on the primary market yield spreads. All the estimated ATTs are highly insignificant in every matching method. Examining results from non-corporate sample reveals a different picture. Average treatment effect on the treated is significant in every method except nearest neighbour without replacement. The difference in spreads between green and conventional bonds is noticeable ranging between -13.668 to -11.803 basis points.

Corporate issues not exhibiting a premium is in line with findings from Flammer (2021) and Tang & Chang (2021) and in contrast to results from Fatica et al. (2021), Gianfrate & Peri (2019), Kapraun et al. (2021), and Teti et al. (2022). Non-corporate issuer green bond premium is an often-documented phenomenon and supported widely by earlier studies. Due to conflicting conclusions from prior studies every result, whether it is premium, discount or no evidence for either is supported by some studies.

However, the effect of currency on primary market yields is less documented and could be the driver of results due to more pro-environmental stance of euro area. To study effects of currency, the original sample is divided into euro and dollar denominated bonds. Euro denominated sample has in total 453 green bonds and 1,389 conventional bonds from which 14 conventional bonds are off support. Dollar sample holds 196 green bonds and 1,327 conventional bonds, but propensity score estimation leads to dismissal of 18 conventional bonds. Table 8 reports the results from currency groups.

Table 8
Primary market treatment effects (bps)

Subsample - Euro denominated						
	NN	NN	NN	Radius	Radius	Kernel
Spread at Issuance	no rep	with rep	N = 3	0.001	0.0005	
ATT	-7.317	-3.196	-6.597	-8.923 *	-8.605 *	-11.394 ***
Std. Err.	5.096	5.806	5.045	4.871	5.072	4.379
n. treat	453	453	453	431	397	453
n. contr.	453	315	699	1 051	797	1 375
Subsample - Dollar denominated						
	NN	NN	NN	Radius	Radius	Kernel
Spread at Issuance	no rep	with rep	N = 3	0.001	0.0005	
ATT	4.652	7.369	0.421	-2.962	0.070	-4.192
Std. Err.	6.798	7.414	6.100	5.626	5.935	5.297
n. treat	196	196	196	194	190	196
n. contr.	196	158	401	981	717	1 309

Notes: NN no rep = Nearest neighbour without matching. NN with rep = Nearest neighbour with replacement. N.treat and n. contr. report the number of used treatment and control observations respectively. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels.

Euro sample shows evidence for the existence of greenium. ATT measured using radius matching methods is significant at 10 % level from -8.923 to -8.605 bps in size. Average treatment effect on the treated calculated using Kernel matching is highly significant at 1 % level and larger than results from radius matching at -11.394 basis points. In contrast, dollar sample exhibits no premium, and the insignificant ATTs are mostly positive. The results are similar to Kapraun et al. (2021) paper where they reported a premium of -8.69 basis points for euro denominated bonds and no significant premium for dollar.

5.4 Secondary market analysis

Issue with primary market analysis is the lack of control for liquidity risk. The lower yield spreads for green bonds could be explained due to higher liquidity of these bonds in the secondary market. For this analysis, I use the sample created by the nearest matching method without replacement and run a panel regression for the secondary market yield spread over benchmark yield curve. Similar to Zerbib (2019) study, the analysis will use closing percent quoted bid-ask spread as proxy of liquidity, which has been argued to be best liquidity proxy for research by Fong et al. (2017). The liquidity measure for given time interval s is defined as

$$\text{Percent Quoted Spread}_s = (\text{Ask}_s - \text{Bid}_s) \,/\, ((\text{Ask}_s + \text{Bid}_s)/2)$$

where Ask_s is the closing ask quote and Bid_s is the closing bid quote in the time interval. Additionally, secondary market analysis will introduce time-to-maturity as variable.

Unfortunately, secondary market data for ask, bid, and yield spread was not available for every bond in the matched sample of 1,298 bonds. A total of 28 bonds were missing data for at least one of the variables, which resulted in omitting the bonds and their matches from the dataset leaving 1,242 bonds for the secondary market analysis. Due to sheer amount of data, I had to conduct the analysis on monthly basis. The final panel data consists of 51,108 monthly observations and results are presented in Table 9.

The analysis shows no evidence of green bond premium in the secondary market in line with the original 1:1 NN matched sample that showed insignificant premium in the primary market, although radius and kernel matching provided evidence for green bond premium in the primary market. In the corporate and dollar subsamples the analysis shows no evidence of premium, consistent with propensity score matching results. In contrast the euro denominated sample, which supported the notion of premium in the primary market, has no significant green label effect in the secondary market. However, the premium in the non-corporate issuances carries over to secondary market and is highly statistically significant with a -6.254 basis point effect on the yield spread. The premium is lower than in the primary market. These secondary market findings are in line with earlier literature. Gianfrate & Peri (2019), Kapraun et al. (2021) and Löffler et al. (2021) report a decrease in premium size after the bond begins to trade in the secondary market after controlling for liquidity.

Table 9
Pooled OLS - Secondary market

	Dependent variable: Yield Spread (bps)				
	Whole sample	Corporate	Non-Corporate	Euro	Dollar
Green Bond	-3.043	2.527	-6.254 ***	-1.666	-2.837
	(2.035)	(3.973)	(1.302)	(1.971)	(5.208)
Liquidity	1.403 ***	1.550 ***	1.063 ***	1.293 ***	0.326
	(0.244)	(0.349)	(0.173)	(0.217)	(0.523)
Time to maturity	1.145 ***	1.138 ***	1.317 ***	1.502 ***	1.597 ***
	(0.196)	(0.282)	(0.135)	(0.372)	(0.253)
Coupon	10.867 ***	10.066 ***	9.597 ***	9.796 ***	10.536 ***
	(1.132)	(1.935)	(1.409)	(1.092)	(1.460)
Rating	13.541 ***	8.012 ***	15.709 ***	14.597 ***	14.468 ***
	(1.932)	(1.414)	(1.190)	(1.279)	(3.072)
Amount (B €)	-0.490	-4.500	-0.259	-0.518	-3.604
	(0.732)	(6.932)	(0.579)	(0.579)	(4.705)
Currency	29.137 ***	37.010 ***	18.598 ***		
	(5.435)	(10.518)	(3.361)		
Covered	8.872		16.168 ***	10.089	28.294 ***
	(6.410)		(4.548)	(5.248)	(10.481)
Guaranteed	-9.802 **	-8.460	-6.626	-12.211	6.207
	(4.766)	(7.115)	(5.877)	(7.543)	(8.000)
Callable	9.324	13.836 *	-14.495 **	13.318 *	2.786
	(6.136)	(8.013)	(5.503)	(6.774)	(4.316)
Constant	-30.617 **	-10.683	-13.720	-5.847	-32.010 *
	(13.632)	(20.906)	(10.657)	(9.791)	(18.789)
Sector FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Observations	51 108	26 469	24 647	34 899	16 209
Adjusted R^2	0.696	0.648	0.732	0.728	0.720

Notes: Yield spread is spread over equivalent government benchmark bond curve. Liquidity is closing percent quoted spread in basis points. Time to maturity is bond's life to maturity. Data is in monthly frequency. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels.

Previous studies have connected the greenium to credibility of the issuer based on the findings that bonds by supranational and government issuers show evidence of premium while banks do not. To study this argument, I divide the non-corporate sample into two groups: banks and SSAs, which includes sovereigns, supranationals, and agencies. Both groups show statistically significant premiums, however the premium effect is stronger for banks, conflicting with the notion that bank issues do not trade at a premium due to green investors not being able to make a connection with the issue and underlying green project (Fatica et al., 2021).

Table 10

Pooled OLS - Non-corporate sample

	Dependent variable: Yield Spread (bps)	
	Banks	SSA
Green Bond	-5.294 **	-2.744 **
	(1.915)	(0.977)
Liquidity	1.440 ***	0.352 ***
	(0.194)	(0.111)
Time to maturity	2.426 *	1.588 ***
	(1.289)	(0.160)
Coupon	11.290 ***	1.469
	(0.607)	(1.269)
Rating	13.903 ***	14.967 ***
	(1.494)	(3.169)
Amount (B €)	-0.183	-0.697
	(3.168)	(0.816)
Currency	17.045 ***	18.074 ***
	(4.731)	(3.343)
Covered	7.621	
	(6.073)	
Guaranteed	-21.745 **	-5.065 **
	(8.126)	(2.096)
Callable	-15.915 *	15.282 ***
	(7.704)	(4.431)
Constant	-6.670	-10.418
	(10.697)	(6.644)
Sector FE	Yes	Yes
Time FE	Yes	Yes
Observations	14 805	9 842
R^2	0.703	0.725

Notes: Yield spread is spread over equivalent government benchmark bond curve. Liquidity is closing percent quoted spread in basis points. Time to maturity is bond's life to maturity. Data is in monthly frequency. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels.

For final analysis I study the effect of increasing supply on the green bond premium. Zerbib (2019) and Teti et al. (2022) both noted how the greenium increased towards end of their sample. A latter study argued that the increasing premium from June 2020 to June 2021 might have been due to demand-supply mismatch where demand was outpacing supply growth causing larger premiums to occur. The study, however, was conducted on small sample of Italian bonds and did not control for liquidity. Figure 1 presented in the Introduction showed how the total yearly volume of green bond issuances almost doubled from EUR 300 billion in 2020 to nearly EUR 600 billion in 2021 and remaining high at over EUR 500 billion for 2022 and 2023. This drastic market growth might have had an impact on the green bond premium and remedied the supply-demand imbalance. Indeed, plotting the mean yield spreads over time for the whole sample plotted in Figure 3 shows how the pricing has steadily equalized between conventional and green bonds, especially after the year 2021 in my sample. To account for this jump in supply I examine the sample before and after the year 2021.

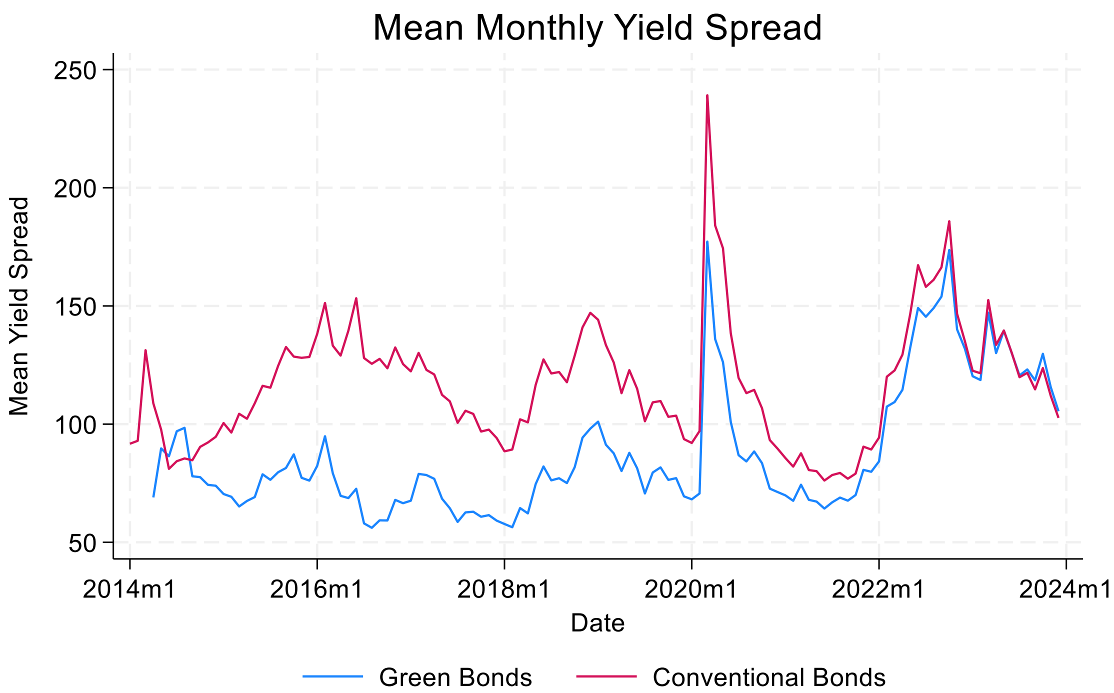

Figure 3 Mean monthly yield spreads of green and conventional bonds.

Table 11 introduces the results for divided sample. Green bond dummy before the year 2021 is significant at 1 % level for the three samples and the effect of the dummy on yield spread is -6.923 basis points in the whole sample. After 2021 the greenium disappears from the whole and corporate sample but remains for the non-corporate sample. The greenium for the non-corporate sample in the later period is -5.085 basis points, lower than the -6.486 basis points in the earlier period, but still significant indicating persistent demand for green bonds by non-corporate issuers. The same effect is consistent within the non-corporate sample

(Appendix 2) where government issuances present a premium of -5.275 basis points before 2021, which disappears in later sample. For banks the effect is opposite where the greenium is insignificant before 2021 but significant at 5 % level in the after 2021 sample. Overall, based on the premium sizes the green bond premium has nearly vanished from 2021 onwards possibly due to increasing supply. Market wide premium has dissipated, and the effect is currently only present in non-corporate issuances indicating that the demand has mostly been satisfied.

Table 11
Pooled OLS - Secondary market

	Before 2021			After 2021		
	Whole sample	Corporate	Non-Corporate	Whole sample	Corporate	Non-Corporate
Green Bond	-6.923 ***	-6.187 ***	-6.486 ***	-0.666	5.294	-5.085 ***
	(1.167)	(2.158)	(1.876)	(2.875)	(5.181)	(1.274)
Liquidity	0.911 **	0.977 *	0.672 ***	1.467 ***	1.874 ***	0.940 ***
	(0.367)	(0.539)	(0.200)	(0.262)	(0.308)	(0.215)
Time to maturity	0.313	0.776 **	0.000	1.431 ***	1.192 ***	1.771 ***
	(0.277)	(0.389)	(0.246)	(0.259)	(0.347)	(0.285)
Coupon	23.736 ***	15.605 ***	23.935 ***	8.454 ***	9.248 ***	6.777 ***
	(3.349)	(3.720)	(2.695)	(0.912)	(1.713)	(1.023)
Rating	13.438 ***	6.320 ***	15.383 ***	12.708 ***	8.851 ***	14.649 ***
	(1.931)	(1.557)	(0.802)	(1.674)	(1.556)	(1.246)
Amount (B €)	0.444	2.204	0.785	-1.234	-6.037	-1.122
	(0.910)	(6.872)	(1.016)	(1.098)	(7.373)	(1.002)
Currency	47.843 ***	44.788 ***	42.436 ***	30.509 ***	36.297 ***	21.532 ***
	(5.931)	(11.800)	(6.483)	(5.937)	(12.073)	(3.544)
Covered	1.232		8.853 **	8.786 *		14.432 ***
	(6.992)		(3.181)	(4.871)		(4.415)
Guaranteed	-3.992	-2.304	-4.340	-13.522 ***	-12.193 *	-9.963 *
	(4.266)	(7.614)	(5.501)	(5.043)	(7.388)	(5.668)
Callable	13.497 *	11.707	2.916	7.476	14.022 **	-15.716 ***
	(7.356)	(9.200)	(8.350)	(6.017)	(6.403)	(4.735)
Constant	-64.790 ***	-14.021	-47.054 ***	-19.982	-14.606	-4.661
	(16.589)	(17.087)	(13.054)	(12.263)	(22.129)	(9.781)
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17 709	9 206	8 501	33 398	17 252	16 146
Adjusted R^2	0.738	0.708	0.771	0.703	0.653	0.735

Notes: Yield spread is spread over equivalent government benchmark bond curve. Liquidity is closing percent quoted spread in basis points. Time to maturity is bond's life to maturity. Data is in monthly frequency. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels.

To study whether the issuance volumes indeed affect the size of greenium, I exported issuance volumes of bonds denominated in euros and dollars issued in Europe and U.S. from the start of 2014 to end of 2023 from LSEG. Furthermore, I calculated the monthly green bond issuance as percentage of total bond issuance for all issuers and by issuer type or currency. Figure 4 plots the monthly share of green bond issuance volumes to total issuance volumes. Noticeably the shares have been increasing over time, especially the post COVID-19 period with EUR denominated green bonds representing fifth of total EUR issuance volumes during a couple of months. USD green bonds have been stagnant, lagging the EUR market. Same observation can be made from the evolution of cumulative share of green bond issuances represented in Appendix 3 where the increase in volume from 2021 onwards is clearly visible although the total share has been stagnating towards the end of 2023.

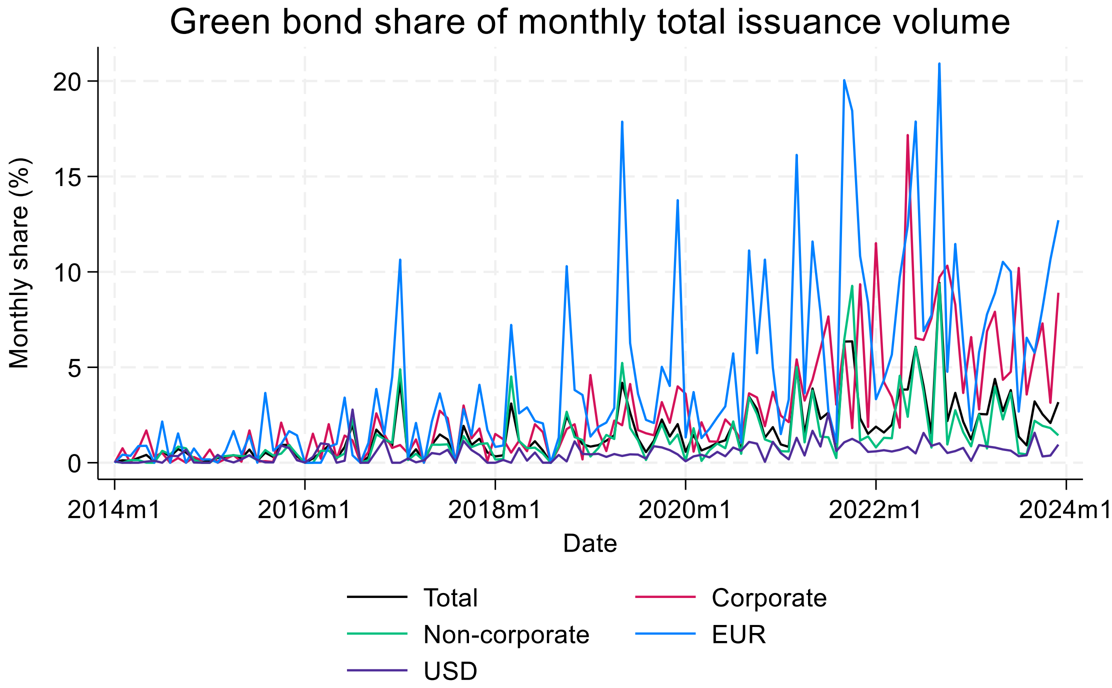

Figure 4 Monthly share of green bond issuance volumes to total monthly issuance volumes denominated in EUR and USD issued in Europe and United States.

Examining the effect of monthly green bond volume share of total issuance volume on green bond premium, presented in Table 12, shows statistically significant effect on the green bonds' yield spreads in whole, non-corporate and EUR denominated samples. The coefficients for green bond dummy range from -7.5 basis points to -3.7 basis points but are reduced when the market experiences surges in monthly issuance volumes. However, the effect is not significant for every sample used as corporate sample shows no significant reaction with the interaction variable while the USD denominated sample spreads react even though the premium is not significant. The highest premium and most muted reaction to increases in monthly %-share in the non-corporate sample supports the notion that pro-environmental investors have more demand for certain green bonds. To study the effect of varying issuance volumes further, I analyze the sample specific shares.

Table 12
Secondary market - Monthly green bond issuance volume to total bond volume

	Dependent variable: Yield Spread (bps)				
	Whole sample	Corporate	Non-Corporate	Euro	Dollar
Green Bond	-5.173 ***	0.165	-7.531 ***	-3.739 **	-4.872
	(1.639)	(3.031)	(1.501)	(1.595)	(5.387)
GB * Share $_{Total}$	0.848 **	0.929	0.510 *	0.826 **	0.807 *
	(0.412)	(0.688)	(0.287)	(0.402)	(0.480)
Liquidity	1.401 ***	1.547 ***	1.062 ***	1.293 ***	0.318
	(0.244)	(0.348)	(0.172)	(0.217)	(0.521)
Time to maturity	1.143 ***	1.137 ***	1.315 ***	1.500 ***	1.598 ***
	(0.196)	(0.282)	(0.136)	(0.371)	(0.253)
Constant	-30.484 **	-10.633	-13.627	-5.731	-31.848 *
	(13.573)	(20.877)	(10.628)	(9.784)	(18.639)
Issue Controls	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Observations	51 108	26 469	24 647	34 899	16 209
Adjusted R^2	0.696	0.648	0.732	0.728	0.720

Notes: Yield spread is spread over equivalent government benchmark bond curve. Liquidity is closing percent quoted spread in basis points. GB * Share is green bond dummy * monthly green bond issuance shares of total issuance volumes in percentages. Time to maturity is bond's life to maturity. Data is in monthly frequency. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels. Issue Controls include controls for coupon, rating, volume, currency, and dummies for bond being covered, guaranteed and callable.

Table 13 examines the effect of increasing green bond issuance volume shares of corporate, non-corporate, euro or dollar green bonds. Again, green bond premium in corporate green bonds is not significant but would seem to react to monthly issuance volumes of corporate green bonds more strongly. Overall, the subsamples have reduced reactions to their respective shares except for euro denominated sample where the coefficient is highly significant at 1 % level. Motivated by the finding the analysis is continued with just EUR share interaction variable. The variable is highly significant for the whole and non-corporate sample in addition to the EUR sample with relatively the same effect across samples. This finding suggests that the greenium is mostly affected by the evolution of the euro denominated green bond market. Overall, the results suggest that green bond premium does indeed decrease with increasing share of monthly green bond issuance. Corporate and dollar denominated green bonds do not show significant premiums, but their yield spreads widen as monthly issuance volumes increase. Per the results, euro and non-corporate green bonds show evidence of premium, but it could disappear as the market matures and issuances become more frequent.

Table 13

Specific shares

	Corporate	Non-Corporate	Euro	Dollar
Green Bond	-2.170	-7.029 ***	-4.581 ***	-4.545
	(2.845)	(1.371)	(1.683)	(6.182)
GB * Share $_{Corp}$	0.938 *			
	(0.565)			
GB * Share $_{Non}$		0.370 *		
		(0.195)		
GB * Share $_{Euro}$			0.399 ***	
			(0.129)	
GB * Share $_{Dollar}$				2.427
				(2.144)
Liquidity	1.542 ***	1.062 ***	1.292 ***	0.321
	(0.347)	(0.172)	(0.217)	(0.522)
Time to maturity	1.136 ***	1.316 ***	1.499 ***	1.597 ***
	(0.280)	(0.136)	(0.371)	(0.253)
Constant	-10.413	-13.678	-5.673	-31.954 *
	(20.775)	(10.641)	(9.775)	(18.700)
Issue Controls	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Observations	26 469	24 647	34 899	16 209
Adjusted R^2	0.649	0.732	0.728	0.720

Share of EUR issues

	Whole sample	Corporate	Non-Corporate	Dollar
Green Bond	-5.997 ***	-0.022	-9.079 ***	-5.494
	(1.847)	(3.114)	(1.672)	(5.846)
GB * Share $_{EUR}$	0.404 ***	0.345	0.388 ***	0.362 *
	(0.139)	(0.217)	(0.107)	(0.221)
Liquidity	1.400 ***	1.547 ***	1.062 ***	0.316
	(0.244)	(0.348)	(0.171)	(0.519)
Time to maturity	1.142 ***	1.137 ***	1.312 ***	1.598 ***
	(0.196)	(0.282)	(0.136)	(0.253)
Constant	-30.417 **	-10.616	-13.500	-31.786 *
	(13.504)	(20.870)	(10.584)	(18.565)
Issue Controls	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Observations	51 108	26 469	34 899	16 209
Adjusted R^2	0.697	0.648	0.731	0.720

Notes: Yield spread is spread over equivalent government benchmark bond curve. GB * Share is green bond dummy * monthly green bond issuance shares of total issuance volumes by characteristic in percentages. Liquidity is closing percent quoted spread in basis points. Time to maturity is bond's life to maturity. Data is in monthly frequency. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels. Issue Controls include controls for coupon, rating, volume, currency, and dummies for bond being covered, guaranteed or callable.

Dividing the non-corporate sample into issues by banks and others reveals an unexpected outcome. While greenium in bank issues lowers as EUR green bond issuances become more frequent similar to most other samples, yield spread of issues by governments, agencies, and supranational entities seem not to react to increasing volumes. It would appear that this sub-section of non-corporate issues is unique and the greenium is stable regardless of increases in supply indicating investors are preferring issues by governments over other issuer types as green bond become more available. The demand for government green bonds might be persistent and has spilled over to other issuer types due to insufficient supply.

Table 14

Secondary market - Non-corporate sample

	Dependent variable: Yield Spread (bps)			
	Banks	Banks	SSA	SSA
Green Bond	-7.725 ***	-6.625 ***	-1.634	-2.613 ***
	(1.855)	(1.676)	(1.299)	(0.888)
GB * Share $_{EUR}$	0.311 **		-0.163	
	(0.094)		(0.199)	
GB * Share $_{Banks}$		0.359		
		(0.245)		
GB * Share $_{Gov}$				-0.079
				(0.211)
Liquidity	1.438 ***	1.440 ***	0.351 ***	0.352 ***
	(0.194)	(0.194)	(0.110)	(0.111)
Time to maturity	2.426 *	2.425 *	1.591 ***	1.588 ***
	(1.288)	(1.290)	(0.159)	(0.159)
Constant	-6.620	-6.694	-10.450	-10.422
	(10.692)	(10.688)	(6.682)	(6.654)
Issue Controls	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Observations	14 805	14 805	9 842	9 842
Adjusted R^2	0.707	0.707	0.737	0.737

Notes: Yield spread is spread over equivalent government benchmark bond curve. GB * Share is green bond dummy * monthly green bond issuance shares of total issuance volumes by characteristic percentages. Liquidity is closing percent quoted spread in basis points. Time to maturity is bond's life to maturity. Data is in monthly frequency. (*) (**) (***) indicate significance at (10%) (5%) (1%) levels. Issue Controls include controls for coupon, rating, volume, currency, and dummies for bond being covered, guaranteed and callable.

5.5 Discussion

Overall, the results from the primary market are in line with prior literature and reinforce earlier findings. Existing studies focusing on multiple markets often find no greenium for the whole sample, but the greenium is restricted to certain markets or issuer characteristics. Propensity score matching conducted in this study found some evidence of greenium in the whole sample, but arguably the results are not significant enough to make strong arguments for or against market wide premiums. Considering the statistically significant kernel matching result, one must recall that the matching methods uses all the observations with weights depending on the propensity score distance from the treatment. This might not be an adequate method to be used for the whole sample as the observation characteristics vary widely. Same argument holds to a lesser extent for radius matching even though the used radius is narrow. As the further analysis showed, the premium presented in the whole sample is driven by non-corporate issuers thus notion of market wide greenium can be debunked. Euro denominated sample has again significant ATTs when using radius and kernel matching, but the results could be driven by non-corporate issuers as they represent over 70 % of the total euro denominated sample. Size wise the premiums vary from low of -6.684 bps in whole sample to a high of -13.668 bps in non-corporate issuer sample, which is reasonable considering the added costs of green bond issuances. Certification by Climate Bond Initiative costs 0.1 basis points of the whole issue volume (Gianfrate & Peri, 2019) and on average the total borrowing costs are up to 10 % higher for green securities compared to conventional securities (Larcker and Watts, 2020).

In the secondary market in the whole and non-corporate issuer samples greenium persists but is lower than in primary market. The lower secondary market premiums have been documented before by Gianfrate & Peri (2019), Kapraun et al. (2021), Löffler et al. (2021), and Teti et al. (2022). Greenium for non-corporate issuances is highly significant at 1 % level and present for both banks and government issuances. Earlier studies have argued that credibility of the issuer affects the greenium, and bonds by governments and supranational issuers often present higher premiums compared to issues by corporates and banks. The results from this study contrast this as the reported effect of the green bond label on the yield spread is higher for banks than other non-corporate issuers. It could be that the banks reporting frameworks have been vastly improved over the years and investors have been able to make the connection between bank issue and underlying green project resulting in bank issuances enjoying a premium in more recent data.

A new finding from this study was the effect of increased green bond supply on the greenium. Originally the idea was to study the three-year period of uncertainty in green bond market where the size of the premium could be affected in U.S. and possibly in the whole sample. On 1st of June 2017 Donald Trump announced the withdrawal of United States from the Paris Agreement of

2015. Due to restrictions within the agreement the withdrawal took place three years later 4th of November 2020. When newly elected Joe Biden took office, he signed an order to rejoin the Paris Agreement which officially took place on February 19, 2021. However, during this period my analysis showed significant greeniums for every year but 2017 possibly due to the effect being restricted to U.S. where green bonds have not been shown to be trading at a price difference consistently.

Dividing the sample to before and after 2021 reveals a market wide premium before 2021 when even green bond by corporations were trading at lower yield spreads in the secondary market. This changed after 2021 where according to the results, only non-corporate issuer bonds have been trading at a premium. My argument for the change is that the steadily increasing green bond market supply is satisfying the demand of environmentally conscious investors, reducing the premium. This could explain why my results do not show a premium for corporations, while prior studies with data ending before the year 2020 find a premium. The high demand for green bonds created a market wide premium, reaching even green bonds by corporations, which has been sated more recently as the monthly green bond issuance volumes have increased on average. For green investors this would mean that they do not have to compromise returns when investing in green bonds, and portfolio managers and traders would be willing to participate in the green bond market. However, for issuers the disappearing premium would create a situation where they are less incentivized to issue green bonds as they are costlier form of raising funds. Green bonds do offer signaling benefits (Flammer, 2021) which might be enough to warrant green issuances, but the benefits get lower for each additional issue. Considering why the bank issuances have significant premiums in the post-2021 sample while previous literature has not found such evidence could be due to better quality reporting and higher impact that might be attracting pro-environmental investors.

Green bond issuances by government, agencies, and supranational institutions not reacting to monthly green bond issuance volume fluctuations highlights their uniqueness pro-environmental investors eyes. It could be that these issues face the most demand due to possibly being seen as the most impactful and trustworthy. If the demand for SSA issuances is constantly high and spilling over to other issuer types during times of high demand, the green bond premium dissipates first in other issuances and then might start to affect these government issues. Examining Appendix 3 illustrates how the %-share of SSA green bonds to total issuance volume is the lowest of all analyzed issuer types. However, the total cumulative volume of green bond issuances (540 billion EUR) by government/other is the highest when compared to bank (280 billion EUR) and corporate (430 billion EUR) volumes. It is possible that as most literature has documented significant premiums, increasing number of issuers have tried to capitalize on the demand by issuing green bonds with lower environmental impact causing investor capital to pursue higher impact credible bonds from non-corporate issuers. Circling back to the Baker et al. (2018) model presented earlier in chapter 2, the green bond pricing should be higher as a higher proportion of capital is flowing to green investments. Given my results, the nonpecuniary utility effect lowering the returns diminishes as the green bond market has become more mature. Diminishing marginal utility could arise because of investors acquiring numerous green bonds resulting in decreased willingness to pay high premiums for additional green bonds.

A question remains: Should green bonds trade at a price difference? Considering that the issuance process is costlier for issuers, they should be compensated in some form. Bonds by listed corporates enhance their market valuations (Flammer, 2021), indicating that issuers gain reputational benefits from issuances which could be adequate compensation for at least listed corporate issuers. Furthermore, there are green incentives that compensate the issuer for undergoing green projects which outweigh the additional costs of green bond issuance. The incentives would mean that investors should not be made to pay the additional costs in the form of a green bond premium. On the other hand, the underlying green projects should decrease the climate risk of the issuer which in turn would warrant higher bond prices due to lower credit risk. Nevertheless, these might not hold in the current market where demand is reportedly higher than supply for reputable issuances and the green bond premium could be driven by scarcity. With institutional investors adopting ESG investment mandates at an increasing pace, the supply-demand mismatch could be distorted for the unforeseeable future until green bonds are adopted widely. The green bond market is still young, and a vast variety of different frameworks cause issues especially for green investors which affects the desirability of green bonds. The EU council adopted a new European green bond proposal on 23rd of October 2023 which will take effect this year. European green bonds will be aligned with EU taxonomy for sustainable activities in an attempt to create uniform regulation and framework for the whole European market (European Council, 2023). It is expected that the proposal will greatly improve one of the largest green bond markets and make the green bonds more transparent and reliable for investors creating additional demand.

5.6 Limitations and further research

This study faced multiple limitations that could affect the results. For instance, I was unable to verify the certification status of green bonds resulting in omitting the variable entirely. This is a major setback as multiple studies have argued that certification increases the green bond premium and could be major contributor. Additionally, importance of issuer sector ESG score was overlooked. It could be that investors prefer green projects in certain sectors over the other, for example polluting energy company undergoing a green project could be seen as more impactful, therefore warranting a premium. Or perhaps issues from sectors with low ESG scores are dismissed by investors as they prefer reputable green sectors.

The most glaring issue considering the data is that I was only able to attain issuance volumes and not outstanding bond volumes thus I could not create a variable for the levels of outstanding green bond volumes. Using just issuance volumes would have distorted the results as the data does not take account for bonds expiring. It is highly likely that the green bond interaction with the monthly issuance share varies depending on the green bond market saturation.

Considering the empirical analysis, if indeed reputation influences bond pricing, propensity score matching might not be the best methodology as issuers are not exactly matched. A problem might rise when a matching conventional bond is issued by a company which has a reputation of being highly environmental-friendly. In this case pro-environmental investors might prefer the company's issues whether they are green or conventional creating a premium even in their conventional bonds thus lowering the estimated ATT. Additionally, unlike previous studies by Bachelet et al. (2019), Kapraun et al. (2021), and Zerbib (2019) that used daily data in the secondary market, this study uses monthly data due to computing power limitations, which might affect the results. Observing secondary market variables on daily frequency would give more robust results and price volatility could be a factor explaining the price difference.

For future research green bonds offer multiple different avenues yet to be explored. Naturally my current analysis could be done with daily data, outstanding issuance volumes, and with omitted ESG and certification factors. The drivers for government, supranational institutions, and agency issuances could be examined as they seem to be different from the rest of issuer types. Furthermore, the effect of green bond issuance on the issuers other outstanding bond prices should be examined to uncover whether the assumed climate risk lowering attribute of green bond issuance truly lowers the perceived riskiness of issuers bonds. Finally, analysis of the riskiness of green bonds might provide an avenue helping to explain the possible pricing differences. Greenium could be a result of green bonds being less risky compared to conventional counterparts.

6 CONCLUSIONS

In this master's thesis I study the existence of green bond premium in U.S. and Europe bond markets, both in primary and secondary markets. While the possible effect of issue/issuer characteristics on the premium have been studied before, the market has been evolving at a rapid pace and especially the recent high number of issuances during the past three years has increased the available observations greatly, thus warranting a new thorough analysis. In addition to larger sample, I also examine the effect of monthly green bond market share on the premium to identify whether scarcity affects the size of the premium.

Using propensity score matching to create a sample of matching conventional and green bonds from 2014 to 2023, I show evidence of greenium existing for bonds issued by non-corporate issuers and weakly significant effect of green bond label on the whole sample and euro denominated bonds in the primary market. In secondary market using a matched sample from the primary market study, I found that the greenium decreases in size, but is still highly significant for non-corporate issuer bonds. Adding a green bond issuance variable shows that the yield spread of green bonds increase in non-corporate, dollar and euro samples as green bond issues account for larger percentage of total monthly issuances. These green bonds seem to react more significantly to increasing amounts of euro denominated green bonds indicating that the premiums are less reliant on overall supply but dependent on supply of green bonds having certain characteristics such as being denominated in euros. Green bonds by sovereigns, supranational institutions and agencies, however, does not react to monthly issuance volumes arguing for persistent demand for these assets.

Tastes for different green bonds has been documented numerous times before, thus this study reinforces the earlier findings with larger dataset. The finding of greenium reacting to monthly issuance volumes is new and would help partly explain the variation in results between the studies as the average green bond issuance share has increased steadily over time. Dissipating greenium as markets mature suggest that green bond markets are possibly becoming more saturated. The growing market might be attracting broader investor base who may not be willing to pay a premium but are looking for diversification or alignment with ESG criteria, equalizing the prices for most issuances. Yet the SSA subsample enjoys consistent premium despite maturing markets. Their issuances could be seen as most credible and impactful; thus, investors might have the strongest appetite for these bonds. Nevertheless, the finding offers a great avenue for further research.

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APPENDIX 1 SUMMARY OF LITERATURE

			Premium	
Author	**Data**	**Method**	**Primary market**	**Secondary market**
Bachelet et al., 2019	International sample from 2013 to 2017 89 green bonds	Matching method		Whole sample: +2.06 to +5.9 Private issuers: +2 to +3 No certification: +3.2 to +12.4 Institutional issuers: -0.9 to -1.87
Baker et al., 2018	U.S sample from 2010 to 2016 2083 green bonds from 190 issuers	Pooled fixed effect regression	Whole sample: -5 to -7 Certified bonds: -15 to -26	
Fatica et al., 2021	International sample from 2007 to 2018 1397 green bonds	OLS regression with a green dummy	Whole sample: No premium Supranational issuers: -80 Financial issuers: No premium Non-financial corporates: -22	
Flammer, 2021	International sample from 2013 to 2018 152 green bonds from 65 issuers	Matching method	No premium	
Gianfrate & Peri, 2019	European sample between 2013 and 2017 121 green bonds	Propensity score matching followed my assessment of average treatment effect on the treated	Whole sample: -14.8 to -19.4 Corporate issuers: -20 to -23 Non-corporate: -14 to -17	Whole sample: -5.4 to -13.8 Corporate issuers: -7.6 to -13.9 Non-corporate: -11.5 to -14.4
Kapraun et al., 2021	International sample from 2009 to Feb 2021 431 green bonds.	OLS regression for primary and secondary market with green dummy Matching method	Whole sample: No premium Certification: -16 No certification: No premium Large green bonds: -14 Sustainable country of issue: -22 Currency: EUR -9, No premium for other Government and supranational issuers: -18.5 Corporate issuers: -6	Whole sample: No premium Certification: -4 premium with large issues No certification: No premium Large green bonds: -6 Sustainable country of issue: -3.6 Currency: No premium Governments and supranational issuers: -4,5 Corporate issuers: No premium

	Data	Method	Primary market	Secondary market
Karpf & Mandel, 2017	U.S. municipal sample 1880 green bonds	Oxaca-Blinder decom-position of yield spread	Whole sample: +23	
Larcker & Watts, 2020	U.S. municipal sample from June 2013 to July 2018 2896 green bonds	Matching method	No premium	
Löffler et al., 2021	International sample from 2007 to October 2019, 2000 green bonds	Propensity score matching and coars-ened exact matching followed by regression with green dummy	Whole sample: -16 to -24	Whole sample: -15 to -21 Sample premium is driven by the years 2018 and 2019
Tang & Zhang, 2020	International sample from 2007 to 2017 41 green bonds	Comparison of green and conventional bond by the same firm, or firm with similar size, market to book and stock liquidity. Regres-sion of yield spread with green dummy.	No premium	
Teti et al., 2022	Italian sample from 2014 to June 2021 40 green bonds	Propensity score matching followed my assessment of average treatment effect on the treated	Whole sample: -28.9 to -39 Corporate issuers: -21 to -41	Whole sample: -12 to -37, in-creasing from June 2020 to June 2021
Zerbid, 2019	International sample from July 2013 to De-cember 2017 135 green bonds	Matching method fol-lowed by two-step re-gression		Whole sample: -2 Financial issuers: -2.5, -8 with low credit rating Currency: EUR bonds -1.7 and USD -2.3

APPENDIX 2 ADDITIONAL TABLES

APPENDIX 2, TABLE 1 Analysis of propensity score

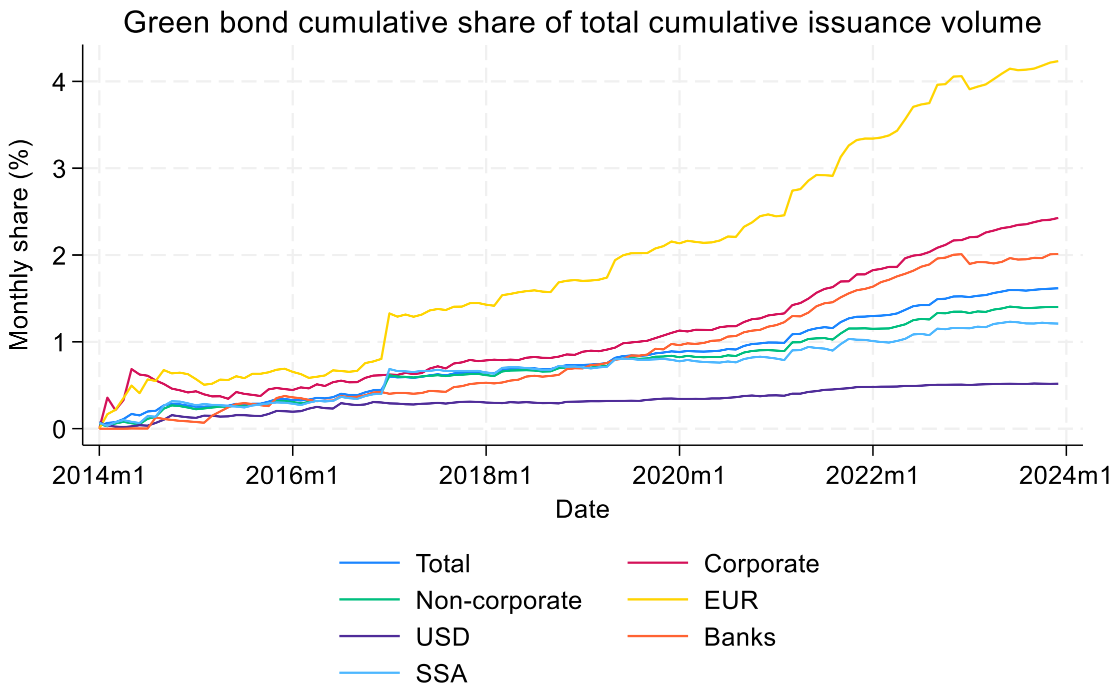
Description of estimated propensity score

	Percentiles	Smallest		
1 %	0.0397457	0.0190016		
5 %	0.0608075	0.0303929		
10 %	0.0742827	0.0308533	Obs	3,360
25 %	0.1055622	0.0311417	Sum of wgt.	3,360
50 %	0.1588753		Mean	0.1927255
		Largest	Std. dev.	0.10687
75 %	0.279779	0.4598672		
90 %	0.3602764	0.4627835	Variance	0.0114212
95 %	0.3846836	0.4633288	Skewness	0.6193898
99 %	0.4375939	0.468327	Kurtosis	2.216323

APPENDIX 2, TABLE 2 Pooled OLS within non-corporate sample

	Before 2021		After 2021	
	Banks	SSA	Banks	SSA
Green Bond	-3.353	-5.275 ***	-4.899 **	-2.008
	(2.724)	(1.717)	(1.963)	(1.504)
Liquidity	1.045 ***	-0.018	1.154 ***	0.524 ***
	(0.265)	(0.062)	(0.174)	(0.161)
Time to maturity	-0.940 *	1.386 ***	4.150 ***	1.685 ***
	(0.548)	(0.220)	(1.261)	(0.289)
Coupon	30.799 ***	-5.151 *	7.648 ***	2.520 *
	(1.513)	(2.927)	(0.610)	(1.356)
Rating	15.034 ***	16.094 ***	11.895 ***	14.474 ***
	(1.955)	(0.801)	(1.260)	(4.732)
Amount (B €)	2.302	-0.813	-5.641	-0.960
	(2.308)	(0.556)	(3.645)	(1.169)
Currency	53.207 ***	-3.373	18.241 **	26.400 ***
	(4.159)	(5.283)	(6.267)	(5.425)
Covered	15.280 *		-3.179	
	(7.731)		(4.805)	
Guaranteed	-24.599 ***	-7.780 **	-20.036 **	-3.213 **
	(6.964)	(2.824)	(8.775)	(1.427)
Callable	7.154		-18.668 **	13.749 **
	(9.800)		(8.990)	(4.735)
Constant	-59.520 ***	10.816	11.820 *	-14.105
	(15.687)	(7.551)	(6.818)	(10.650)
Sector FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Observations	4 762	3 739	10 043	6 103
Adjusted R^2	0.752	0.821	0.724	0.726

APPENDIX 3 ADDITIONAL FIGURES



APPENDIX 3, TABLE 1 Cumulative GB share of total issuance volume

APPENDIX 4 USE OF AI APPLICATIONS

I have used AI tools, specifically ChatGPT, to improve the readability and structure of the text. Additionally, I utilized the application to help write STATA scripts for the empirical analysis.