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JUSTINA VYŠNIAUSKAITĖ

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THE PREMIUM OF GREEN CORPORATE BONDS

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1 INTRODUCTION

Climate change presents a significant challenge to the global economy and ecosystem, emphasising the need for immediate action as outlined in the Paris Agreement. Paris Agreement is an act, signed in 2015, that aims to limit the increase in global temperature to a maximum of 1.5 degrees Celsius. Its purpose is to address climate change by ensuring that global warming remains well below 2 degrees Celsius compared to pre-industrial levels (UNFCCC, 2015). However, despite the presence of global commitments, the present trends suggest a disparity between the goals and the possible results. According to research conducted by Winning, Price, Ekins, Pye, Glynn, Watson, and McGlade (2019), the combined effect of nations' nationally determined contributions (NDCs) might result in a temperature rise of 2.6 to 3.1 degrees Celsius by the end of the century. This underscores the urgent requirement for substantial private investment in sustainable projects.

Green investments, through financial instruments like green bonds, are critical for channelling resources towards climate-resilient activities (Banga, 2019; Flammer, 2021). Such investments address environmental concerns, including climate change, biodiversity loss, and resource inefficiency, thereby paving the way for a more sustainable future and resilient economy. Since the green bonds inception in 2007, green bonds has been seen as a valuable instrument to finance low-carbon projects. Green bonds have garnered considerable support from legislators and investors who are committed to environmental stewardship. The exponential increase in green bond issuance over the last ten years is clear evidence of the growing trend of green investment. For instance, green bond issuance volume reached almost 500 billion US dollars by 2022, showing the increasing momentum toward green investing (OECD, 2O23).

The surge in popularity of green bonds, coupled with increasing funds invested in climate change adaptation and mitigation, has brought them into the scientific limelight, attracting academic attention (Zerbib, 2019; MacAskill, Roca, Liu, Stewart and Sahin, 2021; Flammer, 2021). The price of green bonds is a subject of continuous discussion, since studies demonstrate mixed results of the premium associated with green bonds (MacAskill et al., 2021). The term ”greenium” refers to the premium that investors are willing to pay to hold a green bond instead of a conventional bond, as they are willing to accept lower monetary returns in exchange for supporting environmentally beneficial activities. Thus, the purpose of this thesis is to examine if there is a green bond premium and contribute to the existing research papers.

This study will build on the work of Zerbib (2019), who analyzed the global green bond market from 2013 to 2017 and found the negative green bond premium of around -2 basis points. Unlike Zerbib’s research, this study will specifically target the European corporate green bond market, comparing changes in the green premium across two distinct periods: 2013-2017 and 2013-2024. These timeframes are particularly noteworthy. From 2013 to 2017, the green bond market had a crucial period of growth, with substantial expansion and diversity. By extending the analysis period to 2024, this study aims to investigate recent data and trends, considering if economical uncertainties such as those experienced in 2020 due to the COVID-19 pandemic, have significantly affected the green bond premium. This extended period will offer an overview of the changes in the green bond premium over time, highlighting the impact of new legislations, market trends, and alterations in investor attitudes towards green bonds.

The hypotheses of if this paper are as follows: 1. A green bond premium exists in the European corporate green bond market for bonds issued in euros and dollars. 2. The green bond premium fluctuates across different time periods within the European corporate green bond market.

The perform analysis leads to the conclusion that both hypotheses are valid, with statistically significant negative green premiums indicating that yields of green bonds is often lower than that of their conventional counterparts. Over the entire period under study, from 2013 to 2024, the average green premium was found to be at around -1.28 basis points. A similar analysis of the shorter period, from 2013 to 2017, yielded a premium of -2.42 basis points.

The remaining thesis is presented in the following order. The second chapter, entitled ”Background of the Green Bonds Market”, offers an overview of market trends and challenges, covering the initial development, expansion, resilience during uncertainty, and continued growth of green bonds from 2007 to 2023. The third chapter, named ”Literature Review”, delves into the concept of corporate social responsibility (CSR) and Environmental, social, and governance (ESG), exploring its relationship with the cost of equity, cost of debt, and discusses the concept of the green premium. The fourth chapter, ”Data”, describes the methodology employed to identify green bonds, the relevant regulations, a raw data overview, and the process of matching bonds for analysis. In the fifth chapter, ”Empirical Method”, the thesis explains the methods used to analyse yield differences, liquidity proxies, the identification of the green bond premium, and the factors influencing this premium. The sixth chapter, ”Results”, presents the findings on the analysis. Finally, the thesis concludes with a section ”Conclusion” that summarises the key insights and implications of the research.

2 BACKGROUND OF THE GREEN BONDS MARKET

This section provides an overview of the green bond market's growth since 2007, its diversification, regulatory frameworks, resilience, challenges like greenwashing, and the need for standardized certification frameworks to maintain market integrity.

2.1 Overview of the trends

The green bond market plays a significant role in the financial system. Since its inception in 2007, the market has undergone a significant evolution, moving from a niche segment focused on AAA-rated issues from international institutions such as the World Bank and the European Investment Bank (EIB) to a robust and diverse segment of the financial market (OECD, 2023). The market encompasses a diverse range of issuers, including sovereign states, municipalities, and corporations, which collectively provide the funding necessary to operate, expand, or refinance existing obligations (Reboredo, 2018). This evolution has been shaped by a number of pivotal moments and trends.

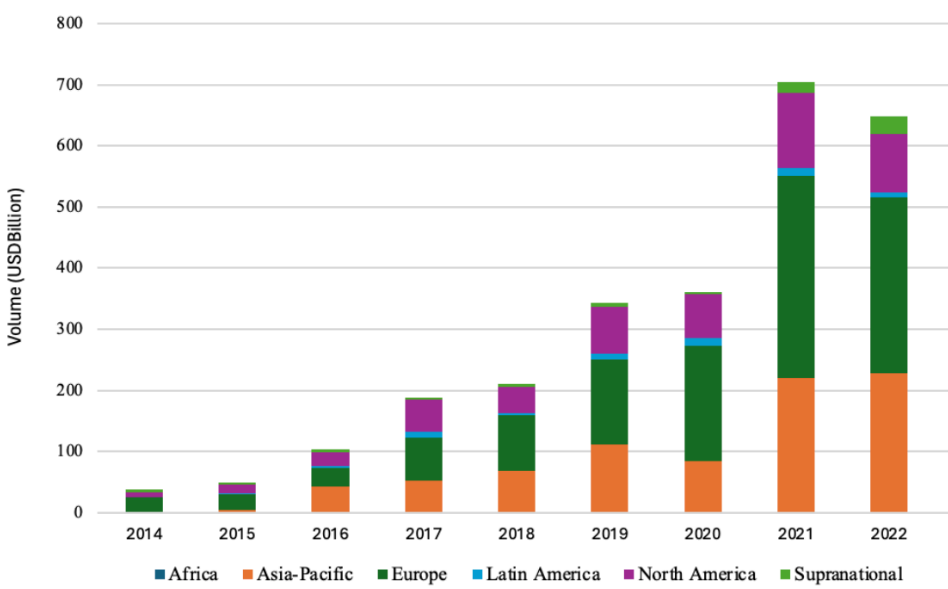

Figure 1: *Growth in green corporate bonds by regions. Note: data retrieved from The Climate Bonds Interactive Data Platform. Source: prepared by the author on the basis of the research.*

2.1.1 Initial development and early growth (2007-2012)

The European Investment Bank launched the first official ”Climate Awareness Bond” in 2007, which raised approximately over 600 million euros from investors, marking the beginning of the path towards green bonds (OECD, 2023). In the initial phases of the market, the annual number of issuances was rather low. Nonetheless, the total amount of green bonds issued in 2012 was close to 3 billion USD, with development banks with the highest credit ratings controlling the majority of the market (OECD, 2015). This period established the foundational market framework and shown the potential of green bonds as tools for raising capital for environmental projects.

2.1.2 Expansion and diversification (2013-2018)

The market's visibility and activity rose between 2007 and 2012 as a result of the successful issuing of green bonds, attracting interest from numerous companies who recognized the potential for substantial investor demand.[1] Corporate issuers sought innovative methods to secure funding dedicated to environmentally sustainable initiatives and began to enter the green bond market in 2013. This led to a notable growth in the market's size, the introduction of new players, and the creation of a much wider customer base. This diversification helped propel the cumulative issuance of green bonds to nearly 20 billion USD (OECD, 2023).

A standardised framework for the issuing of green bonds was established in 2014 with the International Capital Markets Association's (ICMA) establishment of the GBP, which offered important requirements for transparency and integrity (OECD, 2023). These foundational guidelines bolster credibility by mitigating the risk of greenwashing and enhancing transparency regarding the allocation of funds. They provide assurance to investors that their contributions are directed towards established and effective environmental initiatives. By promoting clear reporting and disclosure practices, these guidelines reduce ambiguity and significantly enhance investor confidence, causing the market to almost double in size within a year. In 2014 alone, the issuance reached 37.8 billion USD. Over the next few years, the market reached several significant milestones: 103.2 billion USD in 2016, 187.7 billion USD in 2017, and 209.8 billion USD in 2018. These figures suggested the growing investor

[1] In addition, the market also benefited businesses in a various ways, such as by strengthening supplier chains, opening up new investment chains, and raising consumer demand for environmentally friendly goods (Tang and Zhang, 2018).

appetite and commitment to financing projects that address climate change and promote environmental sustainability.

2.1.3 Resilience during uncertainty (2020-2022)

Significant disruptions were experienced by the worldwide financial and commercial sectors in 2020 during the COVID-19 pandemic.[2] Although the pandemic disrupted the market's supply side, it did not reduce demand (Yi, Bai, Lyu, and Dai, 2021). Major sectors that issue a lot of green bonds, such as transportation and renewable energy, were severely impacted, which caused severe economic instability during the epidemic. Following the COVID-19 outbreak, significant disruptions occurred in the green bond market. Due to investor concerns over credit risks, green bonds were sold for less, which raised the Cumulative Abnormal Return (CAR) and Average Abnormal Return (AAR). Nonetheless, CAR and AAR rapidly decreased as the pandemic situation improved, demonstrating the market's tenacity and effectiveness during the recuperation stage (Yi et al., 2021). The green bond market exhibited remarkable resilience. According to the OECD (2023), financial sector managed to reach an all-time high issuance of 360.9 billion USD in 2020, although the rate of growth was slower than in previous years. This resilience can be mainly attributed to the growing recognition of sustainable investments as an essential safeguard against environmental risks. Furthermore, despite the substantial economic upheaval caused by Russia's invasion of Ukraine in 2022, resulting in significant hikes in energy prices, inflation, and interest rates, the market experienced a 24 percent year-over-year decrease. However, it maintained a consistent 5 percent share of total debt volumes from the previous year. This pattern highlights the durability and increasing commitment to sustainable finance even during the periods of global economic volatility (Climate Bonds Initiative, 2023).

2.1.4 Continued Growth (2022-2023)

The green bond market has been expanding steadily as we approach towards 2022 and 2023. By 2023, the amount issued of green financial securities witnessed a notable increase of 46.12 billion USD compared to the prior year. Europe, which accounted for almost half of the global market, was

[2]For instance, from February 23 to 28, 2020, global stock markets lost around 6 trillion USD due to a strategic escalation in oil production by Russia and Saudi Arabia, followed by a sharper decline in March due to investor risk aversion amid coronavirus pandemic uncertainties (Ozili and Arun, 2023).

the main driver of this expansion (Climate Bonds Initiative, 2023). Specifically, Germany ranked first among nations in issuing green bonds during the third quarter, according to the Climate Bonds Initiative (2023), with a total of 17.7 billion USD over 35 transactions. Consequently, the year 2023 established a new record for green bond sales from corporate entities and governments, amounting to 575 billion USD.

Over various market cycles, a shift in investment preferences favoring green bonds has been observed. This evolution caters not only to conventional financial needs but also to emerging demands, empathizing the dynamic and responsive characteristics of the market.

2.2 Market's challenges

Despite the green bond market's growing prevalence, several challenges remain what are very closely related to each other, including the issue of greenwashing and the absence of a universally accepted certification framework. These challenges have led to debates surrounding the actual environmental impact of projects funded by the green bonds (Flammer, 2021).

Greenwashing occurs when companies present their projects or products as environmentally friendly to gain financial and reputational benefits as sustainable entities. However, such misleading claims can erode investor confidence and diminish the effectiveness of green bonds as instruments for environmental finance (Szabo and Webster, 2021). There is no international standard that defines what constitutes a green project, so there the likelihood of greenwashing is still high. Different countries have varying approaches to environmental projects and green finance due to distinct regulatory environments, economic priorities, and political landscapes. For instance, China categorised clean coal plants as "green" prior to May 2020, which is a considerable deviation from European standards. The absence of universally accepted standards complicates the verification of the true environmental impact of sustainable development projects (Zirek and Unsal, 2023).

Certification helps to reduce information asymmetry, verify an issuer's intentions, and mitigate the risk of greenwashing. Research shows that non-certified green bonds are more prone to greenwashing and have a poorer reputation compared to certified ones (Yeow and Ng, 2021; Lichtenberger, Braga and Semmler, 2022). In addition, studies indicate that smaller issuers bear additional financial burdens, including the cost of certification and strict compliance, which limits the range of projects they can fund, restricting their market access (Baldi and Pandimiglio, 2022).

The lack of transparency and standardization can lead investors to perceive all green bonds as having an average level of greenness, diminishing overall trust and perceived quality. This situation is similar to the ”lemons market” described by economist George Akerlof in 1970, where the presence of lower-quality products (lemons) leads to a general decline in market quality. In a lemons market, asymmetrical information between buyers and sellers results in higher-quality products being undervalued and lower-quality products dominating the market. Comparably, the presence of ”greenwashed” bonds in the green bond market might potentially diminish the perceived worth of all bonds, so adversely negatively affecting investor confidence and impeding the ability of green bonds to promote environmental sustainability.

All things considered, the difficulties facing the market may have a negative impact on it by eroding investor trust, promoting uncertainty, and diminishing the availability of reliable green bonds. As a result, the green premium might decrease because investors are unwilling to pay extra for bonds whose environmental benefits are uncertain. To increase investor confidence, firms issuing green bonds must provide transparent and verifiable financial data in their reports, promoting accountable and responsible investment for the benefit of all stakeholders.

3 LITERATURE REVIEW

The literature review examines the influence of CSR and ESG criteria on financial performance and investment strategies, focusing on the green bond premium and its determinants.

3.1 Corporate social responsibility (CSR) and Environmental, Social, and Governance (ESG)

Since Friedman's 1970 assertion that a firm's sole obligation is to maximize profits for its shareholders, a notion of corporate purpose has undergone significant transformation. In the modern business landscape, companies are increasingly dedicated to generating value for all stakeholders, with sustainability recognized as a crucial element of this value creation. As a result, Corporate Social Responsibility (CSR) became an essential aspect of contemporary corporate operations. Since this thesis focuses on the corporate green bond market, understanding CSR and ESG factors is essential for comprehending the green bond premium. The CSR and ESG factors influence investor behavior, risk perception, financial firms' performance, and market dynamics, which are crucial for analyzing the premium associated with green bonds.

CSR focuses broadly on a company's responsibility towards society and the environment, encompassing voluntary actions taken by companies to improve community well-being and environmental sustainability. In contrast, Environmental, Social, and Governance (ESG) criteria focus on specific measurable aspects within three main areas: environmental, social, and governance. ESG is often used by investors to evaluate the sustainability and ethical impact of their investments in a company. While CSR aims to foster good relations with stakeholders and enhance the company's image through various initiatives, ESG provides a structured framework that investors can use to assess and compare companies' performance on sustainability metrics. Both CSR and ESG play crucial roles in promoting sustainable business practices, but they serve different purposes and are used in different contexts.

In the financial sector, CSR and ESG activities can influence investment decisions, better risk management, and corporate policies, fostering long-term sustainability and ethical practices. Bacha, Ajina, and Saad (2021) note that firms exhibit their dedication to ethical practices and social responsibility by their involvement in corporate social responsibility (CSR) initiatives. This dedication contributes to the establishment of confidence among stakeholders, including employees, investors and consumers, resulting in stronger and more favourable stakeholder connections. Strong relationships with stakeholders make companies perceived as more responsible and trustworthy (Benlemlih and Bitar, 2015). Trustworthy companies are perceived as less risky, which can enhance their market valuation and reduce the cost of capital. Benlemlih and Bitar (2015) utilized regression analysis using the data from more than 3000 enterprises over the period of 1998-2012. This time frame allowed researchers to investigate the CSR effect during the economic crises. Researchers have found that during the crisis the enhanced company's reputation can attract more investors and customers who prefer to associate with socially responsible businesses, thus providing a buffer against economic volatility. Therefore, the stability of CSR firms enables to safeguard their investments from market volatility, as these companies typically exhibit a lower risk profile (Hmaittane, Bouslah and M'Zali, 2019). This finding aligns with the findings of Bouslah, Kryzanowski and M'zali (2018) who investigated the influence of a company's social performance during the global financial crisis of 2008-2009. They discovered that companies with superior social performance, particularly those with significant corporate social responsibility capabilities, were able to maintain or expand their operations.

3.1.1 The relationship between CSR or ESG factors with the cost of equity

The cost of equity refers to the rate of return that a firm must provide to equity investors in order to compensate them for the risks involved with holding the company's shares. This metric is of great importance to financial decision-makers, as it assists in determining the attractiveness of various investments. A reduced cost of equity typically indicates diminished corporate risk and improved prospects for growth.

Prior studies investigating the influence of CSR on equity capital have yielded inconsistent findings. Chava (2014) conducted a study using United States data from 1992 to 2007. The study indicated that companies that are more concerned about the environment, such as dealing with hazardous waste and emitting considerable amounts of pollutants, have higher implied costs of equity. This is because investors recognize these companies to have higher perceived risks and hence demand higher returns on their investments. In contrast, a study by El Ghoul, Guedhami, Kwok, and Mishra (2011) examined 12,915 observations of United States enterprises from 1992 to 2007. The study revealed that firms with higher CSR ratings have considerably reduced equity costs and lower risk compared to firms with lower CSR scores. This reduction is attributed to higher demand from socially responsible investors and reduced perceived risks. The key methodological difference between the studies is that Chava (2014) uses an implied cost of capital based on analysts' profit forecasts, whereas El Ghoul et al. (2011) employs instrumental variables estimation methods to control for endogeneity and provide a more robust analysis of CSR impacts.

Recent research supports that strong CSR performance can lower a company's cost of equity by reducing market risks and encouraging equity diversification. Hmaittane et al. (2019) analyzed 2,006 firm-year observations from U.S. companies between 1991 and 2012, finding that CSR activities notably decrease the cost of equity, particularly in controversial sectors like alcohol and tobacco. This reduction is primarily due to CSR's role in mitigating risks associated with potential negative incidents that could harm the company's value. Additionally, they found that CSR enhances the company's reputation, attracting more investors by reducing information asymmetries and lowering the risk premium they require, thereby decreasing the firm's cost of equity. Notably, Breuer, Müller, Rosenbach, and Salzmann (2018) has expanded the research area, by utilizing data from 30000 firms across 39 different countries. Using regressions with fixed effects to control for country-specific factors and employing instrumental variables to address endogeneity issues, the study investigates how CSR impacts the cost of equity in relation to the level of investor protection. The findings reveal that companies with superior CSR performance has an advantage of reduced capital costs in regions with robust investor protection laws. Conversely, in areas with weaker protections, the cost of equity rises due to higher risk perceptions among investors. Together, these studies highlight the strategic value of CSR and ESG initiatives in reducing financing costs and optimizing corporate financial performance.

The impact of ESG performance on a company's financial metrics, particularly the cost of equity has revealed that ESG also reduces the cost of equity. Pellegrini, Caruso and Mehmeti (2019) conducted an empirical study on the effects of an ESG rankings on the cost of equity and profitability of companies, operating in the oil and gas industries. The research encompassed 182 firms, using return on assets as an indicator to evaluate how ESG scores influence profitability. Departing from conventional models like CAPM or Fama-French, they employed the Easton Model to calculate the implied equity cost. Their investigation using fixed effect regressions shown that organisations with better ESG ratings have reduced costs for equity funding. Specifically, a 10 percent increase in ESG scores led to a 134 basis point reduction in the cost of equity. Conversely, the study also indicated that a 10 percent rise in ESG scores corresponded with a 0.45 percent decrease in return on assets. Chen, Li, Zeng, and Zhu (2023) conducted a similar study on Chinese A-share enterprises from 2010 to 2020. The researchers utilised a bidirectional fixed effects model and a benchmark regression model to analyse the influence of ESG performance on the cost of equity capital. Their research revealed that robust environmental, social, and governance (ESG) performance, particularly in governance, has a substantial impact on reducing the cost of equity across diverse sectors. This effect is shown in both state-owned and non-state-owned firms, as well as in manufacturing and non-manufacturing industries.

3.1.2 The relationship between CSR/ESG and the cost of debt

Understanding the cost of debt is crucial for investors in determining the amount of risk connected with an enterprise. It represents the actual interest rate that a firm incurs on its borrowed capital. Understanding this rate is necessary for evaluating the financial burden associated with debt financing strategies, where a company raises funds by issuing debt securities to investors who thereby become creditors.

Recent research has shown that companies with better corporate social performance and more transparent disclosures are associated with lower costs of debt. Empirical research consistently demonstrates a clear link between strong CSR performance and reduced costs of debt, primarily due to diminished financial distress risks.[3] Enterprises prioritizing social responsibility often receive better borrowing terms, as CSR investments reduce risks and boost perceived creditworthiness. This positive correlation is supported by findings from Boubaker et al. (2020) that institutions view CSR-engaged firms as more creditworthy. As a result, such firms have better access to financing. Boubaker et al.

[3] Good employee relations, community and environmental aspects of CSR play a significant role in reducing financial distress risk (Drago, Carnevale, and Gallo, 2018; Boubaker, Cellier, Manita and Saeed, 2020.

examined 1201 US-listed firms from 1991 to 2012 using robust methodologies like propensity score matching, the generalized method of moments and two-stage least squares (2SLS) regression, finding that strong CSR practices enhance creditworthiness and access to financing. Kordsachia's (2021) study on 778 European companies further supports this, demonstrating a statistically significant negative association between CSR and credit financing costs. Specifically, for each unit increase in the primary CSR measure, the cost of debt decreased by 0.0179, with a p-value of 0.000 (Kordsachia, 2021). Furthermore, research by Drago, Carnevale, and Gallo (2018) found that high corporate social performance ratings correlate with narrower credit default swap spreads among European companies, indicating a reduction in perceived credit risk that typically leads to lower bond yields. Studies by Gigante and Manglaviti (2022) and Chen, Hung and Lee (2018) support the negative correlation between CSR commitments and credit risk by showing that proactive sustainability disclosures and diligent CSR practices significantly reduce specific and idiosyncratic risks, respectively, in various market conditions. As a result, companies that have higher levels of CSR are considered less risky by creditors. This indicates that enhanced CSR efforts can lead to substantial reductions in a company's debt financing costs.

Nazir, Akbar, Akbar, Poulovo, Hussain and Qureshi (2022) investigated how ESG performance influences the cost of debt among leading global technology companies. Analyzing data from 64 firms between 2010 and 2017, they used a two-step Generalized Method of Moments (GMM) regression and discovered a positive correlation between ESG scores and the capital cost for technology enterprises in the sample. In a similar vein, Apergis, Poufinas and Antonopoulos (2022) studied S&P 500 companies from 2010 to 2019 using a multilevel mixed-effects model. Their findings confirmed that higher ESG performance leads to reduced debt costs. Specifically, companies with superior ESG scores enjoy lower borrowing costs as they are perceived by lenders as lower-risk investments. Differently, Maaloul, Zéghal, Ben Amar and Mansour (2023) presented different rationale for the debt cost and ESG performance relationship using Structural Equation Models. Their study shown that the performance and disclosure of ESG factors improve the reputation of corporations, resulting in a reduction in the cost of borrowing. This is because well-managed firms with strong CSR practices are less likely to encounter legal, regulatory, environmental, and social issues, thereby reducing the risk of default and becoming more attractive to debt providers. Together, these studies suggest that robust ESG disclosure and integrated reporting can incentivize companies by reducing their cost of debt. Firms with strong ESG performance are seen as more creditworthy and gain better access to financing, reinforcing the financial benefits of sustainable practices.

CSR activities also contribute to enhanced investment efficiency by reducing information asymmetry and aligning corporate practices with stakeholder interests (Benlemlih and Bitar, 2015; Hamrouni, Boussaada and Toumi, 2019). Benlemlih and Bitar (2015) conducted a comprehensive analysis on a substantial dataset consisting of 21,030 observations of US firms throughout the period of 1998-2012. Their study employed correlation analysis, regression analysis, instrumental variable regressions, propensity score matching and a Heckman's two-step treatment effect model to investigate the relationship between CSR and investment efficiency. Research has shown that CSR activities significantly improve investment efficiency, which in turn can lower the cost of debt. Similarlly, Hamrouni et al. (2019) conducted a study that specifically examined non-financial French companies that are listed on the Euronext stock exchange. The time period of interest is from 2010 to 2015. Their panel data analysis revealed that CSR reporting influences leverage ratios by mitigating information asymmetry between the firms and their lenders. This reduction in information asymmetry makes firms appear less risky to lenders, resulting in more favorable borrowing terms (Hamrouni et al., 2019).

3.2 Green premium

Investors committed to environmental sustainability are increasingly channeling their capital into initiatives that uphold ecological values while also offering competitive financial returns. This trend signifies a notable shift in capital allocation, favoring sustainable projects that not only provide strong financial returns but also diversify portfolios, thereby enhancing their appeal compared to traditional investments (Zerbib, 2019; Baker et al., 2022).[4] In this context, the market for green bonds is receiving significant attention in research due to its importance. However, the findings regarding the presence of a green bond premium are inconclusive.

Nanayakkara and Colombage (2019) analysed the price of green bonds in the primary market.

[4]Diversification of investment portfolios can significantly reduce the risk of losses, leading to more stable returns over time.

They used a worldwide sample of 82 corporate green bonds and discovered that these bonds trade with a lower credit spread of 63 basis points in comparison to similar corporate bonds. The lower spread indicates that investors view these bonds as less risky or more attractive than similar conventional corporate bonds. Wang, Liu, Wang (2022) has focused on Chinese fixed securities market and found during the period 2007 to 2020 corporate green bonds have a lower yield spread of 34 basis points. According to their study, the premium is more noticeable for bonds that are accredited by the Climate Bonds Initiative (CBI), issued by companies with strong CSR scores, are held by long-term institutional investors and have less concentrated structures of ownership. This is supported by findings from Hyun, Park and Tian (2021) who found that green bonds issued between 2014 and 2019 exhibited a premium. More precisely, bonds that were verified by an external reviewer had a premium of 6 basis points, whilst those verified by the CBI had a premium of 15 basis points.

In secondary markets, the outcomes concerning the green bond premium are highly variable. Zerbib (2019) investigated the period 2013-2027 and identified a slight negative green premium of approximately 2 basis points. This suggests that green bonds are valued more than conventional bonds that are equivalent in their characteristics. This finding, based on data from 110 green bonds that were issued globally is attributed to the preferences of pro-environmental investors.[5] The study also found that this premium is more pronounced for financial institutions and bonds that have lower credit ratings. In contrast, Karpf and Mandel (2018) examined 1880 U.S. municipal green bonds and determined that the returns on these bonds are 23 basis points lower compared to conventional municipal bonds, with issuer characteristics primarily driving the pricing spread. They argue that the green attributes of bonds contribute to a premium of approximately 7.8 basis points.

Different academics have detected a green bond premium, however there is no consensus on the reasons for this occurrence. One possible explanation from the perspective of investors is that investors prepared to pay a higher price to support environmentally friendly projects (Zerbib, 2019). sSimilarly, Bachelet et al. (2019) have noted that the green premium might be ascribed to investor preferences or decreased risks, particularly when associated with a well-established issuer reputation or green certification, which reduces information asymmetry and mitigates greenwashing risk. The

[5]The pro-environmental investor preferences imply that investors may accept lower returns in exchange for investing in sustainable projects even if it means forgoing some financial returns.

growing demand for green bonds, fueled by environmentally conscious investors and institutional mandates, enhances their liquidity, leading to tighter spreads and lower yields, thereby contributing to the premium. Hyun et al. (2020) empathized that the liquidity is a crucial factor in the pricing, as increased demand leads to more liquid markets, reducing the required yield and enhancing the premium. As demand for green bonds rises, their prices increase, and their yields decrease relative to traditional bonds (Baker, Bergstresser, Serafeim and Wurgler, 2022).

For issuers, the premium translates to a lower cost of capital, incentivizing the issuance of green bonds and aligning financing strategies with sustainable development goals. Nanayakkara and Colombage (2019) argue that the lower borrowing costs can be particularly beneficial for projects with significant upfront investments and long-term payoffs, explaining why more issuers are entering the market and increasing the supply of financial instruments that contribute to the environmentally friendly initiatives.

Supportive regulatory frameworks and government incentives play a crucial role in enhancing the attractiveness of green bonds. Baker et al. (2022) note that these measures can mitigate risks associated with green projects and boost investor confidence, further contributing to the green premium. By offering tax benefits, subsidies, and other incentives, governments can lower the effective cost of issuing green bonds, making them a more viable option for financing sustainable projects.

The ongoing debate about the green premium reveals diverse academic perspectives. Some researchers advocate for its recognition due to its positive environmental and social impacts and increased transparency, while others caution against potential market distortions and overvaluation. Systematic reviews, such as those by MacAskill et al. (2021), indicate that a green premium is found in half of primary market studies and 70 percent of secondary market studies. The green premium on the secondary market often falls within the range of -1 to -9 basis points. Although the existence of a financial advantage for green bonds is recognised, the available literature is inconclusive, emphasising the necessity for more study to comprehensively understand the impact of green bonds on sustainable financing.

4 DATA

4.1 Identifying Green Bonds

Conventional bonds are debt security agreements where the issuer pays bondholder periodic interest payments and repays the principal amount at a specified maturity date.[6] Green bonds exhibit a high degree of similarity to traditional fixed-income securities in terms of their maturities, seniorities, coupon sizes, and credit ratings. Similarly to conventional bonds, green bonds are issued by entities to raise capital for the projects or operations. Green bonds are unique in their purpose. These bonds fund projects with environmental benefits, including energy-efficient infrastructures, renewable energy initiatives, electrified transport systems and sustainable building projects (Flammer, 2021). However, there is no clear definition of what qualifies as ”environmentally beneficial” across different regions. This absence of a universal standard leads to a diversity of practices regarding how green projects are identified and certified. The process of issuing green bonds involves accreditation of green labels, obtaining second-party opinions, and employing verification methods. Regulations are necessary to create a clear and consistent framework for defining and verifying what qualifies as ”environmentally beneficial”. Such regulations can prevent greenwashing by ensuring that funds are genuinely used for sustainable projects. They improve transparency, enabling investors to understand the usage of their funds and the environmental impact they have.

4.2 Regulations

During the early market stages, the evaluation process was primarily based on self-reporting by issuers (MacAskill et al., 2021). Issuers often lack standardized methods to accurately measure the environmental impact of green bonds, leading to international organizations like ICMA participating in the evaluation process.

[6] There are various types of bonds issued by different entities, including corporate bonds by enterprises, municipal bonds by states and municipalities, government bonds by national governments, and agency bonds by government-affiliated organizations.

The Green Bond Principles, which provide voluntary recommendations to improve transparency in the management and use of revenues from green bonds, were introduced by the ICMA in 2015. The framework establishes four primary standards for optional activities that determine whether bonds qualify as green bonds. According to the first criterion, the ”Use of Proceeds Principle”, money earned through green bonds must only be used for initiatives that result in measurable improvements to the environment. In order to ensure compliance with the environmental criteria outlined by the GBP, issuers are required to establish a strong framework for the examination and selection of projects, as stipulated by the second criterion, the ”Project examination and Selection Process Principle”. The third principle, entitled ”Management of Proceeds”, is clear: transparent tracking and management are necessary to guarantee that the revenues from green bonds are utilised only for the designated ecologically friendly initiatives. This frequently entails monitoring the money through an official internal procedure or separating it into a separate account. Finally, issuers must comply with the ”Reporting Principle” and inform stakeholders on a regular basis about the distribution of funds and the environmental results of the projects they support. This is done through yearly public disclosures that include both qualitative and quantitative measurements.

The European Union (EU) is in the forefront of global green bond standardisation with its comprehensive ”European Green Deal” strategy. By 2050, this plan seeks to make Europe the first carbon-free continent, with a major reduction in emissions expected by 2030. A crucial component of the EU’s approach is the Sustainable Finance Taxonomy, which categorizes economic activities according to their environmental impact, thereby providing a transparent framework for sustainable investments. In line with this taxonomy, the European Green Bond Standard (EUGBS) establishes stringent criteria for green bond issuers, ensuring that only projects with environmental benefits are financed. This standard conforms to the global guidelines set by the GBP, but with the additional verified and official label requiring alignment with the EU Taxonomy. Moreover, the enactment of Regulation (EU) 2023/2631, commonly known as the European Green Bond Regulation, introduces a harmonized framework for green bonds across the European Union. This regulation, scheduled to enter into force in December 2024, allows issuers to channel funds into a wide range of environmentally sustainable activities, consistent with the EU Taxonomy Regulation. It permits up to 15 percent of the proceeds to be used for initiatives that do not fully align with the taxonomy criteria, provided specific conditions are met. The regulation also demands exceptional transparency from issuers, requiring them to provide detailed reports both before and after the issuance of the bonds. These reports include a factsheet and annual updates on fund allocation and impact, with the latter offering the option for external review. The European Securities and Markets Authority (ESMA) will oversee independent reviews to ensure compliance with the regulatory standards. These regulations are aimed at standardizing and promoting green bonds by a structured and credible environment for issuing and investing in green bonds. These regulations standardize and promote green bonds, creating a structured and credible environment for issuance and investment. The framework increases reduces greenwashing by the increase in transparency, boosting investor confidence and driving higher investment and participation, thereby reinforcing the EU's dominant market position globally. In 2020, the EU represented 51% of the global green bond issuances, with 48% bond issuances occurring in euros globally (OECD, 2023).

4.3 Raw data overview

The data used to test the hypotheses was collected from Bloomberg, financial software tool that is widely used for research due to its large amount of financial information. Specifically, the analysis utilized data from Bloomberg's Fixed Income Database, which archives details on fixed financial instruments like green and conventional bonds. This database offers detailed data on various attributes such as securities identification codes, bid and ask prices, issuance volumes, maturities, last trade prices, and credit ratings. Within the ”Use of Proceeds” segment of the database, bonds are systematically categorized based on their type. A bond is green if it complies with the GBP. Meeting the criteria of the GBP enhances transparency and accountability in how the proceeds are used. This classification in the ”Use of Proceeds” section serves to simplify the distinction between different types of bonds. Additional filtering processes were applied to isolate the specific data required for hypothesis testing.

Table 1: *This table presents the criteria and the number of active corporate bonds as of February 2024, distinguishing between green bonds and conventional bonds.*

Active corporate bonds as of February, 2024		
Criteria	**Green bonds**	**Conventional bonds**
Full	6,390	331,186
Issue date is in the range 2013.11.01 - 2024.04.01	6,348	300,828
Has United States Dollar or Euro Currency	2,930	157,096
Region of Incorporation is Europe	1,945	93,695
Has coupon	1,920	90,037
Issuer is not ”Government”	1,884	88,853
Has rating	1,305	23,749
Has maturity	1,279	23,292
Has amount issued	855	21,342
Issuer of green bonds issues conventional bonds	670	4,274

Table 1 illustrates the sequential filtering steps applied within the Bloomberg database. Initially, the total corporate bond universe consists of 337,616 active corporate bonds in the secondary market, segmented into 331,186 conventional bonds and 6,430 green bonds. The research period starts in 2013, coinciding with the issuance of the initial green corporate bond by the Swedish business Vasakronan, and extends until 2024. Applying the issue date restriction led to a reduction in the dataset size, decreasing the number of green bonds to 6,348 and conventional bonds to 300,828. To minimize currency risk and avoid potential distortions in the financial analysis, I selected bonds denominated in either the euro (EUR) or the U.S. Dollar (USD). Moreover, this analysis focuses on the European corporate green bond market. Therefore, the bonds analysed are those that are issued within this specific geographical boundary. Further refinement of the dataset excluded bonds issued

[7] Another rationale for this is the dominance of the Euro (EUR) and the U.S. Dollar (USD) currencies in the corporate bonds market.

by entities classified under the ”Government” category according to the Bloomberg Industry Classification System (BICS). This exclusion criterion applies to issuers, such as development banks and supranational organisations, which, although technically corporate entities, do not align with the conventional framework of corporate entities (Flammer, 2021). Due to the limitations of data acquisition through the Bloomberg terminal, the scope of the study was confined to issuers with both green and conventional bonds in the portfolios. Bonds with incomplete data were excluded from the analysis to eliminate potential pricing noise and ensure accurate matching. Consequently, the final dataset used in this study consisted of 670 green bonds and 4,274 conventional bonds.

Table 2: *Description of 670 green bonds sample segmented by geographical region and credit rating in EUR and USD.*

Region	No. of GB		Rating	Log avg. Amount issued (bn)		Avg. yield (%)		Avg. maturity (years)	
	EUR	USD		EUR	USD	EUR	USD	EUR	USD
	2	–	A	20.03	–	4.61	–	5.75	–
	2	–	BB	20.23	–	5.75	–	5.00	–
Eastern Europe	2	1	BBB	20.20	20.36	4.72	6.34	5.50	5.24
	–	2	CC	–	20.38	–	37.03	–	6.84
	2	1	NR	20.03	16.76	4.28	6.18	4.50	6.45
	28	5	A	20.15	18.95	3.56	5.34	6.50	5.00
	4	2	AA	20.41	20.72	3.54	5.30	5.50	5.00
	4	–	AAA	20.85	–	3.20	–	8.50	–
Northern Europe	2	–	B	19.64	–	9.00	–	5.02	–
	6	4	BB	19.82	20.25	6.22	7.20	5.50	8.55
	54	10	BBB	20.14	19.66	4.04	6.04	7.75	10.00
	13	1	NR	19.84	17.66	3.83	5.52	5.64	10.19
	9	–	A	20.47	–	3.36	–	7.00	–
	2	–	B	19.41	–	11.40	–	5.00	–
Southern Europe	19	–	BB	20.09	–	4.80	–	6.00	–
	91	2	BBB	20.21	17.60	3.86	5.85	7.25	6.96
	21	–	NR	19.29	–	44.13	–	7.00	–
	70	14	A	20.23	19.83	3.47	5.67	10.00	6.00
	8	–	AA	20.08	–	3.26	–	12.00	–
	13	–	AAA	20.25	–	3.14	–	9.87	–
	2	–	B	20.37	–	5.98	–	8.10	–
Western Europe	20	10	BB	20.04	20.22	4.65	7.47	5.75	7.00
	139	14	BBB	20.36	20.42	3.84	5.53	7.50	9.00
	2	–	CC	19.60	–	118.24	–	5.00	–
	81	8	NR	19.24	17.48	3.65	5.89	8.00	8.50

Notes: GB abbreviation represents the green bond.
The financial metrics cover the average of logarithmic amount issued in billions (bn), the average yield (%), and the average maturity (years). The regions considered are Eastern Europe, Northern Europe, Southern Europe, and Western Europe.

Table 3: *Description of 4,274 conventional bonds sample segmented by geographical region and credit rating in EUR and USD.*

Region	No. of GB		Rating	Log avg. Amount issued (bn)		Avg. yield (%)		Avg. maturity (years)	
	EUR	USD		EUR	USD	EUR	USD	EUR	USD
	4	–	A	20.03	–	5.67	–	3.49	–
	–	–	BB	–	–	–	–	–	–
Eastern Europe	3	1	BBB	20.03	20.34	4.31	6.63	6.68	7.00
	–	–	CC	–	–	–	–	–	–
	11	–	NR	19.61	–	4.11	–	5.64	–
	88	181	A	19.58	16.41	3.56	4.37	7.32	7.35
	64	11	AA	18.86	19.42	3.71	5.87	8.07	3.55
	24	–	AAA	19.60	–	3.38	–	11.80	–
Northern Europe	8	6	BB	20.32	20.81	5.23	7.49	33.55	43.45
	86	51	BBB	19.73	20.10	3.84	5.93	10.63	16.22
	237	105	NR	17.78	16.72	3.80	3.50	11.79	9.2
	80	17	A	19.10	19.61	3.82	6.00	8.13	6.00
	32	–	AA	20.52	–	3.68	–	9.97	–
	1	–	B	19.81	–	10.75	–	10.00	–
Southern Europe	44	5	BB	19.83	20.88	5.65	6.80	8.51	12.20
	269	55	BBB	19.70	20.29	4.13	6.38	8.92	13.79
	243	37	NR	19.80	19.35	4.00	5.78	8.37	6.25
	483	177	A	19.02	18.97	3.93	5.79	8.74	7.50
	90	31	AA	18.03	18.56	3.78	5.53	12.79	9.23
	295	–	AAA	19.02	–	3.33	–	13.10	–
	–	–	B	–	–	–	–	–	–
Western Europe	30	9	BB	20.16	19.93	4.56	6.68	8.37	15.24
	332	109	BBB	20.02	20.49	4.08	6.22	9.66	14.54
	–	–	CC	–	–	–	–	–	–
	783	272	NR	17.71	17.33	4.12	5.80	10.92	8.72

Notes: GB abbreviation represents the green bond.
The financial metrics cover the average of logarithmic amount issued in billions (bn), the average yield (%), and the average maturity (years). The regions considered are Eastern Europe, Northern Europe, Southern Europe, and Western Europe.

Table 3 provides a summary of data for the sample of 4,274 conventional bonds issued in Europe. In contrast, Table 2 presents summary information for the 670 green bonds sample. Both types of bonds were issued by 237 different issuers across 27 European countries, with a concentration in developed Western European nations such as France, the Netherlands, and Germany. Overall, comparing those two descriptive statistics, show that yields are generally higher for USD-denominated bonds in both green and conventional bond categories. This trend may be influenced by the higher risk associated with USD-denominated assets or differing economic conditions in regions where these currencies are more prevalent. Notably, green bonds with lower credit ratings (e.g., CC) exhibit exceptionally high yields, empathizing the greater risk and potential returns compared to conventional bonds. This suggests that green bonds tend to offer a higher risk and return profile, particularly in lower credit ratings, compared to conventional bonds. Therefore, green bonds present a more varied range of maturities and yields, indicating different strategic investment opportunities across regions. Investors might choose green bonds for potentially higher returns in the short to medium term, especially in Eastern Europe. Conversely, they might opt for conventional bonds for long-term investments, particularly in regions like Northern and Western Europe. However, further investigation is necessary. Therefore, I will proceed with a matching analysis to provide more robust conclusions.

4.4 Matching

Matching methods are frequently employed in research on the green bonds market (Zerbib, 2019; Flammer, 2021). These robust statistical techniques replicate the parameters of randomized experiment by matching units from treatment and control groups based on their observable characteristics. This strategy effectively mitigates omitted variable bias in cross-sectional observational data by controlling for pre-treatment variables that may confound outcomes. As a result, it isolates the causal impact of the treatment and enhances the credibility of the results (Stuart, 2010).

The matching method of this thesis incorporates a four-step process: initializing the study by raising the hypotheses and defining the groups, executing the matching procedure, evaluating the match quality, and estimating the treatment effect alongside its associated uncertainty. These phases are pivotal in achieving covariate balance, a condition where the distribution of covariates across both groups approximates what would be observed in a well-conducted randomized trial.

4.4.1 Variable selection for matching

For this analysis, green bonds are naturally categorized as the treated group due to their environmental attributes, while conventional bonds serve as the control group. A critical aspect of conducting an effective matching analysis is the careful selection of covariates. It is important to choose a limited yet highly relevant set of variables that can effectively balance the treated and control groups, simplify the matching process, and minimize confounding factors. This strategic approach enhances the likelihood of deriving an estimate of the treatment effect that genuinely reflects a causal relationship, as highlighted by Stuart (2010).

Previous studies, such as Zerbib (2019), have explored the potential for a green premium by employing a model-free approach that focuses on variables differentiating green from conventional bonds. Zerbib's methodology involved pairing each green bond with two traditional bonds, considering multiple factors such as issuer, seniority, currency, collateral, bond structure, rating and coupon type. In contrast, this study adopts a more simplified approach, matching conventional bonds with green bonds according to covariates including currency, coupon, and maturity.

Focusing on currency is crucial as it directly impacts the bond's risk-return profile by influencing factors such as interest rates, inflation, and other macroeconomic elements affecting bond prices. This strategy aids in mitigating discrepancies caused by exchange rate risks (Gadanecz, Miyajima and Shu, 2018). The coupon rate is critical as it determines the periodic interest payment relative to the bond's face value, essential for controlling differences in yield and price sensitivity to interest rate changes. By aligning bonds based on coupon rates, the study ensures that any observed yield spread differences are attributable to the environmental focus of the bonds rather than disparities in their interest income streams. Additionally, bond maturity is a significant factor as it dictates the bond's duration and vulnerability to interest rate fluctuations. Matching bonds with similar maturities ensures they possess similar risk profiles and price volatility as they near maturity, offering a reliable basis for comparison.

Furthermore, an essential decision in the matching process is the choice between matching with or without replacement. By offering a wider range of pairing possibilities and promoting balance among matched groups, matching with replacement improves the quality of matches by enabling control units to be paired with many treatment units. However, this method complicates the variance estimation due to the reuse of control units in multiple matches and may compromise the independence of observations (Shipman, Swanquist, Whited, 2017). On the other hand, matching without replacement, which is the method chosen for this study, ensures that each control unit is used only once, maintaining the independence of observations. This method offers statistical advantages by ensuring that each control contributes independently to the treatment effect estimation, reducing bias and minimizing the risk of overfitting.

4.4.2 Process of matching

In this research, I employ the 1:1 Nearest Neighbor Propensity Score Matching method, which is a well-established approach for estimating causal effects while accounting for potential confounders (Fong, Hazlett, Imai, 2018). Developed by Rosenbaum and Rubin in 1983, this methodology involves calculating a propensity score, e_i, for each unit i in the dataset. Based on the observed features, a logistic regression model is used to produce these scores. This model calculates the probability that each unit will receive the treatment. The propensity score e_i represents the probability that unit i is treated with green bonds, expressed as

$$e_i = P(T_i = 1 \mid X_i), \tag{1}$$

where T_i denotes the treatment status of a binary variable: as the control group, units that are conventional bonds receive 0 and units that are green bonds, receive 1 as the treated group. Now, the logistic function can be expressed as:

$$\text{logit}(e_i) = \log\left(\frac{e_i}{1 - e_i}\right) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik} \tag{2}$$

In this equation $\beta_0, \beta_1, \ldots, \beta_k$ are parameters, estimated from the data, determining how each covariate affects the treatment probability. The covariates X_i in this analysis include key variables such as the coupon, maturity, and currency of the bonds.

The next step is to match each treatment unit to a control unit with the propensity score that is closest to it after the propensity scores have been calculated. This is done using a 1:1 matching without replacement method. This method selects for each treated unit i the control unit j that minimizes the absolute difference in their propensity scores, described mathematically as:

$$D_{ij} = |e_i - e_j| \tag{3}$$

$$j^* = \arg\min_{j \notin M} |e_i - e_j| \tag{4}$$

where e_i and e_j are the propensity scores of the treatment unit i and control unit j, respectively. M denotes the set of control units already matched and thus not available for further matching. This approach ensures that each control is used at most once, mitigating the risk of bias introduced by repeated use of control units in multiple pairs (Stuart, 2010).

4.4.3 Executing the matching procedure

Zerbib (2019) examined green bonds issued between 2013 and 2017 in order to see whether a premium was associated with them. This study extends Zerbib's analysis by comparing the evolution of the green premium over two periods: 2013-2017 and 2013-2024. Two matching processes were employed to account for differences in time periods, each pairing treated units with corresponding control units in a one-to-one matching ratio. The success of this matching process is demonstrated by the balanced tables shown in Table 4 and Table 5. For the period from November 2013 to April 2024, both the treatment and control groups consist of 670 units post-matching (Table 4). For the period from November 2013 to December 2017, both groups consist of 50 units post-matching (Table 5).

Table 4: *Sample sizes. This table represents the bonds issued during the period from 2013 to 2024.*

Group	Control	Treated
All	4274	670
Matched	670	670
Unmatched	3604	0
Discarded	0	0

Table 5: *Sample sizes. This table represents the bonds issued during the period from 2013 to 2017.*

Group	Control	Treated
All	992	50
Matched	50	50
Unmatched	942	0
Discarded	0	0

However, while these samples indicate good levels of balance, further analysis is necessary to comprehensively evaluate the matchings. In order to assess the effectiveness of the matching processes, I examined balance tables for both matched and unmatched data.

Table 6: *Summary statistics and balance metrics for treated (green bonds) and control groups (conventional bonds) before and after matching. This table represents the bonds issued during the period from 2013 to 2024.*

Metric	Means Treated	Means Control	Std. Mean Diff.	Var. Ratio	eCDF Mean	eCDF Max
All Data						
Distance	0.1568	0.1322	0.4681	1.0250	0.1287	0.1958
Cpn	2.8076	2.5558	0.1226	1.0967	0.0322	0.0798
Years	9.1826	10.2729	-0.1326	1.2277	0.0743	0.1462
EUR	0.8955	0.7532	0.4654	-	0.1424	0.1424
USD	0.1045	0.2468	-0.4654	-	0.1424	0.1424
Matched Data						
Distance	0.1568	0.1566	0.0049	1.0710	0.0016	0.0164
Cpn	2.8076	2.8213	-0.0067	1.0864	0.0114	0.0403
Years	9.1826	9.2616	-0.0096	1.2212	0.0295	0.0597
EUR	0.8955	0.8955	0.0000	-	0.0000	0.0000
USD	0.1045	0.1045	0.0000	-	0.0000	0.0000

The Table 6 represents the balance table before matching and revealed noticeable disparities in key variables, particularly in coupon (”Cpn”) and maturity (”Years”), highlighted by higher standardized mean differences (SMD) and empirical cumulative distribution function (eCDF) measures. However, post-matching analysis shown significant improvements in these areas.

Table 7: *Summary statistics and balance metrics for treated (green bonds) and control groups (conventional bonds) before and after matching. This table represents the bonds issued during the period from 2013 to 2017.*

Metric	Means Treated	Means Control	Std. Mean Diff.	Var. Ratio	eCDF Mean	eCDF Max
			All Data			
Distance	0.0512	0.0478	0.3892	0.3890	0.0906	0.2150
Cpn	2.2317	2.2556	-0.0158	0.9852	0.0363	0.1089
Years	12.1661	14.0076	-0.4414	0.3986	0.0475	0.1750
EUR	0.8600	0.8014	0.1688	-	0.0586	0.0586
USD	0.1400	0.1986	-0.1688	-	0.0586	0.0586
			Matched Data			
Distance	0.0512	0.0511	0.0027	0.9910	0.0012	0.0600
Cpn	2.2317	2.3763	-0.0956	0.9760	0.0278	0.1000
Years	12.1661	12.2354	-0.0166	1.0258	0.0134	0.0800
EUR	0.8600	0.8600	0.0000	-	0.0000	0.0000
USD	0.1400	0.1400	0.0000	-	0.0000	0.0000

Table 7 presents summary statistics and balance metrics for the treated and control groups, highlighting significant initial imbalances in the data from 2013 to 2017. For example, the maturity variable (”Years”) had a variance ratio of 0.3986 and a standard mean difference of -0.4414, indicating substantial imbalance. However, after matching, there was a significant improvement in balance, with the standard mean difference reduced to -0.0166 and the variance ratio adjusted to 1.0258.

Comparing the balance tables before and after matching for both periods reveals consistent improvements. The Standardized Mean Differences (SMD) across all analyzed variables, particularly ”Distance,” shown a significant reduction, indicating that the matching algorithms effectively paired treated units with statistically comparable control units based on the selected covariates. This reduction in SMD and the lower eCDF values in the matched datasets suggest that systematic differences, which could potentially bias the outcome assessment, were minimized. Additionally, the improved eCDF metrics confirm that the matching processes effectively aligned the cumulative distributions of observed covariates between the groups, thereby enhancing the study’s internal validity. The near-zero SMD values and variance ratios close to one further indicate good balance, showcasing a tighter alignment in the probability distributions of the covariates within the matched datasets.

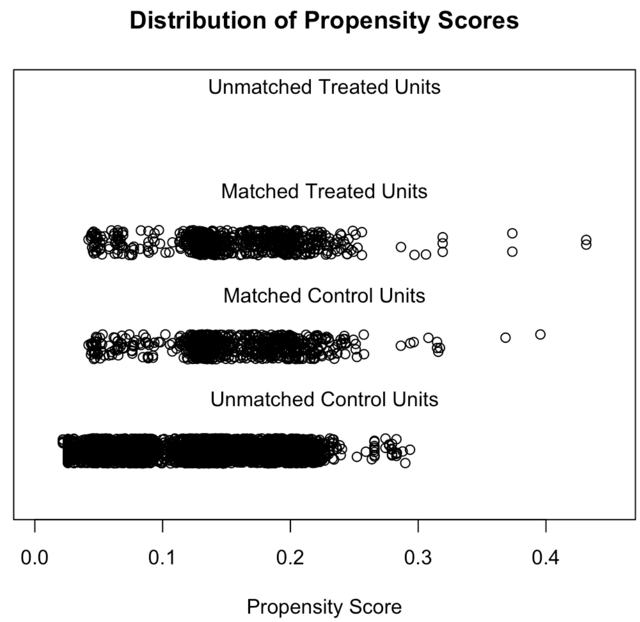

Figure 2: *Distribution of propensity scores for the data sample from 2013 to 2024.*

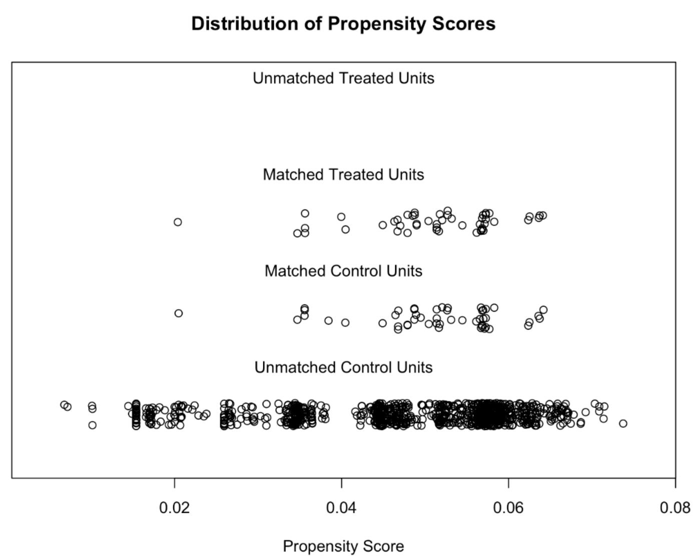

Figure 3: *Distribution of propensity scores for the data sample from 2013 to 2017.*

Figure 2 and 3 illustrate the distribution of propensity scores, which demonstrates the efficacy of the propensity score matching process in this dataset. The close overlap between matched treated and control units highlights the precision of the matching process in selecting pairs with similar propensity scores, essential for equitable comparisons. The absence of unmatched treated units confirms that every treated individual was appropriately matched, ensuring comprehensive data utilization. For unmatched control units, their significant presence indicates a careful selection process, preferring quality matches over merely using all available data, which enhances the validity of comparisons.

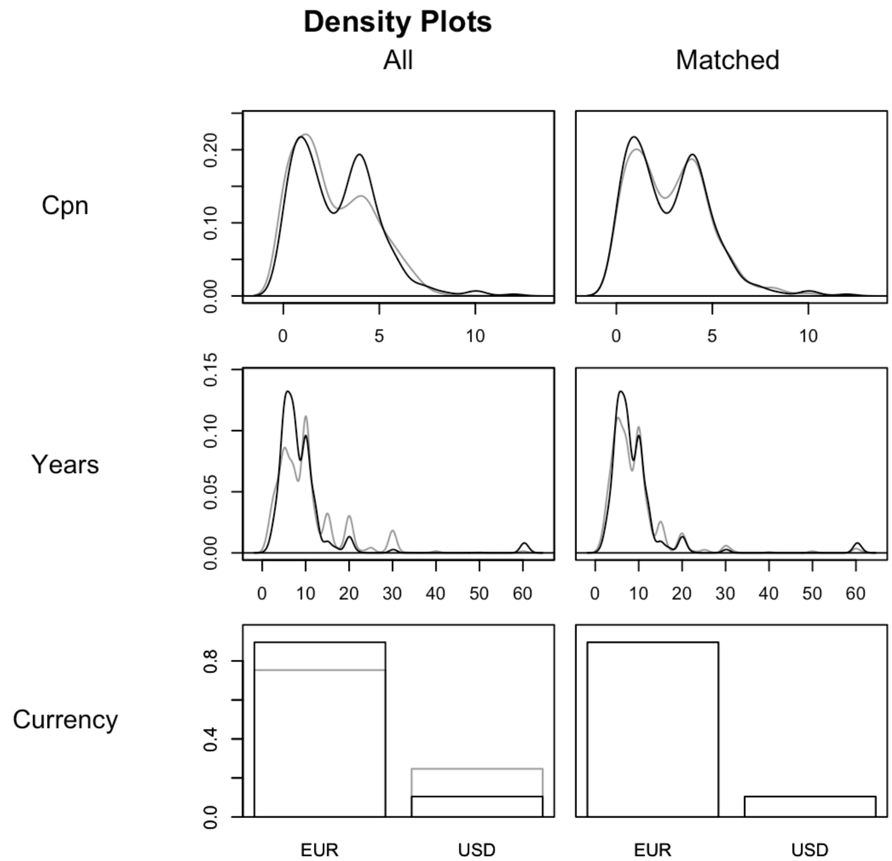

Figure 4: *Density of propensity scores for the data sample from 2013 to 2024.*

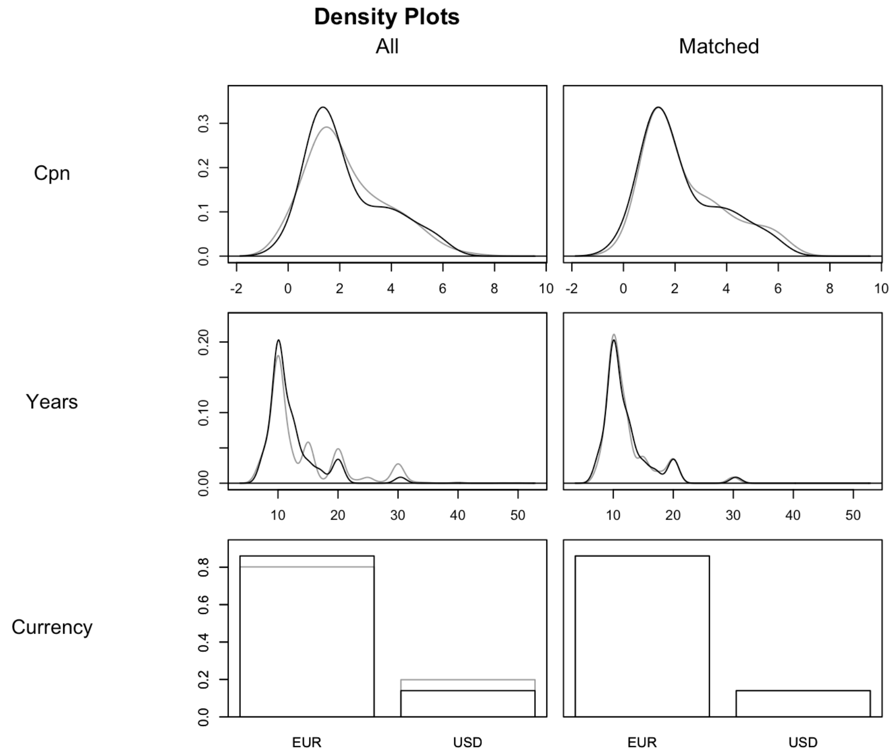

Figure 5: *Density of propensity scores for the data sample from 2013 to 2017.*

5 EMPIRICAL METHOD

5.1 Yield difference

This study examines the correlation between investor demand and issuer supply in the green bond market, specifically focusing on the ask yields of paired green and conventional bonds. Therefore, data on ask yields was collected from Bloomberg, covering the period from the issuance date of each green bond up to April 1, 2024, resulting in an unbalanced panel of 34,993,398 observations. If on any given day, the ask yields information was unavailable, the line was excluded from the analysis, resulting in a refined dataset comprising 601,128 daily observations. Table 8 presents the descriptive statistics for the bonds in the 670-bond pair sample, covering the period from November 2013 to April 2024. Table 9 provides the descriptive statistics for a 50-bond pair sample, spanning the period from November 2013 to December 2017.

Table 8: *This table outlines the distribution of key metrics across 670 pairs of bonds in sample from 2013 to 2024. It details the duration of data available for each bond pair from their issuance, illustrating the length of the time series tracked for each pair. The distribution of the ask yields is shown for both green ($y_{i,t}^{GB}$) and conventional bonds ($y_{i,t}^{cB}$). Yield difference % ($\Delta y_{i,t}$) represents the discrepancy between the ask yield of the green bonds and the conventional bonds.*

	Min.	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**
Number of days per bond	1	173	405	474	723	1233
Ask yield of the GB ($y_{i,t}^{GB}$)	17.08	87.03	94.56	93.21	100.43	148.59
Ask yield of the CB ($y_{i,t}^{cB}$)	0.00	88.42	96.04	94.47	100.71	163.36
Yield difference % ($\Delta y_{i,t}$)	-83.066	-6.140	-0.727	-1.261	3.269	104.445

Notes: GB abbreviation represents the green bond and CB represents the conventional bond.

Table 9: *This table outlines the distribution of key metrics across 50 pairs of bonds in the sample from 2013 to 2017. It details the duration of data available for each bond pair from their issuance, illustrating the length of the time series tracked for each pair. The distribution of the ask yields is shown for both green ($y_{i,t}^{GB}$) and conventional bonds ($y_{i,t}^{cB}$). Yield difference % ($\Delta y_{i,t}$) represents the discrepancy between the ask yield of the green bonds and the conventional bonds.*

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Number of days per bond	18	164	344.5	388.3	547.8	908
Ask yield of the GB ($y_{i,t}^{GB}$)	25.13	89.73	98.45	96.12	102.74	148.59
Ask yield of the CB ($y_{i,t}^{cB}$)	49.99	92.00	99.38	98.26	104.33	163.36
Yield difference % ($\Delta y_{i,t}$)	-79.737	-6.658	-1.172	-2.141	2.172	45.268

Notes: GB abbreviation represents the green bond and CB represents the conventional bond.

The dataset of the ask yields was finalized by calculating the yield spread between the green bond and its matched traditional bond on a daily basis. By comparing the yields of green and conventional bonds on the same day, the analysis aimed to control for fluctuations in the broader market conditions that affect bond yields and issue-specific biases such as credit risk. Let $y_{i,t}^{GB}$ represent the ask yield of the green bond i on day t, and $y_{i,t}^{CB}$ denote the ask yield of the conventional bond i on the same day t. The yield spread for each bond pair on any given day, denoted by $(\Delta y_{i,t})$, was calculated using the formula:

$$\Delta y_{i,t} = y_{i,t}^{GB} - y_{i,t}^{CB} \tag{5}$$

A positive differential signifies that the green bond is being traded at a yield that is higher than its conventional counterpart. This essentially implies that the green bond is being sold at a discount, offering investors a greater return compared to a similar conventional bond.

A statistical analysis of the average yield spread for the period from November 2013 to April 2024 revealed that approximately 49.18 percent of the values were negative, with an average yield spread of -0.67 basis points (bps) and a median of -0.016 bps. A different dataset from November 2013 to December 2017 revealed that 59.14 percent of the values were negative, with an average yield spread of -2.08 bps and a median of -1.54 bps. These statistics indicate that, on average, green and conventional bonds are perceived as similarly attractive, with a slight preference for green bonds yielding less. The second dataset shows a greater negative average yield spread, indicating that the negative yield spreads were more prominent. This means that the gap between the yields was bigger when the spread was negative. This suggests that there is a small premium associated with the environmental attributes of green bonds or their perceived lower risk profile. Subsequent analysis will explore how much of this yield difference can be attributed to the ”greenness” of the bonds.

5.2 Liquidity proxy

Previous research has demonstrated that investors receive a higher yield as compensation for bearing liquidity risk (Rush, 2018). Common metrics to gauge liquidity risk include the size of bond issuance and its age. While standardizing these factors between green and conventional bonds partially mitigates aspects of liquidity risk, critiques by Zerbib (2019) have pointed out that the methods employed by Baker et al. (2018) do not sufficiently address liquidity risk considerations. Langedijk, Monokroussos, and Papanagiotou (2018) determined that the bid-ask spread is the most reliable indicator among various time periods after assessing many liquidity proxies. Moreover, Zerbib (2019) utilised the bid-ask spread as a proxy for liquidity in his research. Therefore, the bid-ask spread will be utilised as the primary indicator of liquidity risk in this study. The bid-ask spread for each bond is determined by the equation:

$$\text{BAS}_{i,t} = \text{ASK}_{i,t} - \text{BID}_{i,t} \tag{6}$$

In this case, the bid-ask spread of bond i at time t is represented by $\text{BAS}_{i,t}$, and the asking and bidding prices are indicated by $\text{ASK}_{i,t}$ and $\text{BID}_{i,t}$, respectively. The aforementioned spread is calculated on a daily basis for both types of bonds.

Subsequently, a liquidity proxy for each bond type at time t is determined using the differential bid-ask spread between green and conventional bonds, defined as:

Afterwards, the disparity in bid-ask spread bonds at time t is used to produce a liquidity proxy for each bond type. This is defined as:

$$\Delta\text{Liquidity}_{i,t} = \text{BAS}_{i,t}^{GB} - \text{BAS}_{i,t}^{CB} \tag{7}$$

5.3 Identification of the premium associated with green bonds

Incorporating the equations 4 and 6 into a new model, expressed in equation 6, allows for the assessment of how liquidity disparities influence the gap in yield between green bonds and their counterparts.The yield difference, which is the dependent variable in the model represented by equation 8, is represented as $\Delta y_{i,t}$. $\Delta y_{i,t}$ captures variations in the ask yields between green and conventional bonds. The independent variable, $\Delta \text{Liquidity}_{i,t}$, represents the disparity in the bid-ask spreads.

The model, provided in equation 8, incorporates p_i as the green premium specific to each bond. p_i captures specific bond traits that remain consistent over time but might affect the yield difference due to the bond's green nature. The coefficient β indicates how much the liquidity difference affects the yield differential. The error term, $\epsilon_{i,t}$, accounts for the residual effects that the model is unable to explain. Specifically, the model in equation 8 is a fixed panel regression set up to control for unobservable heterogeneity across bonds.

$$\Delta y_{i,t} = p_i + \beta \Delta Liquidity_{i,t} + \epsilon_{i,t} \tag{8}$$

However, a Hausman test was initially conducted to ascertain the most appropriate estimator between a fixed-effects model and a pooled ordinary least squares (OLS) model. This test evaluates the suitability of a random-effects model (the null hypothesis) in comparison to a fixed-effects model (the alternative hypothesis). The fixed-effects model appears to be a superior match for the research in question, as seen by the low p-value in Tables 17 and 18 following the Hausman test, which led to the null hypothesis' rejection. Consequently, the fixed-effects model was chosen due to the proven superiority.

Additionally, to examine the presence of heteroskedasticity within the data, the Breusch-Pagan test was utilized. A p-value of less than 0.01 from the Breusch-Pagan test indicated that there was considerable heteroskedasticity in the data. Additionally, we applied the Breusch-Godfrey Wooldridge test to detect serial correlation, which returned a p-value of less than 2.2e-16. Both tests confirmed the existence of serial correlation and heteroskedasticity in the residuals, indicating potential cross-sectional and time-series dependencies (Abadie, Athey, Imbens and Wooldridge, 2023).

Previous research has shown that clustering standard errors across bonds and time enhances robustness against correlated residuals in these dimensions (Zerbib, 2019; Abadie et al., 2023). Therefore, this study will provide estimates with standard errors clustered in both dimensions.

5.4 Factors influencing the green premium

Using equation 9, I performed a multiple linear regression analysis to find the variables affecting the green bond premium. This model, which is based on Zerbib's (2019) work, takes into account factors including credit ratings, bond maturity, the issued amount's natural logarithm and the principal currency based on green bond data only. Here, maturity and issued amount are quantitative variables. The reference groups are EUR currrency and bond's AAA credit rating and perpetual maturity type. Unlike Zerbib (2019), this study does not incorporate the issuer's sector and instead adds the bond's maturity type as a variable. The regression model is defined as:

$$\begin{aligned} p_i =& \beta_0 + \beta_1 \text{Maturity} + \beta_2 \log(\text{Amount Issued}) + \sum_{j=1}^{N_{\text{Rating type}}-1} \gamma_{1,j} 1_{\text{Rating}_j} + \\ &+ \sum_{j=1}^{N_{\text{Maturity type}}-1} \gamma_{2,j} 1_{\text{Maturity type}_j} + \sum_{j=1}^{N_{\text{Currency}}-1} \gamma_{3,j} 1_{\text{Currency}_j} + \epsilon_i \end{aligned} \tag{9}$$

in which j is used as the summation index for each of the categorical variables: Rating type, Maturity type, and Currency. $\gamma_{\text{Rating},j}$, $\gamma_{\text{Maturity type},j}$, and $\gamma_{\text{Currency},j}$ represent the coefficients associated with the j-th category of the respective variable. 1_{Rating_j}, $1_{\text{Maturity type}_j}$, and 1_{Currency_j} are binary indicator variables that take the value 1 if the observation belongs to category j and 0 otherwise.

In the analysis of green bonds, the categorical variables of credit ratings, maturity types, and currencies are converted into numeric ordinal measures in order to reflect their hierarchical nature, as outlined by Fong et al. (2018) and Zerbib (2019). Credit ratings are translated into numeric values as follows: AAA is 1, AA is 2, A is 3, BBB is 4, BB is 5, B is 6, CC is 8, and NR (No Rating) is 9. These values encapsulate the relative risk and creditworthiness of each rating. Similarly, maturity types are numerically ordered to indicate their varying risk levels. Bonds that mature at a specified date are valued as 1, while callable bonds are given a numerical value of 2, perpetual bonds that do not have a maturity date are given a numerical value of 3. This reflects the added risk of early redemption by the issuer. Moreover, EUR is designated as 1, while the USD is designated as 2. This accounts for differences in currency-related risks and economic conditions. The use of ordinal conversions enables the implementation of sophisticated regression analysis, which accurately captures the hierarchical structure of the variables and their influence on bond yields. This, in turn, enhances the robustness and interpretability of the analysis on green bond premiums.

Table 10: *Credit rating conversion table to numerical ordinal measure.*

Rating Level	Ordinal Measure
AAA	1
AA	2
A	3
BBB	4
BB	5
B	6

Table 11: *Maturity type conversion table to numerical ordinal measure.*

Maturity Type	Ordinal Measure
At maturity	1
Callable	2
Perpetual	3

Table 12: *Currency conversion table to numerical ordinal measure.*

Currency	Ordinal Measure
EUR	1
USD	2

6 RESULTS

6.1 Liquidity proxy

Tables 13 and 14 present the descriptive statistics for the bid-ask difference. Table 13 indicates an average bid-ask difference of -0.035, which suggests that the bid price is typically slightly lower than the ask price. Despite this average, the bid-ask spread shows considerable variability, with a range from -76.364 to 101.084. This wide range indicates the presence of outliers or extreme values, which are significant for understanding market behaviour and liquidity conditions. In contrast, the statistics for the shorter period dataset in Table 14 reveal a slightly more negative mean bid-ask spread of -0.0357, indicating a larger average difference between bid and ask prices within this timeframe. However, the the bid-ask spread's range in the shorter period is narrower (-74.829 to 82.063) compared to the longer period (-76.364 to 101.084). This suggests that the shorter period dataset contains fewer extreme values or outliers. Consequently, the data from the shorter period exhibits a larger average bid-ask difference with fewer extreme values. This highlights the presence of significant outliers, which could impact market behaviour and liquidity analysis.

The narrower bid-ask spread range in the shorter period (2013-2017) suggests a more stable and liquid market compared to the longer period (2013-2024), which experienced more significant economic disruptions leading to a wider spread range. The 2013-2024 period includes more recent economic events such as the COVID-19 pandemic, which introduced significant market volatility and uncertainty. The wider range reflects these turbulent economic conditions, with periods of both high and low liquidity and increased information asymmetry.

Table 13: *Descriptive statistics of the bid-ask spread (ΔLiquidity) for the period from November 2013 to April 2024*

Variable	Obs	Mean	Std. Dev	Min	Max
ΔLiquidity	189489	-0.03569036	14.45888	-76.364	101.084

Table 14: *Descriptive statistics of the bid-ask spread (ΔLiquidity) for the period from November 2013 to December 2017*

Variable	Obs	Mean	Std. Dev	Min	Max
ΔLiquidity	66420	-0.3165918	14.10015	-74.829	82.063

As outlined in the methodology section, clustered standard errors are employed to address problems of serial correlation and heteroskedasticity. Therefore, fixed-effects regression with clustered standard errors was used to assess the liquidity proxy's efficacy. The coefficients for the bid-ask spread (ΔLiquidity) between different time periods in the ordinary fixed-effects regression and the one with clustered standard errors are consistent, as Tables 15 and 16 demonstrate. Moreover, the R-squared values are comparable between the two models, suggesting that the explanatory power of the models remains unaltered by the incorporation of clustered standard errors.

Table 15: *Regression Results for Fixed Effects (FE) and Fixed Effects (FE) with Clustered Standard Errors for the period from November 2013 to April 2024. The estimated coefficient for ΔLiquidity in the fixed effect with clustered standard errors model was adjusted for both bond and time factors.*

	(1) FE	**(2) FE Clustered**
Δ Liquidity	0.5572952	0.557295
	(0.0012098)	(0.069299)
t-value	460.66	8.0419
Pr(>|t|)	$< 2.2 \times 10^{-16***}$	$< 2.2 \times 10^{-16***}$
R^2	0.52905	0.52905
Adjusted R^2	0.52759	0.52759
N	189489	189489

Notes: Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

To find out if the coefficient for ΔLiquidity differs from zero considerably, a t-test is employed. The typical fixed-effects regression's considerably high t-value of 460.66 shows that there is a considerable connection between the dependent variable and ΔLiquidity.

A t-test is used to determine if the coefficient for ΔLiquidity differs from zero considerably. There is a considerable correlation between ΔLiquidity and the dependent variable, as indicated by the significantly high t-value of 460.66 at 1% significance level in the fixed-effects regression model. However, this value drops to 8.0419 when using clustered standard errors, though the p-values remain exceedingly low (below 2.2×10^{-16}) in both models, affirming the statistical significance of ΔLiquidity at 1% significance level.

This decrease in the t-value with clustered standard errors suggests a more conservative estimation of statistical significance, taking into account heteroskedasticity and serial correlation. Therefore, the fixed-effects model with clustered standard errors provides robust and reliable estimates.

Table 16: *Regression Results for Fixed Effects (FE) and Fixed Effects (FE) with Clustered Standard Errors for the period from November 2013 to April 2017. The estimated coefficient for ΔLiquidity in the fixed effect with clustered standard errors model was adjusted for both bond and time factors.*

	(1) FE	**(2) FE Clustered**
Δ Liquidity	0.5508957	0.550896
	(0.0020163)	(0.089376)
t-value	273.22	6.1638
Pr(>|t|)	$< 2.2 \times 10^{-16***}$	$< 2.2 \times 10^{-16***}$
R^2	0.53005	0.53005
Adjusted R^2	0.52838	0.52838
N	66420	66420

Notes: Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 16 presents the regression results for the fixed effects (FE) model and the fixed effects model with clustered standard errors (FE Clustered) for the period from 2013 to 2017. The coefficient for the liquidity variable is nearly identical in both models, at 0.5508957 for the fixed effect model and 0.550896 for fixed effect regression with clustered standard errors, indicating a strong positive relationship between changes in liquidity and the dependent variable. The p-value remains highly significant in both models (below 2.2×10^{-16}), thereby demonstrating a robust statistical relationship. The R^2 (0.53005) and Adjusted R^2 (0.52838) values for both models are the same, meaning that they explain the same proportion of variation in the dependent variable. The results show that there is a substantial, positive and statistically significant association between the dependent variable and liquidity. The fixed effects model with clustered standard error provides a more conservative estimate of the standard error.

The consistency in the R-squared values and the significance of ΔLiquidity at 1% significance level in the models in both time periods confirm that the measures controlling for potential biases, such as clustering standard errors, are effective. This implies that the liquidity proxies used in the analysis are sufficiently robust to minimise the disparities in liquidity between green and traditional bonds. The successful application of a matching method, in conjunction with clustered standard errors, effectively addresses the discrepancies in liquidity between these bond types. The enhanced balance of key variables post-matching, together with the robust estimates derived from the regression, serve to reinforce the credibility of the causal inference.

As previously stated in Section 5.3, additional tests should be employed to substantiate the resilience of our models. The outcomes, presented in Tables 17 and 18, illustrate that utilising fixed effects models with clustered standard errors enhances the robustness of the models against correlated residuals. These additional tests, including the Breusch-Godfrey Wooldridge test and the Breusch-Pagan test, indicate significant heteroskedasticity and serial correlation in both datasets. By clustering standard errors, we account for these issues, leading to more reliable and robust estimates.

Table 17: *P-values of various statistical tests for the data sample representing the period 2013-2024. The Hausman test detects systematic differences between fixed and random effects and Honda test evaluates random effects versus fixed effects models. The Breusch-Pagan test ensures constant error variance. The Breusch-Godfrey Wooldridge test identifies serial correlation in residuals.*

	Hausman test	**Breusch-Pagan test**	**Breusch-Godfrey Wooldridge test**	**Honda test**
p-value (FE)	0.08767	$< 2.2 \times 10^{-16}$	$< 2.2 \times 10^{-16}$	$< 2.2 \times 10^{-16}$
p-value (FE clustered)	–	2.2×10^{-16}	2.2×10^{-16}	2.2×10^{-16}

Table 18: *P-values of various statistical tests for the data, representing the period 2013-2017. The The Hausman test detects systematic differences between fixed and random effects and Honda test evaluates random effects versus fixed effects models. The Breusch-Pagan test ensures constant error variance. The Breusch-Godfrey Wooldridge test identifies serial correlation in residuals.*

	Hausman test	**Breusch-Pagan test**	**Breusch-Godfrey Wooldridge test**	**Honda test**
p-value (FE)	0.02846	$< 2.2 \times 10^{-16}$	$< 2.2 \times 10^{-16}$	$< 2.2 \times 10^{-16}$
p-value (FE clustered)	–	2.2×10^{-16}	2.2×10^{-16}	2.2×10^{-16}

6.2 Green bond premium

The results from Table 19 show that the mean (median) of the green premium is -1.386 (-0.850) basis points. A premium of -1.386 basis points is a small percentage of the average ask yield for the green bonds. The first quartile is -6.728 basis points, and the third quartile is 3.410 basis points, indicating a relatively symmetrical distribution around the central value. Overall, the green premium is quite small compared to the average yield of green bonds, with some variability and instances of higher positive premiums.

Table 19: *The distribution of the green premium $\hat{p}_i$ in basis points, estimated from equation 8 using the coefficient corresponding to the green bond indicator for the period from November 2013 to April 2024.*

	Min	1st Quartile	Median	Mean	3rd Quartile	Max	SD
$\hat{p}_i$ (bp)	-79.737	-6.728	-0.850	-1.386	3.410	104.445	10.767

The distribution of the green bond premia for the data sample covering the years 2013 through 2024 is displayed in Figure 6. The steep peak at zero indicates that most green bonds have prices that are little to nothing higher than those of their conventional equivalents. However, the plot shows that there is a tendency towards negative premia, indicating that investors generally accept lower yields for green bonds, likely due to their environmental and sustainability benefits. The symmetrical nature of the distribution with a sharp peak also suggests that significant deviations from zero premium are relatively rare.

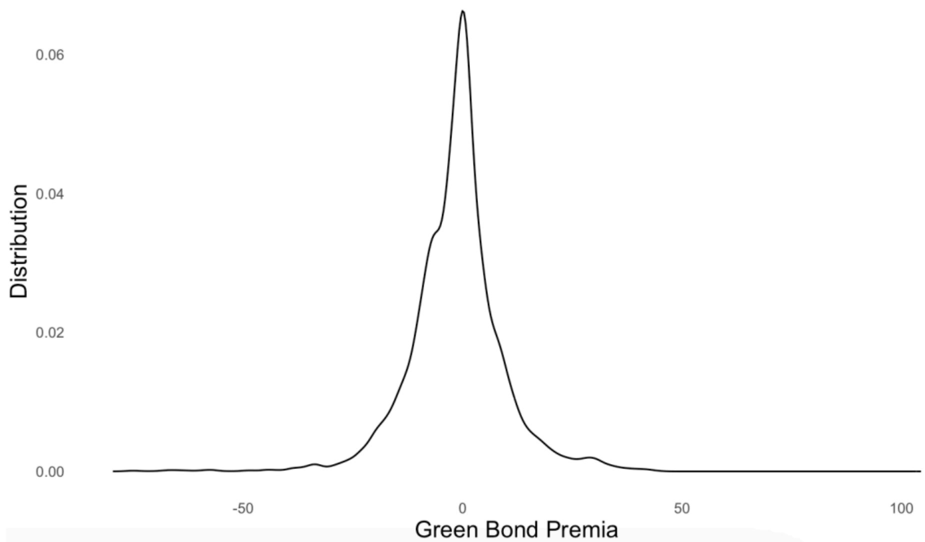

Figure 6: *The distribution of green bond premiums was analyzed using a data sample spanning from 2013 to 2024.*

The results from Table 20 show that the mean (median) of the green premium is 1.669 (-2.787959) basis points. A premium of 1.669 basis points is a small percentage of the average ask yield for the green bonds. The first quartile is -7.523 basis points, and the third quartile is 10.114269 basis points, indicating a relatively symmetrical distribution around the central value.

Table 20: *The distribution of the green premium $\hat{p}_i$ in basis points, estimated from equation 8 using the coefficient corresponding to the green bond indicator for the period from November 2013 to December 2017.*

	Min	1st Quartile	Median	Mean	3rd Quartile	Max	SD
$\hat{p}_i$ (bp)	-79.737	-7.523	-1.6215	-2.787959	1.669	35.053	10.114269

Figure 7 represents a significant peak at around 0, indicating that the most common green bond premia are centred around this value. According to this, green bonds typically have a premium close to zero, meaning that they are frequently issued at par with conventional bonds or without a sizable premium or discount. However, the distribution is skewed to the left, as there are more observations of negative premiums compared to positive ones. This suggests that a sizable portion of green bonds are issued at yields that are lower than those of conventional bonds.

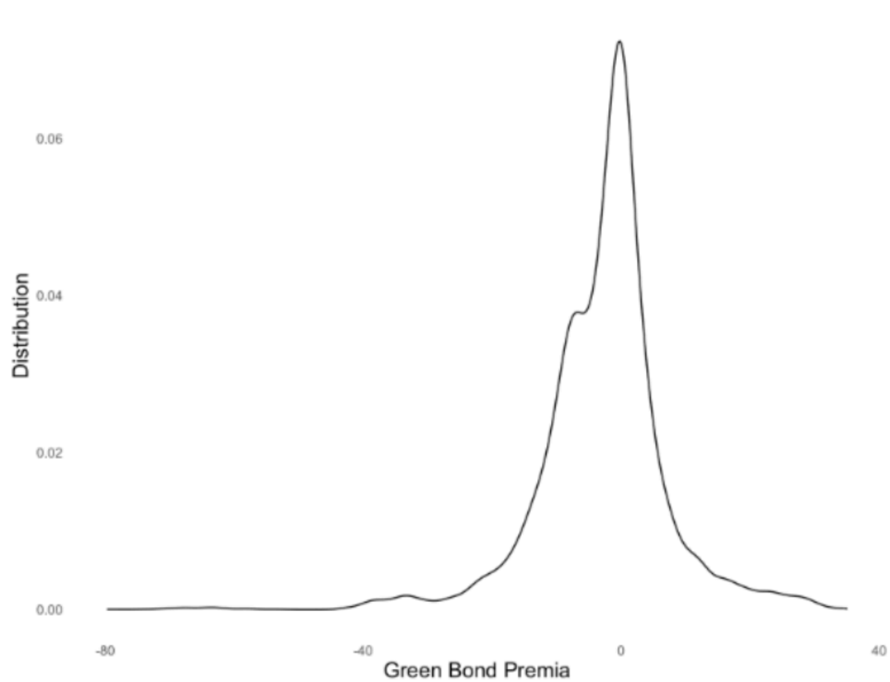

Figure 7: *The distribution of green bond premiums was analyzed using a data sample spanning from 2013 to 2017.*

To ascertain if the green premium, the median yield difference between green bonds and conventional bonds, is substantially different from zero, I employed the Wilcoxon signed-rank test with continuity correction. The test's null hypothesis states that there is no significant yield difference between conventional and green bonds, with the median green premium being zero. The median green premium does not equal zero, according to the alternative hypothesis.

Table 21: *Results of the Wilcoxon Signed-Rank test with continuity correction for the data sample from the period 2013-2024*

Statistic	Value
Test Statistic (V)	7335093898
p-value	$< 2.2 \times 10^{-16}$
Confidence Interval	[-1.318573, -1.241003]
Pseudo Median	-1.279951

The results, as shown in Table 21, indicate that the null hypothesis is rejected at the 1% significance level, with a p-value lower than 2.2×10^{-16}. The confidence interval for the difference in medians is $[-1.318573, -1.241003]$, which is entirely negative, and the pseudo median is -1.279951. These results suggest that the yields on green bonds are, on average, around 1.28 basis points lower than those on conventional bonds. Because of their perceived advantages to sustainability and the environment, investors may be ready to accept lower returns on green bonds, as indicated by this negative green premium. The studies conducted by Zerbib (2019) and Kapraun et al. (2021) produced similar findings. Consequently, the market favors green bonds despite their lower returns, underscoring their attractiveness for socially responsible investing.

Table 22: *Results of the Wilcoxon Signed-Rank test with continuity correction from November 2013 to December 2017*

Statistic	Value
Test Statistic (V)	704079062
p-value	$< 2.2 \times 10^{-16}$
Confidence Interval	[-2.478467, -2.353458]
Pseudo Median	-2.41598

For the data from 2013 to 2017, test results in Table 22 demonstrate a statistically significant negative green premium. The test statistic (V) is 704,079,062, and the p-value is less than 2.2×10^{-16} . Such results suggest that there is a considerable difference between zero and the median green premium, allowing to reject the null hypothesis. Moreover, the 95% confidence interval for the pseudo median is $[-2.478467, -2.353458]$, with a pseudo median value of -2.41598 basis points. This means that, on average, green bonds yield approximately 2.416 basis points less than their non-green counterparts. Therefore, investors seem willing to accept lower returns for sustainable investments. This result aligns with the negative ”greenium” that was previously reported in the literature by Zerbib (2019) and Kapraun et al. (2021).

The comparison of results from Table 22 and Table 21 highlights a consistent trend of a statistically significant negative green premium in the bond market, emphasizing the willingness of investors to accept lower yields for green bonds in exchange for their sustainability benefits. Both tables report p-values less than 2.2 × 10−16, rejecting the null hypothesis at the 1 percent significance level. However, the magnitude of the green premium differs slightly between the two datasets. Table 22 indicates a pseudo median yield differential of −2.42 basis points over the time period 2013-2017. In contrast, Table 21 reports a smaller pseudo median of −1.28 basis points over the time period 2013-2024. The economic intuition for such differences lies in the different economic conditions and implementation of the regulations.

During the 2013-2017 period, the European corporate bond market experienced a higher green premium of -2.416 basis points due to several intertwined economic factors and significant events. The Paris Agreement underscored the global commitment to sustainability, increasing investor interest in sustainable investment vehicles. Investors began to perceive green bonds as a means to mitigate long-term environmental risks, valuing the positive externalities such as reduced carbon emissions. Initially, green bonds were often self-verified by the issuers, leading to concerns about credibility and potential greenwashing. This increased the perceived risk, requiring a premium to compensate investors. Yet supportive regulatory policies, such as the EU's commitment to sustainable finance and the introduction of the Green Bond Principles (GBP) in 2014, further fueled demand. These policies incentivized green investments and provided subsidies for green projects. Additionally, the demand for green bonds surged as institutional investors, driven by ESG mandates and a growing preference for sustainable investments, outstripped the limited supply of green bonds. Over time, the gradual establishment of third-party verification standards increased credibility. However, initially, the self-verification by issuers necessitated a higher green premium to offset the associated risks and lower liquidity. Thus, the higher green premium of -2.416 basis points in the European corporate bond market from 2013 to 2017 can be attributed to the interplay of risk perception, supply and demand dynamics, supportive regulatory policies, and market liquidity considerations.

Between 2013 and 2024, the European corporate bond market experienced a notable shift in the green premium, moving from a higher premium to a lower one, ultimately reaching a green premium of -1.28 basis points. This shift was largely influenced by the market's maturation post-2017, driven by the establishment of robust third-party verification standards that enhanced investor confidence and reduced risk premiums. Implementation of initiatives such as the EU Taxonomy and the Green Deal, alongside the increasing importance of climate-related financial disclosures, made green bonds more attractive to investors. As green bonds became mainstream, their supply increased, narrowing the premium gap. These bonds began offering competitive or even lower yields compared to conventional bonds due to their perceived lower long-term risk and alignment with ESG strategies, resulting in a negative green premium. During economic uncertainties like the COVID-19 pandemic in 2020, investors shown a strong preference for green bonds, accepting lower yields for their long-term benefits and lower risks. Initially, heightened risk perceptions increased yields, but as uncertainty diminished, green bonds returned to their lower-yield status, partly due to increased liquidity. As shown in Tables 15 and 16, liquidity was higher during the 2013-2024 period, mainly due to turbulent economic times. Increased liquidity in the green bond market narrowed the yield gap with conventional bonds, reflecting their comparability in terms of risk and return. Despite temporary disruptions from events like the pandemic and the Russian invasion of Ukraine, central bank interventions and sustained demand for green investments supported a recovery in liquidity over the medium to long term.

6.3 Robustness check

One potential concern with the observed green premium is that it might merely reflect the decreased risk attached to green bonds in comparison to conventional bonds. Including more risk control factors to equation 9 was necessary in order to address this. Following Zerbib (2019), I have added the differences in 10-day and 30-day volatility variables as controls. This adjustment takes into consideration both short-term and longer-term price volatility in an effort to better isolate the impact of the green label on bond pricing from the underlying risk differences between green and conventional bonds.

The formula for the regression, incorporating a control for volatility, is presented as follows:

$$\Delta y_{i,t} = p_i + \beta \Delta \text{Liquidity}_{i,t} + \Delta \text{Vol}_{i,t} + \epsilon_{i,t} \tag{10}$$

This regression model, following Zerbib's methodology (2019), aims to explain the variation in the green bond premium by considering three main factors: bond-specific characteristics (p_i), changes in liquidity (ΔLiquidityi, t), and changes in 10- and 30-day volatility (ΔVoli, t). The coefficients β and the implicit coefficient for $\Delta \text{Vol}_{i,t}$ offer insights into how these factors influence the green bond premium over time.

Table 23: *Results of the regression model with the 10- or 30-day volatility taken into consideration, as stated in equation 10. The data sample spans the years 2013-2024.*

	(1) FE	(2) FE Clustered
Δ Liquidity	0.4321204**	0.432120**
	(0.0020156)	(0.085472)
Δ 10-day Volatility	-0.0000347	-0.0000347
	(0.0000124)	(0.0000151)
Δ 30-day Volatility	0.0000218	0.0000218
	(0.0000187)	(0.0000193)
t-value	214.36	5.0584
Pr(>|t|)	$< 2.2 \times 10^{-16***}$	$6.701 \times 10^{-7***}$
R^2	0.58732	0.58732
Adjusted R^2	0.58576	0.58576
N	80567	80567

Notes: Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 24: *Results of the regression model with the 10- or 30-day volatility taken into consideration, as stated in equation 10. The data sample spans the years 2013-2017.*

	(1) FE	(2) FE Clustered
Δ Liquidity	0.312***	0.3165***
	(0.010)	(0.045)
Δ 10-day Volatility	-0.00045	-0.00045
	(0.00008)	(0.00012)
Δ 30-day Volatility	0.00005	0.00005
	(0.00015)	(0.00018)
t-value	31.20	6.93
Pr(>|t|)	$< 2.2 \times 10^{-16***}$	$4.2 \times 10^{-6***}$
R^2	0.482	0.482
Adjusted R^2	0.480	0.480
N	100567	100567

Notes: Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Tables 23 and 24 show that there is a substantial and significant effect of changes in liquidity (ΔLiquidity) on the green bond premium in both models. Specifically, Table 23 shows that over the time period of 2013-2014, at the 5% significance level, ΔLiquidity significantly and positively affects the dependent variable, and the models account for around 58.7% of the variation in the dependent variable. The Table 24, represents the results using the data from 2013-2017, where ΔLiquidity shows a strong positive correlation, significant at the 1% level, with the models accounting for about 48.2% of the variance. This indicates that liquidity changes have a robust explanatory power for the green bond premium, especially in longer periods, as evidenced by the better model fit in Table 23.

Conversely, both 10-day and 30-day volatility changes (Δ 10-day Volatility and Δ 30-day Volatility) in both tables exhibit negligible and statistically insignificant effects on the green bond premium. The coefficients for these volatility measures are very close to zero, with standard errors indicating no statistical significance. This insignificance is further underscored by the fact that the coefficients are much smaller than their respective standard errors. The observed lack of significance in the effect of 10-day and 30-day volatilities on the green bond premium aligns with the findings of Zerbib (2019), who also reported no significant impact.

These findings suggest that while liquidity changes significantly influence the green bond premium, short-term volatility does not. This stability in green bond premiums underscores their attractiveness as stable investment instruments, particularly for those with a lower risk tolerance.

6.4 The determinants of the green bond premium

In order to identify the factors influencing the green bond premium, a linear regression analysis of the change in the premium, Δp_i, on the characteristics of the green bond was performed. The results of this analysis are presented in Tables 27 and 28, which explain the correlation between the green bond premium and various bond characteristics. The regression models utilized to identify the determinants of the green bond premium are as follows:

1. Model [(a)]: The full model expressed in equation 9;
2. Model [(b)]: A reduced model that excludes the variables log(Issue Amount), maturity and currency dummies from equation 9.

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Table 25: *The results of the linear regressions with robust standard errors, based on a data sample from 2013 to 2017.*

Variable	Model (a)	Model (b)
(Intercept)	-4.6361	3.58217***
	(3.1747)	(0.16023)
Maturity	0.0262	–
	(0.0346)	–
Log (Amount Issued)	-0.3880*	–
	(0.1556)	–
Rating: BBB	-0.0055	-0.23495
	(0.1395)	(0.25668)
Rating: BB	-1.1518**	-1.13760**
	(0.2459)	(0.35550)
Rating: B	-2.0916***	-2.26122***
	(0.1617)	(0.29436)
Maturity type: callable	0.4108	0.13710
	(0.1249)	(0.20098)
Maturity type: at maturity	-0.35**	-0.238**
	(0.13)	(0.21)
Currency: USD	1.9202***	–
	(0.0868)	–
t-value	214.36	5.0584
Pr(>|t|)	$< 2.2 \times 10^{-16***}$	$6.701 \times 10^{-7***}$
Multiple R^2	0.7342	0.6833
Adjusted R^2	0.7069	0.6607
p-value	$< 2.2 \times 10^{-16}$	3.14×10^{-16}
F-statistic	26.84 on 7 and 68 DF	30.21 on 5 and 70 DF

Notes: Standard errors in parentheses.

Regressions were performed using dummy variables for each rating, maturity type and currency.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 26: *The results of the linear regressions with robust standard errors, based on a data sample from 2013 to 2017.*

Variable	Model (a)	Model (b)
(Intercept)	-8.24745*	-3.5450***
	(3.79711)	(0.1533)
Maturity	-0.03623	–
	(0.02599)	–
Log (Amount Issued)	-0.55953**	–
	(0.18732)	–
Rating: BBB	-1.06601**	-0.1599**
	(0.26866)	(0.1878)
Rating: BB	-2.03286***	-0.6547***
	(0.34128)	(0.2736)
Rating: B	-2.0916*	-1.9122*
	(0.1617)	(0.3796)
Maturity type: callable	0.50582	0.5232
	(0.13972)	(0.1437)
Maturity type: at maturity	-0.768**	-0.3675**
	(0.103)	(0.2742)
Currency: USD	2.01775***	–
	(0.20528)	–
t-value	214.36	5.0584
Pr(>|t|)	$< 2.2 \times 10^{-16***}$	$6.701 \times 10^{-7***}$
Multiple R^2	0.7918	0.5181
Adjusted R^2	0.7601	0.4624
p-value	$< 2.2 \times 10^{-16}$	0.0007422
F-statistic	24.99 on 7 and 46 DF	5.714 on 4 and 49 DF

Notes: Standard errors in parentheses.

Regressions were performed using dummy variables for each rating, maturity type and currency.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The results from the regression Model (a) and Model (b) in Table 27 and Table 28 reveal an intriguing aspect of green bond market dynamics: the coefficient for maturity, despite its theoretical importance in bond investment decisions, lacks statistical significance. A bond's risk profile is typically influenced by its duration, with longer maturities typically yielding higher rates to compensate the increased risk over time (Banga, 2019). However, this expected relationship appears to diverge in the case of green bonds, making it somewhat surprising that the maturity coefficient is not statistically significant. Bond yields and maturity have a positive relationship, as evidenced in the Table 27. The positive maturity's coefficient in Model (a) indicates that, holding other variables constant, a bond's maturity increases are correlated with an increase in the green bond premium.

Conversely, Table 28 indicates a negative relationship, with Model (a) showing a maturity coefficient of -0.036. This finding—that maturity has a negative, albeit statistically insignificant, relationship with bond yields—aligns with observations made by Zerbib (2019).

The findings from both Table 27 and Table 28 indicate that the coefficient for the log of the amount issued is negative and statistically significant, as shown in Model (a). This implies a notable relationship between the issued amount of green bonds and their pricing dynamics. Table 28, which covers the period from 2013 to 2017, demonstrates that the relationship between the green bond premium and the log of the amount issued is negative at a 5% significance level. Similarly, Table 27 also shows a negative relationship, albeit at a 10% significance level. This relationship suggests that as the issuance amount of green bonds increases, the absolute premium also increases. This contrasts with the findings of Zerbib (2019), who did not observe a significant effect of the issued amount on the green premium. Larger issue sizes are often perceived as more significant and may be more likely to attract attention from institutional investors (Banga, 2019). Consequently, it was expected that the issued amount will negatively impact the green premium. Larger issuances likely attract more investors to green bonds, which has a greater impact on yields than lower issuance volumes of green bonds.

During the period from 2013 to 2024, the models in Table 27 show that credit ratings have negative coefficients, ranging from -0.00055 to -2.0916. Analysis of the two models consistently reveals significant negative coefficients for BB and B credit ratings, indicating lower yields compared to the base category. This finding is statistically significant at the 1% level for both BB and B credit ratings in Model (a), and at the 5% and 1% levels, respectively, in Model (b). Hachenberg and Schiereck

(2018) suggest that sustainable funds might prioritize maximizing returns for their investors, leading to a higher demand for lower-rated bonds, which typically offer higher yields. Similar results are observed for the earlier period from 2013 to 2017, as evident in Table 28. Lower-rated bonds (BB and B) show a negative relationship at the 1% and 5% significance levels, respectively. However, there are different results for medium-rated bonds (BBB). Both models (a) and (b) indicate that BBB-rated bonds have a significant negative relationship at the 5% significance level. In contrast, Zerbib (2019) did not find medium-rated bonds to be significant components during the same period. Typically, lower-rated bonds (e.g., BB and B) are expected to yield higher returns due to their increased risk. However, the observed negative coefficients may be attributed to factors such as investors' willingness to accept lower yields for these bonds, possibly due to their perceived future potential or specific issuer characteristics (Zerbib, 2019). The significant negative coefficients for lower-rated bonds indicate that investors in the green bond market may prioritize environmental impact and sustainability over traditional risk-return profiles.

In Table 27, Model (a) reveals a positive coefficient of 1.9202 for USD-denominated bonds, which is statistically significant at the 1% level. This indicates that green bonds issued in USD yield higher returns. Similarly, Table 28, Model (a) shows an even higher positive coefficient of 2.01775, also significant at the 1% level. Since Zerbib (2019) used USD as a reference point, a direct comparison with these results is not possible. One explanation for the observed positive coefficients is that the demand for green bonds in different currencies can influence their yields. Higher demand for USD-denominated green bonds tends to drive down their yields, while lower demand for green bonds in other currencies might require higher yields to attract investors (Nanayakkara and Colombage, 2019).

Unlike Zerbib (2019), I have decided to investigate the relationship between bond maturity type and the premium associated with green bonds. Understanding how the bond maturity type affects premium is crucial for investors making informed decisions. Risk-loving investors need to take on more risk when buying callable bonds, which give issuers the option to redeem the bond before maturity. Risk-loving investors might face early redemption, especially when interest rates fall, allowing issuers to refinance at lower costs. The positive coefficients for callable bonds in both models, ranging from 0.4108 to 0.13710 in Table 27, indicate that these bonds command higher yields to compensate for the call risk. Similar results are seen in Table 28, where callable bonds also have positive, though insignificant, coefficients. In contrast, non-callable bonds, which are held to maturity, provide a more stable investment since they are not subject to call risk. From Table 27 and Table 28, we can see that the coefficients for non-callable bonds in both models are negative and significant at the 5% significance level. The typically lower yields for non-callable bonds reflect their stability and lower risk relative to callable bonds.

Table 27: *Results of the Studentized Breusch-Pagan tests for different models based on the equation 9 from November 2013 to April 2024.*

Model	BP Statistic	Degrees of Freedom (df)	p-value
(a)	6.4244	7	0.4912
(b)	4.6694	5	0.4575

Table 28: *Results of the Studentized Breusch-Pagan tests for different models based on the equation 9 from November 2013 to December 2017.*

Model	BP Statistic	Degrees of Freedom (df)	p-value
(a)	6.5515	7	0.477
(b)	2.8091	4	0.5903

The results shown in Tables 25 and 26 represent the outcomes of the Studentized Breusch-Pagan tests for different models (a) and (b) based on the specified equation over two distinct time periods. For both time periods, Model (a) has a BP statistic slightly above 6 with a p-value well above the common significance levels (0.05, 0.01). Model (b) shows no significant evidence of heteroscedasticity, as indicated by the p-values of 0.4575 and 0.5903 for the data samples from 2013-2024 period and 2013-2017 period, respectively. The high p-values (all above 0.45) across both models and time periods suggest that heteroscedasticity is not a concern for these regression models. Therefore, the null hypothesis of homoscedasticity (constant variance of errors) cannot be rejected for any of the models or time periods.

7 CONCLUSION

The study confirms the existence of a premium for green bonds in the European corporate green bond market for bonds denominated in EUR and USD. The results show statistically significant negative green premiums, meaning that the yield on green bonds is often lower than that of conventional bonds. The green bond premium was found to be defined at 2.42 basis points for the shorter period from 2013 to 2017, and at 1.28 basis points for the longer period from 2013 to 2024. These findings are in line with Zerbib's (2019) research, that discovered a negative green bond premium for bonds issued between 2013 and 2017 of about 2 basis points. This that the hypothesis is correct and the green bond premium exists in the corporate green bond European market. This indicates that investors from Europe are willing to accept lower rates on green bonds due to their positive environmental effects. Consequently, green bonds are priced higher relative to conventional bonds, underscoring the market's valuation of their positive environmental impact.

The analysis identified several factors affecting the green premium, including bond maturity, amount issued, credit ratings, and currency denomination. Bonds issued in USD and those with higher credit ratings shown a lower green premium in absolute terms.

It was also found that the green bond premium exhibits notable variation across different time periods. Specifically, the study demonstrates that the green premium was more pronounced during the nascent stages of the green bond market (2013-2017), with an average yield differential of 2.42 basis points. During the period from 2013 to 2024, the green bond premium was equal to 1.28 basis points. This variation suggests that the green bond premium is influenced by evolving market dynamics, shifts in investor perceptions, and regulatory changes over time. The higher premium found over the period 2013-2017 can be attributed to the strong environmental preferences of early adopters and the novelty of green bonds, which appealed to a specific investor segment willing to pay a premium for sustainability. The lower premium for the period 2013-2024 can be explained by the liquidity channel, which is influenced by various geopolitical and Covid-19 events, that created shocks and increased the volatility. Therefore, the second hypothesis that the green bonds varies over time is also valid.

Overall, this paper contributes to the existing literature by shedding light on the complex interplay between the dynamics of the green bond premium. The continued existence of a negative green premium highlights the increasing significance of sustainable investments and the readiness of investors to accept marginally reduced financial gains in order to back ecologically advantageous initiatives.

This study highlights several noteworthy limitations. Firstly, since retrieving data from Bloomberg was difficult, I was unable to obtain information on the issuer's sectors. Consequently, the analysis lost important insights about the issuer's sectors, as different sectors have distinct risk profiles, market behaviors, and economic sensitivities. Not including the issuer's sector in the analysis results in missing significant variations in how bonds from different sectors behave and respond to market conditions. Secondly, the empirical analysis uses matching to compare green bonds to conventional bonds. While these methods help control for observable differences, they fall short in accounting for unobserved factors that may impact bond yields and investor behavior. This limitation could result in residual confounding, compromising the accuracy of the estimated green premium. Consequently, future research could benefit from employing qualitative approaches, such as interviews and surveys, to gain deeper insights into investors' motivations for choosing green bonds. Thirdly, the study's focus is limited to Europe and specific time periods, which may not adequately represent the global diversity and dynamic evolution of the green bond market. This geographic and temporal limitation constrains the generalizability of the findings to other contexts and periods. Europe's unique situation may not fully illustrate the true impact of a green premium due to several intertwined challenges. For instance, Europe has adopted stricter regulations for green bonds than other regions to ensure the market's integrity and transparency. Despite these stringent regulations, greenwashing remains a prevalent issue, with companies often misrepresenting their projects as environmentally friendly to attract investment, owing to the lack of universally accepted certification standards.

Future research should examine the effectiveness of various policy measures and incentives in encouraging the issuance and adoption of green bonds. Additionally, it should explore how stringent regulations influence the growth and effectiveness of the green bond market in Europe compared to regions with more lenient standards.

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THE PREMIUM OF GREEN CORPORATE BONDS

Bachelor thesis

Quantitative Economics

Vilnius University, Faculty of Economics and Business Administration

Supervisor - Eglė Jakučionytė

Vilnius, 2022

Summary

This paper investigates the existence of a green bond premium within the green bond market, focusing on European companies issuing bonds denominated in euros or US dollars. The study spans two periods: November 2013 to April 2024 and November 2013 to December 2017. Additionally, it explores if the green bond premium fluctuates across different time periods. The thesis consists of seven chapters: introduction, green bond market background, literature review, data description, methodology, findings, and conclusions.

The introduction provides an overview of the study's objectives, highlighting the investigation of green bond premiums and the factors influencing these premiums. It sets the stage for the subsequent chapters by outlining the importance and relevance of the green bond market.

The context chapter presents an overview of market trends and challenges, delving into periods of initial development, growth, and economic instability. Despite its relative novelty, the green bond market is attracting increasing interest. However, significant gaps and shortcomings persist, such as the lack of universally accepted standardized certification regulations to ensure global market integrity and efficiency.

The literature review analyses the impact of corporate social responsibility (CSR) and environmental, social, governance (ESG) variables on financial markets, including their correlation with equity costs, debt costs, and financial risk management. The thesis also examines previous studies on the premiums associated with green bonds, highlighting that the presence of these premiums differs based on the geographic locations and research methods used by different writers.

The data description section describes the data that was used for the analysis and details the process of data collection from the Bloomberg system. It also describes the construction of a balanced dataset using a 1:1 nearest-neighbor propensity score matching method. This method enables a more accurate comparison between green bonds and conventional bonds based on similar characteristics such as currency, coupon, and maturity.

The methodology section outlines the econometric methods used to assess yield differences, liquidity indicators, the green bond premium, and the factors influencing this premium. Fixed-effect regression models with clustered standard errors are employed to account for unobserved heterogeneity and control for factors affecting bond yields that are not directly observable. The analysis includes additional risk control variables, such as 10-day and 30-day volatility, to mitigate yield differences arising from varying risk levels between green and conventional bonds.

The results section presents the findings from econometric models applied to determine the yield premium of green bonds issued by European companies. The thesis found that the green bond premium exist and is estimated at -1.28 basis points for the period from 2013 to 2024 and -2.42 basis points for the period from 2013 to 2017. It was also observed that the green bond premium varies when looking at different time frames. These results align with previous empirical studies on green bond premiums, such as Zerbib (2019) and Hyun et al (2020), who also found that the green bond premium exists.

The conclusions section summarizes the key insights, implications, and suggestions for further research. It emphasizes the significance of understanding green bond premiums and the factors influencing them, contributing to the broader discourse on sustainable finance and its impact on financial markets.

ĮMONIŲ ŽALIŲJŲ OBLIGACIJŲ PREMIJA

Bakalauro darbas

Kiekybinė ekonomika

Vilniaus universitetas, ekonomikos ir verslo administravimo fakultetas

Vadovė - Eglė Jakučionytė

Vilnius, 2022

Santrauka

Pagrindinis šio darbo tikslas - atskeisti, ar žaliųjų obligacijų rinkoje egzistuoja žaliųjų obligacijų priemoka. Tyrimas buvo orientuotas į Europoje esančias įmones, kurios obligacijas leido eurais ar JAV doleriais. Buvo nagrinėjami du skirtingi laikotarpiai: nuo 2013 metų lapkričio mėnesio iki 2024 metų balandžio mėnesio bei nuo 2013 metų lapkričio mėnesio iki 2017 gruodžio mėnesio. Taip pat, buvo siekiama išsiaiškinti ar žaliųjų obligacijų priemoka svyruoja įvairiais laikotarpiais. Darbą sudaro 7 skyriai: įvadas, žaliųjų obligacijų rinkos kontekstas, literatūros apžvalga, duomenų aprašymas, metodika, rezultatai ir išvados.

Žaliųjų obligacijų rinkos konteksto skyriuje buvo apžvelgiamos rinkos tendencijos ir iššūkiai. Buvo gilinimąsi į pradinės plėtros, plėtros, ekonominio nestabilumo laikotarpius. Nors žaliųjų obligacijų rinka yra pakankamai nauja, tačiau ji sulaukia vis daugiau susidomėjimo. Nepaisant augančio populiarumo, rinkoje esama didelių spragų ir trūkumų. Pavyzdžiui, nėra visuotinai priimtų standartizuotų sertifikavimo reglamentų, siekiant išlaikyti rinkos vientisumą ir veiksmingumą.

Šio darbo literatūros apžvalgoje nagrinėjami įmonių socialinės atsakomybės (ĮSA) bei aplinkos, socialinių ir valdymo (ESG) vaidmenys finansų rinkose, daugiausia dėmesio skiriant ryšiui su nuosavo kapitalo kaina, skolos kaina ir finansinės rizikos valdymu. Taip pat, apžvelgiami ir žaliųjų obligacijų

premijų tyrimai. Tokios premijos įrodymai literatūroje nėra aiškūs, nes tai priklauso nuo skirtingų, autorių tyrinėjamų geografinių regionų ar naudotų skaičiavimo metodų.

Duomenų skyriuje aprašomi duomenys, kurie buvo panaudoti analizei, išsamiai aprašytas duomenų rinkimo iš Bloomberg sistemos procesas. Taip pat, buvo paminėta, kaip buvo sudaromas subalansuotas duomenų rinkinys taikant 1:1 artimiausio kaimyno polinkio balų atitikimo metodą, leidžiantį tiksliau palyginti žaliąsias obligacijas, kurios buvo tiriamoji grupė, ir įprastines obligacijas, kurios buvo kontrolinė grupė, pagal panašias obligacijų charakteristikas, pavyzdžiui, valiutą, kuponą ir terminą.

Metodologijos skyriuje buvo paaiškinami metodai, taikyti analizuojant pajamingumo skirtumus, likvidumo rodiklius, nustatant žaliųjų obligacijų priemoką ir šiai priemokai įtakos turinčius veiksnius. Siekiant atsižvelgti į nepastebėtą heterogeniškumą ir kontroliuoti veiksnius, kurie gali turėti įtakos obligacijų pajamingumui, bet nebuvo tiesiogiai pastebimi, buvo naudojami fiksuoto efekto regresijos modeliai su klasterizuotomis standartinėmis paklaidomis. Analizė apėmė papildomus rizikos kontrolės kintamuosius, tokius kaip 10 dienų ir 30 dienų nepastovumas. Kontroliuojant riziką, tyrimas siekė užtrinti, kad žaliųjų ir įprastų obligacijų pajamingumo skirtumai nebūtų nulemti rizikos lygių skirtumų.

Europos bendrovių išleistų žaliųjų obligacijų pajamingumo priemokai nustatyti taikomi statistiniai modeliai. Konkrečiai nustatyta, kad priemoka yra -1,28 bazinio punkto 2013-2024 m. laikotarpiu ir -2,42 bazinio punkto, o 2013-2017 m. laikotarpiu. Taip pat buvo pastebėta, kad žaliųjų obligacijų priemoka skiriasi žiūrint į skirtingus laikotarpius. Šie rezultatai prisideda prie ankstesnių empirinių tyrimų, pavyzdžiui, Zerbib (2019) ir Hyun ir kt. (2020), patvirtinančių, kad žaliųjų obligacijų premija egzistuoja.

Rezultatų skyriuje buvo pateikiamos išvados dėl likvidumo rodiklių, žaliųjų obligacijų premijų, patikimumo patikrų ir žaliųjų obligacijų premijos lemiančių veiksnių. Galiausiai dokumentas baigiamas išvadomis, kuriose apibendrinamos pagrindinės tyrimo įžvalgos, pasekmės ir pasiūlymai tolimesniems tyrimams.