Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Economics and Management
NTNU Business School

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Do Corporate Green Bonds Fetch A Greenium?

Master's thesis in Economics and Business Administration
Supervisor: Marianna Russo

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Preface

This thesis was written to fulfill the graduation requirements of the Master of Science program in Economics & Business Administration at the Norwegian University of Technology and Science (NTNU). We have taken on the project of writing this thesis from January 2021 until May 2021.

The motivation for our research is based on our interest in green finance as it has become a large and important topic. Our research questions was formulated together with our supervisor, Marianna Russo. The research has been challenging, though very interesting. Through a lot of work and great help from our supervisor it has enabled us to answer our research questions.

We would like to express our deepest appreciation to our supervisor Marianna Russo (NTNU) for providing valuable feedback on the structure and content of this thesis. We also wish to thank our co-students for great support during the last few months.

NTNU has no responsibility for views or content in the thesis. It is solely at the expense of the authors.

Trondheim, May 25, 2021

Abstract

This thesis uses a matching method to investigate whether investors are willing to pay a premium to invest in green projects. To isolate the green premium, we estimate the yield differential between corporate green bonds and conventional corporate bonds with the same characteristics after controlling for liquidity. Furthermore, we examine potential determinants of the green premium. Finally, we analyze the green premium on a quarterly basis in an attempt to explore the impact of the COVID-19 pandemic on investors' preferences. We find a nonsignificant greenium over the period from March 2016 to January 2021 and thus cannot conclude that investors are willing to forego yield to invest in green projects during the researched period. While the greenium has not significantly changed after the spread of COVID-19, we observe a change in the investors' preferences across sectors with the pandemic. Specifically, the yield differential of the financial sector is found to be negative before the pandemic and positive during the pandemic. The opposite holds in the energy and housing sectors, where a negative yields differential is observed during the pandemic. Our results point to the issued amount and maturity as the main drivers of the greenium. Findings in this study imply that pro-environmental preferences have a negligible impact on investors preferences on bond prices. While the amount of available data is still limited, our findings suggest that these preferences may have changed across sectors after the spread of COVID-19.

Sammendrag

Denne oppgaven bruker matching-metoden for å undersøke om investorer er villige til å betale en premie for å investere i grønne prosjekter. For å isolere den grønne premien estimerer vi differansen på avkastning mellom grønne bedriftsobligasjoner og konvensjonelle bedriftsobligasjoner med samme egenskaper, kontrollert for likviditet. Videre undersøker vi potensielle determinanter for den grønne premien. Til slutt analyserer vi den grønne premien kvartalsvis i et forsøk på å undersøke effekten av COVID-19-pandemien på investorenes preferanser. Vi finner en ikke-signifikant grønn premie i perioden mars 2016 til januar 2021, og kan derfor ikke konkludere med at investorer er villig til å si fra seg avkastning for å investere i grønne bedriftsobligasjoner i løpet av perioden. Selv om den grønne premie ikke har endret seg vesentlig etter spredningen av COVID-19, observerer vi en endring i investorenes prefersanser på tvers av sektorer etter pandemien. Avkastningsdifferansen i finanssektoren er funnet til å være negativ før pandemien, og positiv under pandemien. Det motsatte gjelder i energi- og boligsektoren, hvor en negativ avkastningsdifferanse observeres under pandemien. Resultatene våre peker på utstedelsesbeløp og obligasjonens løpetid som de viktigste driverne for den grønne premien. Resultatene i denne studien antyder at miljømessige preferanser har en ubetydelig innvirkning på investorenes preferanser for obligasjonsprisene. Likevel kan disse preferansene ha endret seg på tvers av sektorer etter spredningen av COVID-19.

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1 Introduction

Climate change is one of the most significant global problems we are facing today. The Paris Agreement, which was adopted in December 2015 and entered into force in November 2016 after its ratification by 196 parties, acknowledges the necessity of innovation to address the challenge of climate change. The ultimate goal of this agreement is to limit the temperature increase to 1.5°C above pre-industrial levels, as this would significantly reduce the risks and impacts of climate change (United Nations, 2015). This involves reducing emissions of heat-trapping greenhouse gases in the atmosphere, that is pursuing the "mitigation" process. In addition, there is a need to adapt to the impacts of climate change already taking place, which is referred to as the "adaptation" process (NASA, 2021). The United Nations Framework Convention on Climate Change (UNFCCC, 2021) states that large-scale investments are required to significantly reduce emissions in the years to come. Climate finance is thus needed for mitigation, but it is also important for adaptation, as significant financial resources are required to address adverse effects and reduce the impact of the climate change.

The green bond market has seen significant growth since 2014, when US $37 billion in bonds were issued. In 2020, a total of US $269.5 billion in bonds was issued, with the expectation of further growth in the years to come, especially with the United States recommitted to the Paris Agreement. Green bonds have been created to fund projects that have positive environmental benefits. The bonds‘ proceeds are earmarked for green projects and backed by the entire balance sheet of the issuer, with otherwise similar structure to that of the conventional bond (CBI, 2020a). The International Capital Market Association (ICMA) writes in the Voluntary Process Guidelines for Issuing Green Bonds (ICMA, 2018, p 2) that "the green bond market aims to enable and develop the key role that debt markets can play in funding projects that contribute to environmental sustainability."

Incentives to invest in green projects can be of financial interest if investors believe that the instrument will have a better financial performance (Nilsson, 2008, Bauer and Smeets, 2015, Hartzmark and Sussman, 2019) or be of lower risk (Krüger, 2015) than conventional projects. Investors may also invest in green instruments out of prosocial and pro-environmental motives, (i.e., investors interest in social and environmental issues; (Zerbib, 2019)). Incentives like these may not necessarily be what an investor might prefer as standard theory about portfolio optimization suggests that investors optimize their portfolio based on expected return and risk of the underlying asset.

How strong the investors' pro-environmental preferences are can be identified by the green bond premium, that is the "greenium". This premium is the difference between a green bond yield and a conventional bond yield with the same characteristics, except for the green label (Zerbib, 2019). If the investors are paying a greenium, they effectively forgo yield that they could have earned on a conventional bond with similar risk and return characteristics.

With this in mind, our thesis explores whether investors are willing to pay this premium to invest in green projects. Our first research question is therefore: *"Are investors willing to pay a premium to invest in corporate bonds labeled as green?"* . We also explore possible determinants of the greenium. Furthermore, we investigate whether investors' preferences may have changed following the COVID-19 pandemic. Our second research question is therefore: *"Has the greenium changed with the spread of COVID-19?"*.

The number of research papers on green bonds and the greenium has increased over the last decade, parallel to the increase in the issuance of green bonds. However, there has been limited research on green corporate bonds even though their issuance has accelerated in recent years. Our thesis, contributes to the literature by investigating the greenium and its determinants among corporate green bonds. Furthermore, our thesis contributes to the literature by analyzing the greenium's resilience to the pandemic. Therefore, this study provides a contribution towards understanding which sectors investors prefer to invest in and how investors' preferences might have changed during the pandemic.

To answer our research questions, we investigate whether there is empirical evidence of a yield difference between corporate green bonds and conventional corporate bonds. First, we apply Zerbib's (2019) methodology to analyze the yield difference in the secondary market after controlling for liquidity. We use panel data analysis with fixed-effects to account for time-invariant unobserved individual characteristics that can be correlated with observed independent variables. Second, we use cross-sectional regression to explore the potential determinants of the greeniums. Finally, we analyze the greenium for each quarter from Q1 2019 to Q1 2021 to shed light on whether and eventually how investors preferences might have changed during the pandemic.

This thesis is organized as follows. In Section 2, the background for green bonds is provided, and the current state of the market is described. The literature on the topic of interest is reviewed in Section 3. In Section 4, the methodology used to collect data and construct the yield differential is explained. In Section 5, the methodology used to investigate the greenium and its determinants is explained, while in Section 6 we present the results from the empirical analysis. Results and limitations of the thesis are discussed in Section 7. The conclusions of our findings are summarized in Section 8.

2 Background

2.1 Definition of Green Bonds

The ICMA defines green bonds as “any type of bond instrument where the proceeds will be exclusively applied to finance or refinance, in part or in full, new and/or existing eligible Green Projects and which are aligned with the four core components of the Green Bond Principles” (ICMA, 2018, p. 3). The green bond universe mainly consists of “use of proceeds,” or asset-linked bonds (CBI, 2021d). Green bonds often incur additional transaction costs because of the need to track, monitor, and report on the use of proceeds. This initial cost is often offset by highlighting their green assets or businesses, creating positive marketing stories, diversifying their investor base, and collaborating with other businesses. The credit profile of the green bond is pari pasu to the vanilla issue. Therefore, the green bond market has developed around the idea of flat pricing. (CBI, 2021d). In the next section, we describe what distinguishes a green bond from a conventional bond in greater detail and explain the process an issuer must undergo to successfully label their bond as green.

2.2 The Certification Process and the Green Bond Principles

In 2014, a set of voluntary best practice guidelines called the “Green Bond Principles” (GBPs) was established by a consortium of investment banks. Since then, it has become an independent secretariat that is hosted by the ICMA (CBI, 2021e). The GBPs intends to promote integrity in the green bond market with guidelines that recommend transparency, disclosure, and reporting (ICMA, 2018). They consist of four core components: (1) use of proceeds, (2) process for project evaluation and selection, (3) management of proceeds, and (4) reporting.

The ICMA (2018) refers to the first core component—utilization of the proceeds of the bond for green projects—as the cornerstone of a green bond. It states that all green projects should provide clear environmental benefits, which must be assessed and—where feasible—quantified by the issuer. Some of the broader categories of eligibility for green projects are climate change mitigation, climate change adaptation, natural resource conservation, biodiversity conservation, and pollution prevention and control (ICMA, 2018). The second guideline states that the issuer of the green bond should clearly communicate to investors the environmental sustainability objectives, the process by which the issuer determines how projects fit within the eligible green project categories. The related eligibility criteria or any other process used to identify and manage potentially material, environmental, and social risks associated with the projects must also be communicated (ICMA, 2018). Management of proceeds, which is the third core component, states that the net proceeds of the green bond should be credited a sub-account, moved to a sub-portfolio, or tracked by the issuer. Furthermore this should be attested to through an internal process that is linked to the investment and lending process. Then, the balance should be adjusted relative to the allocation of proceeds as long as the bond is outstanding. (ICMA, 2018). Finally, the issuers of green bonds should generate up-to-date information on the use of proceeds and ensure that they are renewed annually until full allocation and on a timely basis in case of material developments (ICMA, 2018).

The ICMA recommends that issuers of green bonds appoint external reviewers to confirm the alignment of their bond with these four core components of the GBPs. Independent external reviews are broadly grouped into the following types: (1) second party opinion from an independent institution with environmental expertise, (2) verification against a designated set of criteria, typically pertaining to business processes and/or environmental criteria, (3) certification against a recognized external green standard or label, and (4) green bond scoring or rating by specialized research providers or rating agencies, according to established scoring or rating methodologies (ICMA, 2018).

The Climate Bonds Initiative is an international organization working to mobilize the bond market toward a low-carbon and climate-resilient economy (CBI, 2021a). It has developed a trusted climate bonds standard and a certification scheme for labelling bonds and loans. The climate bonds taxonomy, developed by the CBI, works as an important tool for issuers, investors, governments, and municipalities to understand the key investments and the contributions of their investments towards a climate-resilient economy. In addition, strict scientific criteria is used to ensure that certified green bonds and loans are consistent with the 2°C warming limit according to the Paris Agreement (CBI, 2021b). If the bond or loan is verified to be in alignment with the Climate Bonds Standard it will get the approval as a "Certified Climate Bond". The issuer must therefore appoint to an approved verifier, who assures that the bond meet the requirements. The final confirmation of all certifications is provided by the Climate Bonds Standard Board. The certification mark, under the climate bonds standard version 3.0, confirms that the debt instrument is fully aligned with the green bond principles as described above. In addition, it confirms that the issuer uses best practices for internal controls, tracking, reporting, and verification; it must also finance assets in a manner consistent with achieving the goals of the Paris Climate Agreement.

The CBI's certification process works parallel to the traditional bond issuance process and is divided into two phases: (1) pre-issuance verification, the period when the bond is formulated, confirmed, launched, registered, priced, and marketed and the (2) post-issuance verification, which takes place within 12 or 24 months after issuance. Such certification enables the issuer and underwriters to market the bond as a certified green-labelled bond to their investors (CBI, 2021c). The costs of certification is divided into two categories: internal and external. Internal costs include the internal process and controls to meet certification requirements. Tracking the performance of projects may also lead to extra internal costs. External costs are based on commercial negotiations between the issuer and the verifiers, as well as a certification fee equivalent to one-tenth of a basis point of the bond principal (CBI, 2021c).

2.3 Development of the Green Bond Market

New Climate Economy estimated that up to US $93 trillion in investments is needed across the global economy by 2030 (CBI, 2017). Reaching the goal of the Paris Agreement requires both public and private sector capital, including institutional investors. At the Paris Agreement conference in 2017, institutional investors committed to help develop the green bond market. The insurance industry also stated its commitment planning to increase climate-related investments tenfold by 2020 (CBI, 2017). Every year, the CBI publishes a report called "Green Bonds Global State of the Market." This report overviews the most important developments in this market every year and explains new guidelines, initiatives, and happenings in the green bond market. In this section, we survey the most important developments in the latest years from 2016 until the latest published report in H1 2020.

The allocation of capital from green bonds financing is largely driven by the energy, construction, and transportation sectors. Energy is the largest contributor to global greenhouse gas (GHG) emissions, and energy demand have increased in parallel with the rising population and income levels. The energy sector is facing a need to decarbonize, which means that they have to transition to more and more generation of renewable energy. Therefore, the majority of this sector consists of wind, solar, and mixed renewable energy projects (CBI, 2017).

The climate theme of "buildings" identifies mostly green-labelled bonds where the proceeds are used to finance energy efficiency investments. This includes the financing of low-carbon buildings, energy efficient products, and industrial energy efficiency processes and technology. A large part of the proceeds is allocated to green buildings (CBI, 2017).

The transportation sector is the second largest contributor to GHG emissions and is a dominant climate theme, as clean transport infrastructure will be vital in the transition of moving away from fossil fuel vehicles. Large auto manufacturers have committed to develop electric and alternative fuel vehicles. Despite this, many bonds in this category cannot be considered "climate-aligned," as their revenue primarily comes from fossil fuel vehicles. Most of the proceeds from the green bonds in the transportation sector are used to finance rail infrastructure, with China Railway as the largest issuer (CBI, 2017).

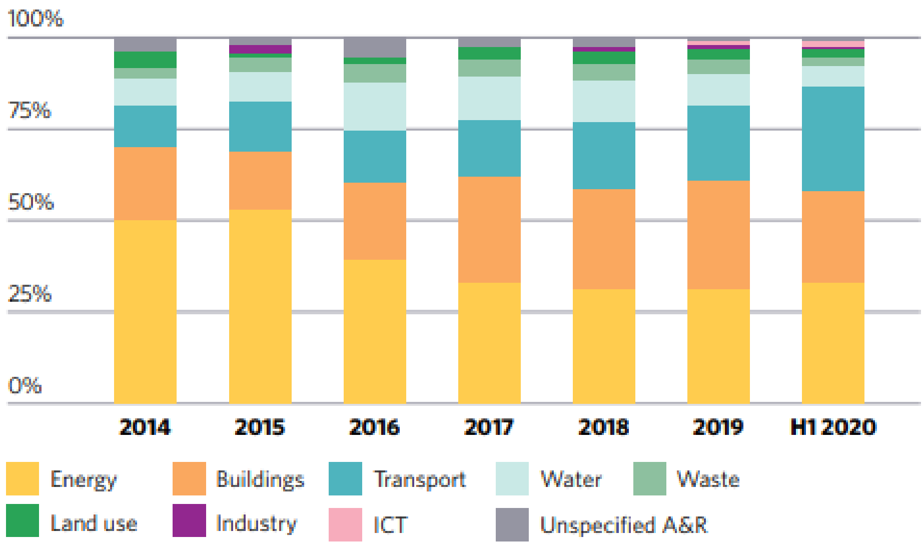


Figure 1: Use of proceeds among non-financial issuers
This figure presents where the proceeds from green bonds are allocated from 2014 until H1 2020.
Source: CBI, 2020.

In 2016, issuance of green bonds nearly doubled from 2015, constituting a record-breaking year by all metrics. Most importantly, Chinese entities' green debt rose from around US $1 billion to over US $23 billion, accounting for more than a quarter of the total amount issued in 2016. This year was when the market substantially matured, with bonds from an increasing number of countries, as well as different bond types, issuer types, ratings, and uses of proceeds. Investors with a mandate showed increasing interest in the market, with oversubscription to green bonds. The tight pricing on green bonds also demonstrated the strong demand for green products, and in addition, the demand for green ratings increased, with both Moody's and Standard & Poor's publishing methodologies for rating green impact. For climate, however, 2016 was a distressing year. At the end of 2016, global sea ice coverage was at record lows, and CO_2 levels surpassed 400 parts per million. According to NASA, it was the hottest year on record, and the need for substantive changes in environmental policy was emphasized (CBI, 2016).

In 2017, green-labeled bonds made up 25% of the climate-aligned universe. There was also a noticeably increasing diversity of structures, with green covered bonds, green Schuldschein, and the first green residential mortgage-backed securities. Country issuance was

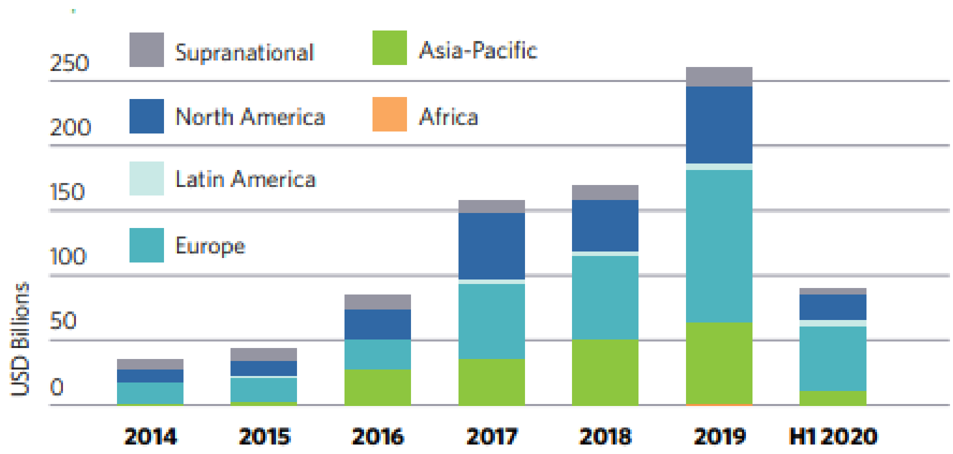


Figure 2: Yearly issuance of green bonds

This figure illustrates the issuance of green bonds on a yearly basis for the different continents. Source: CBI, 2020.

still driven by China and the major North American and European markets, but with increasing issuance from emerging markets, including India, Brazil, and South Africa, as well. The lack of green bond issuance from Japan was also expected to change, given new green bond guidelines from the Ministry of the Environment of Japan established in March 2017 (CBI, 2017). There was also increasing demand for green bonds in 2017, driven by two notable features. Green bond-specific funds and indices had been launched in the previous year, indicative of strong demand. Another key to the increasing demand was that green bonds had identical structures to vanilla bonds, where investors without a green mandate would see them as equally attractive. At the same time, climate bonds certification gained increasing traction, with certified issuance increasing from 4% in 2015 to 11% in 2017. Moreover, issuance from corporations and commercial banks also grew, with plenty of room for further issuance (CBI, 2017).

The increasing diversity of green bonds continued in 2018. Issuers applied the green bond label to several structures in order to achieve funding from specific types of investors. Introduction to green asset-backed securities (ABS) and Property Assessed Clean Energy ABS were examples of this. These were instruments designed to refinance pools of green loans and leases that was made available by the green securitization market. This would free up capacity for lenders as they could sell of financial assets (CBI, 2018a).

In March 2018, the European Commission announced an action plan for sustainable finance. It was then presented three legislative proposals with the mission of establishing a European Union (EU) taxonomy for sustainable finance, improving the reporting on Environmental, Social and Governance (ESG) performance, and at the same time creating benchmarks for low-carbon usage. Subsequently, a technical expert group (TEG) on sustainable finance was established to report on the progress of these proposals. This group was divided into four subgroups with the task of developing the EU taxonomy on sustainable finance, an EU green bond label, low-carbon indices, and metrics for climate-related disclosure (CBI, 2018a).

In 2018, the distribution on bond tenors moved from longer ones to shorter ones, likely due to higher market volatility and rising interest rates. The opposite happened in 2019, as the trends reversed with the market recovering and interest rates remained low. Overall, green bonds with longer tenors increased far more than shorter ones, and perpetuals continued their steady growth (CBI, 2019).

The top three currencies, USD , EUR, and CNY, accounted for 81% of green bonds in 2019. These currencies had stayed at the top for many years, but SEK and JPY were rapidly growing currencies in terms of issuance. In 2019, four new currencies also emerged: DKK, CZK, KES, and BDD. This was indicative of increased diversification, making it more appealing and visible to foreign investors. (CBI, 2019).

2019 was the first year since 2016 in which all regions (corporate, governmental, municipal, etc.) increased the volume of green bonds issued, with Latin America and Africa having their best years yet. Within private sector issuance, non-financial corporates performed particularly well, almost doubling their issuance. The average green bond size jumped from US $108 million in 2018 to US $144 million in 2019, which could bring more liquidity and depth to the market. It could also attract more investors, and help mainstream the green bond market as it could be included in market indices and allocate more funds from a single issuance (CBI, 2019).

2020 was largely affected by the COVID-19 pandemic, as another confirmation of the society's social and environmental issues, and our vulnerability and unpreparedness to handle shocks. However, CBI (2020c) stated this as an opportunity for systemic change with the possibility to address these issues. The market's composition was noticeably different in 2020, with a much more even split between climate themes than before. Most of the sustainability bonds issued in the first half of 2020 financed COVID-19 measures, where green bonds were not prioritized. However, green bond issuance was less affected in developed markets than in emerging markets. This was expected, as developed markets are less vulnerable to shocks and pandemic-related expenditures tend to prioritize emerging markets. The public sector also experienced a lesser decline in the issued amount, also due to less vulnerability to market dynamics. Of the issuers in the private sector, non-financial corporations proved themselves to be less volatile than financial corporations.

In addition renewable energy investments was less affected than the overall market (CBI, 2020c).

Furthermore, green bond volumes were the most negatively impacted of all themes. Anyway, some signs indicated better performance and increasing demand in the green bond market versus conventional bonds. The EU taxonomy in EU and People's Bank of China's green bond-endorsed project catalogue in China had some breakthroughs in adopting the two taxonomies and determine investments that contribute to environmental projects. These are to serve as blueprints toward net-zero GHG emissions. In addition, stock exchanges, central banks, and other regulators became increasingly involved, creating networks to share knowledge and implementing joint initiatives (CBI, 2020c).

The CBI (2020c) has indicated that the ongoing pandemic is likely to accelerate development in sustainable finance with increased attention given to sustainability themes. The global danger of COVID-19 can unite the community under a mutual understanding of the urgent call to address climate change. The need to rebuild economies worldwide can be seen as an opportunity to change and reconstruct the world in a better way, and this can be done with the inclusion of labeled-debt.

2.4 COVID-19 and the Climate Crisis

The International Energy Agency (IEA) announced that the pandemic is having a large impact on the global energy systems, threatening to slow down the expansion of creating new technologies needed for a cleaner future. COVID-19 has presented an opportunity to rethink our systems and possibly solve environmental problems; employers could implement work-from-home policies to reduce emissions from passenger transport over the next few years. Digitalization could improve data availability and quality to help finance sustainable projects. This by reducing transaction costs and promote innovative solutions for more effective and circular business models. (CBI, 2020c).

Green instruments, including green bonds, could help to build these new systems, and help to reduce the risk of future recessions caused by climate change. Green instruments can possibly play a large role, and governments can use green-labeled debt to send a clear market signal of the direction ahead. In order to recover from the damages caused by COVID-19 the European Parliament, European Commission and EU leaders have agreed on a recovery plan to build a more modern and sustainable Europe (European Commission, 2020). Thirty percent of its recovery fund will be earmarked for climate-related expenditures and guided by the EU Sustainable Finance Taxonomy. Since green bonds address the issue of responsible finance and long-term sustainability, they may help to increase acceptance and willingness to increase debt levels and stimulate growth. Green bonds can serve as an important tool to achieve greater economic and financial resilience and reduce disruptions from chronic climate change and shocks, such as COVID-19 (CBI, 2020c).

3 Literature Review

3.1 Environmental Performance and Cost of Financing

A number of studies has addressed the relationship between corporate social responsibility (CSR) and financial performance over the last decades. Murphy (2002) showed that there is a clear correlation between environmental performance and corporate profitability, especially for those companies that score well according to independent environmental criteria. Kempf and Osthoff (2007) found a positive impact of good environmental performance on a company's stock returns. Further studies on the financial performance of the equity market (see El Ghoul et al. [2011]; Dhaliwal et al. [2011]) have concluded that there are similar effects on the cost of equity capital, as firms with better corporate social performance (CSP) are rewarded with a lower cost of equity capital.

As the first studies focused primarily from the perspective of the stock market, Menz (2010) investigated the relationship between valuation of Euro corporate bonds and standards of CSR. Contrary to what was expected, the study concluded that the risk premium for socially responsible firms was higher than for non-socially responsible companies, but that this association was only weakly significant. Some years later, Oikonomou et al. (2014) investigated the differential impact that various dimensions of CSP had on corporate debt pricing. Their empirical analysis suggested that overall, good CSP is rewarded with lower corporate bond yield spreads, while corporations' social transgressions are penalized.

Bauer and Hann (2010) studied corporate environmental management and its implications for bond investors, using environmental information on 582 U.S. public corporations between 1995 and 2006. They concluded that proactive environmental practices are associated with a lower cost of debt, and vice versa. Chava (2014) also analyzed the impact of a firm's environmental profile on the cost of its debt capital. His findings are consistent with those of Bauer and Hann (2010), who found that firms with more environmental strengths than problems tend to be charged with lower interest rates on bank loans. In contrast with these findings, Magnanelli and Izzo (2017) found that CSR is not a value driver with an impact on a firm's risk profile. They used a database of 332 companies worldwide from 2005–2009 and are among the few authors that claimed corporate social performance increases the cost of debt.

Raimo et al. (2021) conducted one of the most recent studies available on the benefits of ESG and its effect on the cost of debt financing. They conducted a fixed-effects analysis on a sample of 919 firms between 2010–2019. These results showed a negative effect of ESG disclosure on the cost of debt financing and demonstrated that companies with greater levels of transparency in the dissemination of ESG information benefited from accessing third-party financial resources at better conditions. In a review of ESG and CSR research in corporate finance, Gillan et al. (2021) also found a growing body of evidence suggesting that ESG and CSR activities can reduce risk and increase firm value; however, they emphasized that the evolving nature of ESG and CSR, innovations in data availability, and the potential for new empirical designs may provide more precise answers in the future. It is, thus, clear that the majority of the research indicates that firms enjoy an advantage in the cost of financing when successfully implementing ESG and CSR.

3.2 Green Bonds and Evidence of the Greenium

As green bonds are a relatively new financial instrument, research on them is more limited than on ESG and CSR as a whole. Nevertheless, green bonds have been garnering much attention within the last decade, especially within the last couple of years, parallel to the exponential growth in their issuance, as previously described. One of the most cited papers regarding green bonds and the greenium is Zerbib's (2019) "The effect of pro-environmental preferences on bond prices: Evidence from green bonds." Zerbib used green bonds as an instrument to identify the effect of non-pecuniary motives—in particular, pro-environmental preferences—on bond market prices. To identify the green premium, he constructed a dataset of 110 matched green bonds, which accounted for about 10% of the global green bond universe and 17% of the total outstanding green bond debt at the time. Using daily bid-ask yield from 2013–2017 and matching it with a synthetic conventional bond from the same issuer, he found a 2 bps negative yield difference, which effectively means that green bonds, on average, traded at a 2 bps discount compared to conventional bonds. Nevertheless, Zerbib highlighted the low impact of investors' pro-environmental preferences on bond prices and emphasized that supporting the expansion of the green bond market does not represent a disincentive for investors. Furthermore, Zerbib analyzed different market segments in an attempt to identify determinants of the green premium. In particular, the green premium seems to be more negative for the financial sector and for low-rated bonds compared to the sample as a whole.

In a systematic literature review, MacAskill et al. (2020) examined studies published between 2007 and 2019 that examined the green premium. Amongst the researchers addressing the secondary market, Zerbib (2019), Karpf and Mandel (2018), Bour (2019), Baker et al. (2018), Agliardi and Agliardi (2019), and others are cited. MacAskill et al.'s findings are summarized in Figure 3, which indicates that 70% of the papers found a green premium in the secondary market, while 13% found none. The size of the greenium varies between the research papers, with 36% concluding that it was -1 to -9 bps, 27% concluding that it was -9 to -17 bps, and 5% concluding that it was lower than -17 bps.

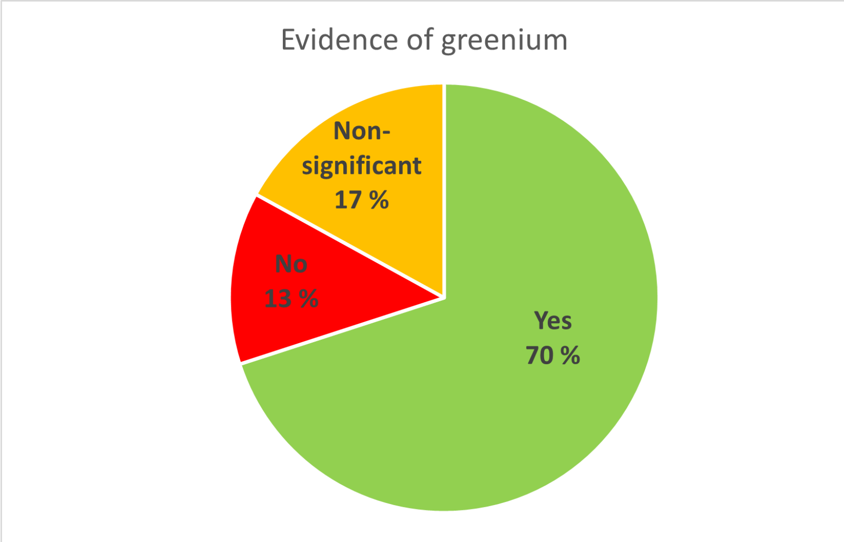


Figure 3: Evidence on the greenium in the secondary market
This figure summarizes the earlier research on the green premium in the secondary market. Source: Macaskill et al., 2020.

Fourteen percent found a positive premium ranging from 1 to 9 bps, and 18% found no significant difference. Furthermore, MacAskill et al. (2020) examined the determinants of the green premium, performing a correlation analysis using the Pearson correlation coefficient. Bond governance characteristics were determined to have the greatest impact on the green premium, with CBI-certified bonds showing the highest correlation with the green premium. Investment grade bonds and government or municipal issuers also showed high correlation.

Larcker and Watts (2020) examined U.S. municipal issuers from 2013 to 2018 in search of the greenium. They chose this sample as these issuers have been one of the largest issuers of green bonds; additionally, the credit for the green bonds is identical to ordinary municipal bonds in almost every way except for the allocation of funds. After constructing a matched sample, they found little evidence of a pricing differential between green and non-green bonds. Their results strongly suggest that U.S. municipal investors were generally unwilling to give up yield to invest in green bonds versus conventional bonds. They also stated that the cost of capital benefits appeared to be largely hypothetical, but that it could rise as the market matures. However, they highlight the diversification of the issuer's investor base as an apparent benefit. As one might expect to find a green premium based on previous literature, Larcker and Watts (2020) discussed the possibility that the green projects are profitable enough to generate competitive returns. When discussing the generalization of these results, they suggested the importance of understanding that the municipal market is quite different from other markets, and that a green premium could be found in other markets, such as the corporate green bond market.

Large parts of the early literature on the subject were focused on the pricing of municipal bonds, and less so on corporate green bonds. In the research paper "Corporate Green Bonds," Flammer (2021) sheds light on this by performing a matching similar to Larcker and Watts' (2020) matching on municipal bonds, but with corporate green bonds from 2010–2018. She found a nonsignificant difference in yield of -1.9 bps, with a median of exactly zero. She thus arrived at the same conclusion as Larcker and Watts (2020) did with the municipal bonds, namely that there is no pricing difference between a green versus a conventional corporate bond. In her discussion, Flammer underlines that the market for corporate green bonds is still in a relatively early stage and constitutes a small part of the total issuance in the period of the research. She also stresses that green bond investors could eventually settle for lower yield compared to non-green bonds, as the number of profitable green projects could eventually become scarcer.

One of the most recently published papers on the greenium in corporate green bonds, to our knowledge, is IHS Markit's "Searching for 'Greenium,'" by Meyer and Henide (2020). They examined the secondary Euro-denominated investment-grade corporate bond market, using data until August 31st, 2020 in search of a green pricing premium. They carried out a slightly different analysis than the majority of green premium studies by looking at the iBoxx Global Green Social and Sustainability Bond index and defining the greenium as the differential between the Z-spread of a green bond and the Z-spread of an implied non-green bond, controlling for various characteristics. They found a market value-weighted greenium of -1.84 bps. Greenium was most pronounced amongst the highest emitting sectors, such as the oil and gas sector, utilities, and industrials. In their conclusion, they emphasize that greenium is not static over time, and as the frequency and magnitude of bond issuance grows, evidence of its existence as well as its limiting factors could become more visible.

3.3 Green Bonds During the COVID-19 Pandemic

The literature on the green bond market during and after the COVID-19 pandemic is, unsurprisingly, still pauce, due to the ongoing pandemic spread and the still poor availability of data. Nevertheless, some newly published research has focused on pricing dynamics and efficiency in the green bond market during this period, which can have an effect on the green bond premium. Naeem et al. (2021) studied the impact of COVID-19 on the pricing of fixed-income securities and compared the efficiency of green and conventional bond markets before and during the COVID-19 pandemic by applying asymmetric multifractal analysis. Their empirical evidence showed that the conventional bond market tends to be more efficient than the green bond market in overall, upward, and downward trends. Furthermore, their analysis found that inefficiency increased in both bond markets following the COVID-19 outbreak, but the green bond market exhibited a higher level of efficiency, which can be attributed to the fact that green bonds attract a special type of investors who want to be a part of the transition to a greener economy. These investors often have the perception that green bonds are less risky on a long-term basis due to lower environmental risks and as part of a longer-term strategy. Therefore, green bonds have proven themselves to be less vulnerable to systemic risks, such as the global COVID-19 pandemic. The empirical evidence suggests that green bonds can serve as a valuable diversifier in times of extreme negative events, such as pandemics, financial crises, or natural disasters. Researchers have suggested that the green bond market's inefficiency is due to the limited size and maturity of this market, emphasizing that policies and transparency in this market can help to increase the level of efficiency.

Another study by Arif et al. (2021) explored the hedging and safe-haven potential of green bonds for equity, fixed-income, currency, and commodity investments. They used a cross-quantilogram approach to understand the dynamic relationship between assets under different market conditions. The empirical analysis and their full sample results revealed that the green bond index could serve as a diversifier for medium- and long-term equity investors. Moreover, the index can serve as a hedging and safe-haven instrument for currency and commodity investments. Arif et al. (2021) also explained that the resilience of green bonds during the pandemic suggests that they could serve as sustainable instruments to reboot the global economy.

4 Matching Method, Data Description, and Descriptive Statistics

4.1 Data Retrieval

We constructed our dataset by filtering out the bonds labeled as "green bonds" from the Thomson Reuters Eikon database for corporate bonds. To ensure comparability across sectors, we excluded supranational bonds, sub-sovereign bonds and municipal bonds, as their tax treatment varies from corporate bonds (Baker et al., 2018). Many studies focused on municipal bonds, but less on corporate bonds. As Flammer (2021) mentioned, the corporate bond market is still in its early stages, and more research is needed. Therefore, we addressed our interest on corporate green bonds.

We wanted to identify all the corporate green bonds that were issued in the secondary market between January 2013 and January 2021. Since we wanted to study the whole corporate green bond market, we included all of the countries that have issued green bonds on several different exchanges in different currencies. By using the Thomson Reuters green bond filter, we identified a total of 2,990 corporate green bond issuances from 985 different companies. From these bonds we downloaded information about the coupon, maturity, ISIN, sector, domicile, currency, issue date, coupon type, seniority and amount outstanding. We chose data from this period because March 2013 is when the wider bond market started to react after the first US $1 billion green bond sold within an hour of issue by the International Finance Corporation (IFC); this was also when the green bond market actually started to grow (CBI, 2021d). We only focused on the first bond issued, to gather as much data as possible and because we expected that the first green bond issued would be representative of other green bonds issued by the same issuer. In addition, we avoided analyzing several green bonds that were matched with the same conventional bonds. We only considered bonds from publicly listed companies because of the need for data availability, including firm characteristics from the issuers and bid-ask yields from the respective bonds. This resulted in a sample of 340 green bonds from 340 unique issuers.

One of the problems with the green bond label is that there is no agreed-upon definition of what makes a bond a "green bond." It is up to the issuer itself to define whether the bond issued is a green bond or a conventional bond, taking into consideration its alignment with the GBPs. Since there could be benefits for the issuer to have their bond labeled "green," this may create chances for opportunism in the market and the possibility of greenwashing is a concern. Thomson Reuters Eikon defined green bonds as fixed income products that offer investors the opportunity to participate in the financing of large sustainable energy "green" projects that can help countries mitigate climate change and adapt to the effects of climate changes. These projects include renewable energy projects, energy efficiency projects, sustainable waste management projects, sustainable land use projects, biodiversity conservation projects, clean transportation projects, clean water projects, and drinking water projects. Thomson Reuters Eikon also identified four categories of green bonds: project bonds, revenue bonds, use of proceeds bonds, and asset-backed bonds. The GBPs, as explained in Section 2.2, describe a voluntary process to be followed when issuing a green bond. Even though the GBPs provide transparency to the investor about the use of proceeds, it is not necessarily confirmed that this transparency is accurate. For this reason, some issuers have sought to have their bonds certified by the CBI, reviewed by a second-party consultant, or assured by a third party. These options have measured the extent to which investors can verify the "greenness" of the bond, bringing value to the investor.

According to Refinitiv's ESG brochure, Thomson Reuters Eikon provides green bonds from the CBI's database (Refinitiv, 2021). The CBI screens self-labeled green debt instruments to identify bonds and similar debt instruments that are eligible for inclusion in the CBI Green Bond Database through certification, according to the criteria described in Section 2.2. Therefore, our dataset of green bonds includes only certified green bonds that allow for greater transparency to investors, as proceeds are confirmed to be allocated to green projects. This helps to mitigate concerns of greenwashing and therefore results in value for investors.

After retrieving our sample of green bonds, we found the conventional bonds to be matched with the green bonds in the same Thomson Reuters Eikon database. This was done by filtering out corporate bonds according to our matching criteria, which is further described in Table 1 in Section 4.2. The matching criteria were used to remove bias, as we wanted the characteristics to be equivalent in order to better isolate the green premium. We first tried to find conventional bonds available from the same issuer, but if there were no bonds available, we tried to find conventional bonds within the matching criteria from issuers operating in the same industry. As it is difficult to find conventional bonds with the exact same maturity as the green bonds, we searched for the two conventional bonds with the closest maturity to build a synthetic conventional bond. We constrained the maturities of the conventional bonds to be neither more than two years shorter nor two years longer than the green bond's maturity. These limitations were imposed to make it easier to estimate the synthetic conventional bond yield more accurately (Zerbib, 2019).

After matching the green bonds with conventional bonds within the constraints, we downloaded bid-ask yield prices using the formula builder add-in function in Excel, connected to the Thomson Reuters Eikon database. The database provided close market bid-ask prices in addition to all the necessary characteristics of the bonds. The preference for daily bid-ask yield prices is because they offered the most precise estimation, resulting in a more accurate view of the yield difference and liquidity difference between the bonds.

4.2 Matching Method

This thesis' goal is to isolate the green premium related to investors' preferences by separating it from the effects that other factors might bring upon it. Generally, the bond price is dependent on the credit risk of the issue, the risk-free rate, liquidity, and bond characteristics (Bour, 2019). The empirical method regularly used to analyze bond spreads in CSR literature is by performing a suitable regression (Zerbib, 2019). This means that all determinants of the bond's yield must be included to explain variations in the prices of the bonds. A dataset constructed without controlling for these factors would mask the presence of green bond premium and would not be very insightful.

Therefore, the most frequently used method to analyze the greenium is the matching method, also called a model-free approach or a direct approach (Zerbib, 2019). The matching method is popular in literature that analyzes the green premium because it allows us to match two similar bonds from the same issuer when the factors explaining the yield are identical. In this way, omitted variable biases can be avoided. The matching procedure can be done by matching a green bond with one or two conventional bonds. Helwege et al. (2014) used this approach to assess the cost of liquidity by matching pairs of bonds issued by the same firm. This approach has also been used to evaluate additional returns of ethical funds when comparing them to identical conventional funds (Kreander et al., 2005, Renneboog et al., 2008, Bauer et al., 2005). Helwege et al. (2014) used the matching procedure by matching a bond to the one with the closest maturity. Zerbib (2019) recognized this as giving rise to a small maturity bias, where he instead chose to match a green bond with the two closest conventional bonds, similar to the method used in this thesis. He did this to create a synthetic bond with the exact same maturity as the green bond, using interpolation and extrapolation, thus eliminating the maturity bias.

In the process of selection, all the conventional bonds in our dataset had the same currency, rating, bond structure, seniority, collateral and coupon type as the green bond with which they were being matched (Zerbib, 2019). Because they had the same rating, the bonds were considered to have the same credit risk, canceling out the effect on the yield spread difference of the two bonds. The risk-free rate is accounted for since the yields that are being compared are both priced at the risk-free rate. Our choice of bonds with the same bond characteristics enabled us to accurately match pairs of bonds, consisting of a green and a synthetic conventional bond that otherwise shared the same characteristics, with the remaining factors being the green premium and bond liquidity (Zerbib, 2019).

Even though we were able to match bonds with equal characteristics in many areas, it was difficult to perfectly match issue size and coupon size, in addition to the maturity date and issue date. Therefore, we used constraints that are equal to those of Zerbib (2019), with one exception. Zerbib (2019) only considered matching bonds from the same issuer, which allowed him to construct a sufficient dataset by including governmental, municipal, and supranational bonds. When focusing only on corporate green bonds, matching based on the same issuer would result in a sample too small to conduct an analysis. Therefore, we allowed matching based on the same industry as well, as Bour (2019) did in his paper about the green premium.

The remaining difference between the bonds, other than the green premium, is their liquidity. Several studies have researched the effect that liquidity has on bond spreads. Helwege et al. (2014) found that bond liquidity significantly affects corporate bond spreads even though it only explains a small fraction of it. Chen et al. (2007) found that illiquid bonds earn higher yield spreads, and improvement in liquidity causes a significant reduction in yield spreads. Dick-Nielsen et al. (2012) showed that the spread contribution from illiquidity increased dramatically with the onset of the subprime crisis. Therefore, bond liquidity needed to be accounted for in this thesis. The liquidity of a bond can be assessed by the issue date or the amount issued (Bao et al., 2011; Houweling et al., 2005). We therefore use the approach of Zerbib (2019) by restricting the conventional bonds chosen to those with an issue amount of less than four times the green bond's issue amount and greater than one-quarter of this amount. The selected bonds were also constrained to have an issue date that was at most six years earlier or six years later than the green bond's issue date. This allowed us to better control for any residual liquidity bias in the estimation of the green bond premium (Zerbib, 2019). The green bonds that were not matchable with two conventional bonds within these constraints were excluded from our dataset. Table 1 summarizes the matching criteria.

In the next stage, we eliminated the maturity bias by building a panel that consists of bond triplets, where the ask yields of each triplet are retrieved as far back as possible after January 1st, 2013 and until January 29th, 2021. Since this is a study about investors' demand, we focused on the ask yields of each bond to conduct a more precise analysis (Zerbib, 2019). The bond triplets included the green bonds and equivalent synthetic conventional bonds with the same maturity. If one of the three ask yields were not available, we removed the entire line from our panel (Zerbib, 2019). Then, in the next step, we followed Zerbib's (2019) approach and interpolated (extrapolated) the two conventional bond's

Table 1: Matching criteria used to match conventional bonds with green bonds

Bond Characteristic	Matching criteria
Maturity	± 2 years
Amount outstanding	± 25%-400%
Coupon rate	± 0.25
Issue date	± 6 years
Currency	Same
Rating	Same
Issuer	Same Industry
Coupon Type	Same
Seniority	Same

This table summarizes the matching criteria used to choose conventional bonds that are eligible to be matched with the respective green bond.

yields linearly at the green bond maturity date to obtain the synthetic conventional bond yield, with equal factors explaining yield except for liquidity. Accordingly, we eliminated the maturity bias from our dataset: for each triplet, a* is the slope and b* is the intercept of the affine function passing through $(Maturity_{\text{CB1}}, y^{\text{CB1}}) and (Maturity_{\text{CB2}}, y^{\text{CB2}})$. The yield of the synthetic conventional bond is, thus, given by:

$$\widetilde{y}^{CB} = a^{*} Maturity_{GB} + b^{*} \tag{1}$$

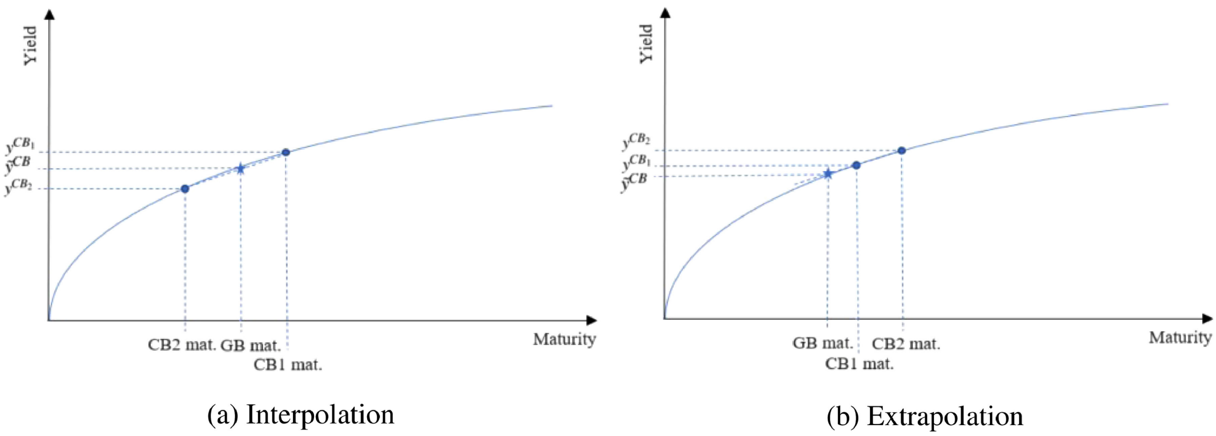


Figure 4: Intrapolation and extrapolation of bond yield

This figure illustrates the calculation of the conventional syntethic bond yield. Source: Zerbib, 2019

4.3 Defining the Yield Spread

To identify the green premium, we moved from computing the green bond yield and the conventional bond yield. Let $y_{i,t}^{GB}$ and $\widetilde{y}_{i,t}^{CB}$ to indicate the green bond and the synthetic conventional bond i's ask yields, respectively, on day t. Following Zerbib (2019) we defined the greenium as their difference, i.e.:

$$\Delta\widetilde{y}_{i,t} = y^{GB}_{i,t} - \widetilde{y}^{CB}_{i,t} \quad (2)$$

4.4 Liquidity Proxy

Although our constraints on maturities and issue amounts captured some of the liquidity effects, we still needed to control for the residual liquidity. We were limited in the same way as Zerbib (2019), as we could not use intraday data to calculate intraday liquidity indicators; we also did not have information about daily trading volumes that could have been used as liquidity proxies. Following Zerbib's (2019) methodology, using a within regression, we were also constrained from using issue amount and issue date proxies. On the basis of our data sources and the type of regression, we used the closing percent quoted bid-ask spread, as Fong et al. (2017) showed that this may be the best low-frequency liquidity proxy:

$$BA_{i,t} = \frac{AskPrice_{i,t} - Bidprice_{i,t}}{(AskPricei,t + BidPrice_{i,t})/2} \quad (3)$$

The synthetic conventional bonds are made up of two conventional bonds; therefore, their bid-ask spread is constructed by defining the distance-weighted average of CB1's and CB2's bid-ask spreads. Practically, by following the methodology of Zerbib (2019), we let:

d1 = |GB maturity - CB1 maturity|
d2 = |GB maturity - CB2 maturity|

Then, we defined the synthetic conventional bond's bid-ask spread as:

$$BA^{CB}_{i,t} = \frac{d2}{d1 + d2} BA^{CB1}_{i,t} + \frac{d1}{d1 + d2} BA^{CB2}_{i,t} \quad (4)$$

Finally, we constructed a variable that captures the liquidity difference of the green and the conventional synthetic bond, which is used as an independent variable to estimate the fixed-effects linear panel, which has been defined as follows:

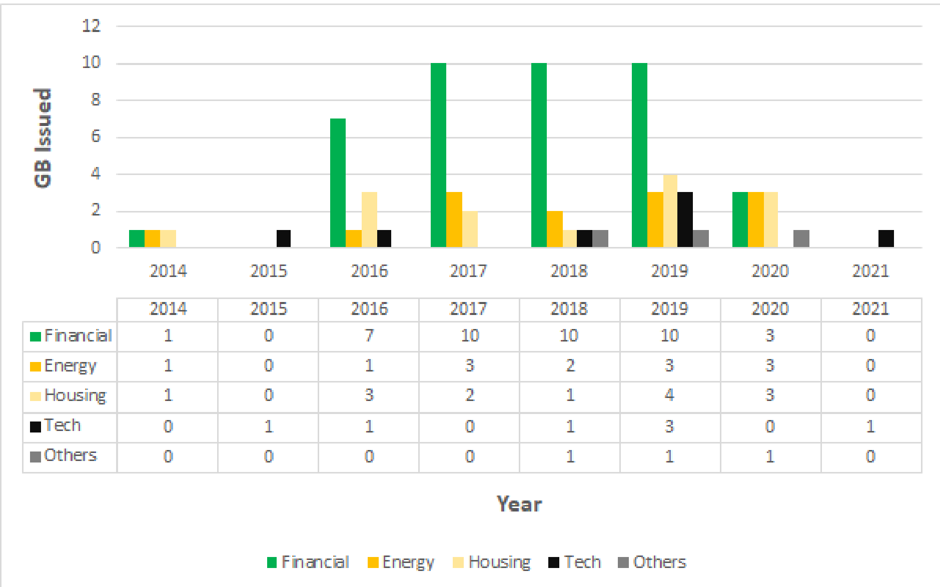
$$\Delta BA_{i,t} = BA^{GB}_{i,t} - BA^{CB}_{i,t} \quad (5)$$

4.5 Preliminary Data Analysis

The matching process left us with 78 matched green bonds from 78 unique issuers. This included a total of 154 conventional bonds in making bond triplets. Two of the green bonds were matched with only one conventional bond due to the fact that the conventional bond had the exact same characteristics, including issue date and maturity. Ultimately, 42 of the bonds were matched with conventional bonds within the same industry, and 36 bonds were matched with conventional bonds from the same issuer. The sample accounted for 2.6% of the green bond secondary market and 22.9% of the publicly listed firms that have issued green bonds.

The bonds have been categorized into different sectors: financial, energy and utilities, housing, technology, and others. This categorization was based on the sector description of the company in Thomson Reuters Eikon's database. The financial sector mainly included large banks but also some other financial corporations, such as investment funds. The energy and utilities sector included corporations from the utility and gas sector, technology included corporations in the electronics and telecommunications sector, and housing included real estate investment funds, building products, and home builders. The bonds classified as "others" included one corporation in the transportation sector, one in the textiles, apparel, and shoes sector, and one in the automotive manufacturing sector. The bond's ratings were also clustered into five different rating classes: Aaa-Aa1, Aa2-Aa3, A1-A3, Baa1-Ba2, and non-rated (NR), based on Moody's and Fitch‘s ratings. See Appendix table A1, A2 and A3 for a full description.

Figure 5 illustrates that most of the green bonds in the sample were issued between 2016 and 2020, with 2019 as the year with the largest number of issuances. With daily observations, this provides a dataset consisting of 36,110 observations, with the earliest observation dating back to March 3rd, 2016 and the latest dated January 29th, 2021.



	2014	2015	2016	2017	2018	2019	2020	2021
Financial	1	0	7	10	10	10	3	0
Energy	1	0	1	3	2	3	3	0
Housing	1	0	3	2	1	4	3	0
Tech	0	1	1	0	1	3	0	1
Others	0	0	0	0	1	1	1	0

Figure 5: Yearly issuance of green bonds included in our sample
This figure shows when the green bonds in our sample were issued and how many green bonds we have in the different sectors.

Table 2 reveals that the sample contains bonds denoted in ten different currencies, with bonds in Euro and USD making up 51.28% and 32.05% of the total sample, respectively. Furthermore, we can see that the majority of green bonds in our sample comes from the financial sector, making up over half of the sample, followed by the housing and energy sectors. Lower-rated bonds were perhaps overly represented, as approximately 44% of the bonds in the sample had a rating between Baa1 and Ba2. Table 3 shows descriptive statis-

Table 2: Currencies, Sectors and Ratings of the green bonds

Currency	**N**	**In %**
AUD	3	3.85%
CNY	1	1.28%
EUR	40	51.28%
INR	1	1.28%
JPY	1	1.28%
NOK	1	1.28%
SEK	4	5.13%
TWD	1	1.28%
THB	1	1.28%
USD	25	32.05%
Total	78	100%
Sector		
Financial	41	52.56%
Energy/Utility	13	16.68%
Housing	14	17.95%
Tech/Electronics	7	8.97%
Others	3	3.85%
Total	78	100%
Rating		
Aaa-Aa1	3	3.85%
Aa2-Aa3	10	12.82%
A1-A3	19	24.36%
Baa1-Ba2	34	43.59%
NR	12	15.38%
Total	78	100%

This table summarizes the sample and explains all the currencies, sectors and ratings included in our sample and the number of observations of green bonds in the respective categories.

tics for the green bonds. Among all the green bonds in our sample, the average coupon was 1.9%, the average maturity was 5.19 years, and the average issue amount per bond was US $634 million. Within the sectors, the technology and electronics sector had the highest coupon and issue amount on average, with 2.6% and $720 million, respectively.

The energy and utilities sector had the longest maturity compared to the other sectors, with an average of 9.64 years. Bonds from the financial sector had the lowest coupon and maturity with 1.6% and 3.22 years respectively. Housing showed the lowest issue amounts with US $486 million on average. Unsurprisingly, Aaa-Aa1 rated bonds gave the lowest coupon with 1.1%, while the Baa1-Ba2 gave the highest with 2.2%, not taking the non-rated class into account. Aa2-Aa3 rated bonds had the shortest tenors on average, and Baa1-Ba2 rated bonds had the longest. Regarding issue amount, the highest rated green bonds had the largest issue amounts on average, while the lowest issue amount was found in the Aa2-Aa3-rated green bonds. Table 4 presents the average yield and maturity across bonds from different sectors, with their different ratings and their respective denoted currencies.

Table 3: Description of the sample of 78 bonds

	Full Sample	Mean	Median	Std.dev	N
	Coupon(percent)	1.9	1.5	1.5	78
	Maturity(year)	5.19	3.78	5.63	78
	Amount(mUSD)	634	602	387	78
	By sector				
Financial	Coupon(percent)	1.6	1	1.6	41
	Maturity(year)	3.22	2.87	2.14	41
	Amount(mUSD)	665	602	412	41
Energy	Coupon(percent)	2	1.5	1.3	13
	Maturity(year)	9.64	6.73	9.16	13
	Amount(mUSD)	680	602	237	13
Housing	Coupon(percent)	2.4	2.2	1.5	14
	Maturity(year)	6.51	5.01	7.45	14
	Amount(mUSD)	486	500	305	14
Tech	Coupon(percent)	2.6	2.4	1.7	7
	Maturity(year)	5.23	4.7	2.91	7
	Amount(mUSD)	720	903	518	7
Other	Coupon(percent)	1.9	1	1.7	3
	Maturity(year)	6.62	8.32	4.11	3
	Amount(mUSD)	492	167	616	3
	By rating				
Aaa-Aa1	Coupon(percent)	1.1	0.25	1.5	3
	Maturity(year)	4.5	2.9	3.5	3
	Amount(mUSD)	1102	1203	458	3
Aa2-Aa3	Coupon(percent)	1.6	0.7	1.5	10
	Maturity(year)	1.3	1.2	0.6	10
	Amount(mUSD)	505	594	138	10
A1-A3	Coupon(percent)	1.4	1.1	1	19
	Maturity(year)	5	3.7	6.4	19
	Amount(mUSD)	785	602	475	19
Baa1-Ba2	Coupon(percent)	2.2	1.75	1.46	34
	Maturity(year)	7	5.5	6.2	34
	Amount(mUSD)	701	602	281	34
NR	Coupon(percent)	2.4	1.7	2.2	12
	Maturity(year)	3.7	3	3	12
	Amount(mUSD)	195	113	223	12

This table presents the average coupon, the maturity and amount outstanding of the 78 green bonds in our sample, distributed on the sector, rating and currencies.

Table 4: Further description of the sample of 78 green bonds

		AUD	CNY	EUR	INR	JPY	NOK	SEK	TWD	THB	USD
Financial											
Aaa-Aa1	Avg. yield(%)			(0.31)							
	Avg. maturity(year)			5.67							
	GB(N)			2							
Aa2-Aa3	Avg. yield(%)	1.83		(0.04)							2.45
	Avg. maturity(year)	0.79		1.60							1.32
	GB(N)	3		5							2
A1-A3	Avg. yield(%)			0.25							1.15
	Avg. maturity(year)			3.47							2.61
	GB(N)			8							6
Baa1-Ba2	Avg. yield(%)			0.58							2.85
	Avg. maturity(year)			4.01							5.14
	GB(N)			9							3
NR	Avg. yield(%)			2.25	8.89	0.69					
	Avg. maturity(year)			3.86	0.16	8.82					
	GB(N)			1	1	1					
Energy/Utility											
A1-A3	Avg. yield(%)			0.39							2.47
	Avg. maturity(year)			3.81							30.14
	GB(N)			1							1
Baa1-Ba2	Avg.yield(%)			0.52							2.72
	Avg. maturity(year)			5.99							11.10
	GB(N)			6							5
Housing											
A1-A3	Avg. yield(%)			0.70							
	Avg. maturity(year)			3.07							
	GB(N)			1							
Baa1-Ba2	Avg.yield(%)			0.38				1.71			2.99
	Avg. maturity(year)			8.32				3.04			10.58
	GB(N)			2				1			5
NR	Avg. yield(%)			1.13			1.84	0.78			
	Avg.maturity(year)			5.96			2.64	0.49			
	GB(N)			2			1	2			
Tech/Electronics											
Aaa-Aa1	Avg. yield(%)										2.12
	Avg. maturity(year)										2.06
	GB(N)										1
A1-A3	Avg.yield(%)			0.15							
	Avg. maturity(year)			4.70							
	GB(N)			1							
Baa1-Ba2	Avg. yield(%)			0.37							2.09
	Avg. maturity(year)			5.82							9.00
	GB(N)			1							2
NR	Avg. yield (%)		4.33					0.86			
	Avg. maturity(year)		2.89					3.15			
	GB(N)		1					1			
Other											
A1-A3	Avg. yield(%)			0.23							
	Avg. maturity(year)			9.61							
	GB(N)			1							
NR	Avg. yield(%)								0.73	3.06	
	Avg. maturity(year)								1.94	8.32	
	GB(N)								1	1	

This table presents the average yield, maturity and number of observations when combining the ratings, sectors and currencies across the sample.

Table 5: Average ask yields for the green- and synthetic conventional bonds

Ask yield	Min	1.quartile	Median	Mean	3.quartile	Max	Std.dev
GB	−0.622	0.278	0.921	1.339	2.340	11.105	1.368
CB	−0.747	0.298	0.900	1.352	2.660	11.150	1.377
$\Delta GB - CB$	−3.627	−0.085	−0.006	−0.013	0.059	2.417	0.241

This table presents descriptive statistics for the ask yields of the sample, both for conventional and green bonds.

Table 5 presents the average yields of the green and conventional bonds, with an average ask yield of 1.339 for green bonds and 1.352 for conventional bonds. The green bond has a median of 0.921 and a standard deviation of 1.369, with a range from -0.622 to 11.105. The distribution of the conventional bond is similar to that of the green bond, with a median of 0.900, a standard deviation of 1.377, and ranging from -0.747 to 11.150. On average, the ask yield difference between the green and conventional bonds was -1.3 bps. This may be an indication of a potential negative premium in our sample, though concluding this would be premature, as we have not yet adjusted for potential differences in liquidity between the green bond and the synthetic conventional bond.

Table 6: Descriptive statistics for the Liquidity proxy

	Min	1.quartile	Median	Mean	3.quartile	Max	Std.dev
$\Delta BA_{i,t}$	−2.230%	−0.007%	0.000%	−0.008%	0.002%	2.522%	0.085%

This table shows the distribution of the bid-ask liquidity proxy used to control for liquidity in the estimation of the green bond premium

The distribution of the bid-ask spread liquidity proxy is presented in Table 6. It shows a large variation, but with a relatively normal distribution, where the mean is close to zero and the median is exactly zero. This indicates relatively small differences, on average, in liquidity between green and conventional bonds. The min and max observations of the $\Delta BA_{i,t}$ are very large. Daily observations from some bonds show a large difference in the bid and ask yield. For example Wallenstam AB's green bond have a bid yield of 2.128 and an ask yield of -0.494, which give a bid-ask spread of 2.622 on August 14th 2020. However, there are only 205 observations that are larger than 0.5 in absolute value, out of the 36.110 observations.

5 Estimating the Greenium and its Determinants

In the previous section, we showed how we identified the green bond and conventional bond spread by using the matching method. In this section we estimate the greenium and identify its determinants, after controlling for liquidity effects. Our matching criteria ensures that green bond and conventional bond yields are comparable, thus, eliminating the possibility that variations in yields are determined by different bond characteristics.

5.1 Estimating the Greenium

According to Zerbib (2019), the green premium can be defined as the negative yield difference between green bonds and synthetic bonds, after controlling for differences in liquidity. Thus, after controlling for the defined yield spread between the green bond and the synthetic conventional bond as well as the effects of liquidity, we defined the unobserved green premium p_i in the fixed-effects (FE) panel regression as follows:

$$\Delta\widetilde{y}_{i,t} = p_i + \beta\Delta BA_{i,t} + \epsilon_{i,t} \tag{6}$$

where $\Delta\widetilde{y}_{i,t}$ is the yield difference defined in Eq.(2), $\Delta BA_{i,t}$ is the liquidity difference defined in Eq.(5), p_i is the unobserved green premium and $\epsilon_{i,t}$ is the error term.

The fixed-effects regression was the preferred method in this research because it allowed us to adjust for unobserved, unit-specific, and time-invariant confounders in the estimation of the green premium. This method relies on the assumption of strict exogeneity of the error term $\epsilon_(i,t)$, which ensures a lack of bias in this estimator. That is, it does not restrict the difference in liquidity effects to be uncorrelated with the time-invariant specific effects over time (Imai and Kim, 2019). In other words, we estimated the unobserved green bond premium, assuming that the other bonds and their respective liquidity effects do not influence each other over time.

Following the methodology of Zerbib (2019), we used a within regression to estimate the unobserved effect in the green bond premium because we have a large number of observations, which reduces the complexity of our estimation. This involved subtracting the time-mean of each green bond away from the values of the variable (Brooks, 2019). Formally, we defined $\Delta\overline{y}_{i,t}$ as the time mean of the observations on y for cross-sectional unit i, and similarly calculated the mean of all the explanatory variables. In the next step, we subtracted the time means from each variable and obtained a regression with only demeaned variables. In that regard, p_i represents the green premium for each of the 78 triplets of bonds, where $\Delta BA_{i,t}$ and $\epsilon_{i,t}$ are independent and identically distributed across individuals.

To see if fixed-effects estimation is preferred over random-effects estimation, we used a Hausman test. Generally, when it is likely that the omitted variables are correlated with the independent variables, fixed-effects are the preferred option. The Hausman test is used to see if a correlation indeed exists and investigates whether the regression coefficients to the fixed- and random-effects models are statistically significant (Studenmund and Johnson, 2017). The results show that the two estimation techniques provide similar results, but that random-effects estimation would give more precise estimates and would be a preferred option. However, random-effects models have a major drawback because they are only valid when the error term is uncorrelated with all the explanatory variables (Brooks, 2019). This is also true for the consideration of whether any omitted variables are uncorrelated with the independent variables in the model. If they are assessed to be correlated, a fixed-effects model is preferable. In addition, our data is not drawn from a random sample since it consists of a matched sample, indicating that fixed-effects estimation would be preferred in this situation.

For the use of fixed-effects models, it is necessary to decide whether these effects are in fact observable (Kőrösi et al., 1992). Therefore, we applied an F-test and a Breusch-Pagan test, with a null hypothesis that there are no individual effects. Fixed-effects estimation ignores all the variations in the independent variables across individuals in the sample (Murray, 2005). To check whether these ignorations is necessary, these tests are appropriate. Both tests rejected the null hypothesis at the 1% significance level, suggesting that our model should include individual effects. This further solidifies fixed-effects estimation as the preferred option. Table 7 presents the results from these tests.

Table 7: Test for individual effects

Test	**Statistic**	**P-value**	**Decision**
F-test	265.58	0.000***	FE>Pooled reg
Breusch-Pagan	$1.30E+06$	0.000***	RE>Pooled reg
Hausman	2.52	0.1126	FE=RE

This table shows the results from the F-test, Breusch pagan test and Hausman test.
Note: $^{*}p < 0.1;^{**}p < 0.05;^{***}p < 0.01$.

Heteroskedasticity and serial correlation and can affect the error terms in panel datasets, which could make random- or fixed-effects estimators biased (Tsionas, 2019). Therefore, we performed tests for these disturbances by applying a modified Wald test for heteroskedasticity and a Wooldridge test for serial correlation. The results indicate the presence of groupwise heteroskedasticity and within serial correlation in the residuals. Table 8 presents the results from these tests.

Table 8: Test for heteroskedasticity & serial correlation

Test	Statistic	P-value	Decision
Modified wald test	$7.00E + 06$	0.000***	Groupwise heteroskedasticity
Woolridge test	24.794	0.000***	Within serial correlation

This table shows results from the modified wald test and woolridge test.
Note: $^{*}p < 0.1$;$^{**}p < 0.05$;$^{***}p < 0.01$.

Error correlation does not cause any problems for the Ordinary Least Squares (OLS) estimators, but the classical OLS standard errors is affected (Tsionas, 2019). By using robust estimation, we overcame serial correlation, cross-sectional dependence, and heteroskedasticity across groups or time (Tsionas, 2019).

After isolating the green premium for our total sample, we divided the sample into subsamples, distributed on the characteristics of the bond: sector, rating, and currency. This allowed us to identify the possible presence of a green premium across different bonds and whether it varied between them. In the respective subsamples, we calculated the mean and the median green premium to test if they were significantly different from zero. First, we used a Shapiro-Wilk normality test, where we rejected the null hypothesis about normality. We were thus limited to non-parametric methods in which no assumptions were made about the underlying distribution (Harris and Hardin, 2013).Therefore, a non-parametric Wilcoxon signed-rank test is applied, with the null hypothesis that the median difference between the absolute values of positive and negative paired differences is zero (Harris and Hardin, 2013). We limited the tests to be run on subsamples that included seven or more bonds since too few bonds or observations would not be sufficient to be subject to an analysis.

5.2 Determinants of the Green Bond Premium

In the next step, we examined if the potential premium can be explained by the different bond characteristics. Following the methodology of Zerbib (2019), we applied a linear OLS regression of the estimated greenium $\widehat{p}_i$ in Eq.(6) to explore potential determinants of the green bond premium. To conduct this analysis, we considered the rating, the sector, the currency, the maturity, and the issue amount of the green bond as independent variables. Table 9 describes the construction of the variables.

As a dependent variable, we used the 78 greeniums $\widehat{p}_i$ from our fixed-effects estimation. To transform the values into linear form, we took the logarithm of the issue amount, which was denoted in USD for all bonds. Then, as Zerbib (2019) did, we considered three different specifications where (a) is the general specification, (b) excludes maturity

Table 9: Possible determinants of the green bond premium

Variable	Type	Unit	Description
Rating	Qualitative		The ratings of the bonds are sampled from Moodys and Fitch. We chose the highest rating from these two ratings agencies, and Fitch ratings are transformed into the equivalent rating value from Moodys. They are then clustered in groups, classified as Aaa-Aa1, Aa2-Aa3, A1-A3, Baa1-Ba2 or Non-rated (NR). The reference value is Aaa-Aa1 rated bonds.
Sector	Qualitative		We use Thomson Reuters Eikon's Sector description to classify the bonds into one of five categories: Financial (Banking and Other financial), Energy (Utility and Gas – Utility), Housing (Real Estate Investment Trust, Home Builders and Building Products), Tech (Electronics and Telecommunications) and Others (Transportation, Automotive Manufacturing and Textiles/Apparel/Shoes). The reference value is the Financial Sector.
Currency	Qualitative		The denoted currency of the bonds issued. This sample contains the following currencies: AUD, CNY, EUR, IN, JPY, NOK, SEK, TWD, THB and USD. The reference value is EUR.
Maturity	Quantitative	Years	The bond's maturity, denoted in years, on January 29, 2021.
Issue amount	Quantitative	mn USD	The amount outstanding on January 29, 2021.

This table explains the variables used to possibly explain the variation in the green bond premium. It includes the rating, sector, currency, maturity and issued amount

and log(issued amount), and (c) excludes currency. Specification (d) in Zerbib (2019)s paper was excluded in this thesis because our descriptive statistics do not show that this specification will promote the greenium. The specifications are described by equations (7), (8), and (9).

$$\begin{aligned}\widehat{p}_i = \alpha_0 + \sum_{j=1}^{N_{Rating}-1} \alpha_{1,Rating_j}\,, 1_{Rating_j} + \sum_{j=1}^{N_{Sector}-1} \alpha_{2,Sector_j}\,, 1_{Sector_j} + \\ \sum_{j=1}^{N_{Currency}-1} \alpha_{3,Currency\ j}, 1_{Currency_j} + \alpha_4 Maturity + \alpha_5 log(IssueAmount) + \varepsilon_i\end{aligned} \tag{7}$$

$$\begin{aligned}\widehat{p}_i = \alpha_0 + \sum_{j=1}^{N_{Rating}-1} \alpha_{1,Rating_j}\,, 1_{Rating_j} + \sum_{j=1}^{N_{Sector}-1} \alpha_{2,Sector_j}\,, 1_{Sector_j} \\ + \sum_{j=1}^{N_{Currency}-1} \alpha_{3,Currency_j}\,, 1_{Currency_j} + \varepsilon_i\end{aligned} \tag{8}$$

$$\widehat{p_i} = \alpha_0 + \sum_{j=1}^{N_{Rating^{-1}}} \alpha_{1Rating_j}, 1_{Rating_j} + \sum_{j=1}^{N_{Sector^{-1}}} \alpha_{2Sector_j}, 1_{Sector_j} \\ + \alpha_4 Maturity + \alpha_5 log(IssueAmount) + \varepsilon_i \tag{9}$$

We check the sample for heteroskedasticity by running a Breusch-Pagan test, which does not indicate a significant problem with heteroskedasticity on the 5% and 10% levels. In addition, we checked for multicollinearity by calculating the variance inflation factor (VIF) index. A general rule is that VIF scores larger than 5 in small samples could indicate problems with multicollinearity (Studenmund and Johnson, 2017). With most values well below this threshold, we did not detect any problems with multicollinearity, and OLS regression could be applied. Even though the Breusch-Pagan test did not detect significant heteroskedasticity, we applied robust standard errors on the basis of earlier studies and the fact that the p-value is relatively low. The results from both tests are presented in Table 10.

Table 10: Test for heteroskedasticity and multicollinearity

Test	Variable	Model (a)	Model (b)	Model (c)
Breusch Pagan		0.1448	0.1144	0.3982
	Energy	1.53	1.37	1.52
	Real Estate	1.66	1.56	1.48
	Technology	1.31	1.25	1.21
	Other	1.22	1.19	1.21
	Aaa-Aa1	1.92	1.37	1.81
VIF	Aa2-Aa3	3.57	2.61	2.75
	A1-A3	4.55	2.72	4.08
	Baa1-Ba2	5.28	3.15	4.75
	AUD	1.47	1.39	
	SEK	1.86	1.34	
	USD	1.28	1.20	
	Issue Amount	3.07		3.17
	Maturity	1.42		1.32

This table shows the results from the Breusch-pagan and VIF tests on model (a),(b) and (c), as described by Eq. (7), Eq. (8) ad Eq. (9).
Note: $^{*}p < 0.1;^{**} p < 0.05;^{***} p < 0.01$.

5.3 Investor Preferences Before and After COVID-19

To explore how investors preferences for green bonds may have changed due to the COVID-19 pandemic, we performed the same regression as in Section 5.1 per quarter, using specification (6). For each quarter, we included the green bonds that had daily observations for the whole three-month period to make sure the estimated greenium was representative. We performed our analysis on a quarterly basis from Q1 2019 until Q1 2021 (only

January).

For each quarter, we analyzed the average greenium, standard deviation, skewness, kurtosis, minimum, maximum, and first and third quartiles to see how they might have changed over the period. Q2 2020 is of special interest for this thesis since it is the first full quarter in which the world economy was responding to the pandemic. By comparing the quarters after Q2 2020 with the quarters before, we give some indications of how investors' preferences might have changed as a result of the pandemic.

We carried the analysis of the COVID-19 effects by considering the different sectors. The aim was to explore if and how fluctuations in the greenium may have differed across sectors. We considered the financial sector, the energy and utilities sector, and housing sector. The technology sector was excluded due to a lack of observations.

5.4 Market Volatility's Impact on the Greenium

Lastly, we wanted to analyze the greeniums response to financial distress and uncertainty in the market. We performed the same regression as in section 5.1, but added a new variable to capture the volatility in the stock market. We explore this to see if investors turns to the green bond market in times of uncertainty in the market. As examined in the literature review, Arif et al. (2021) discussed that the green bond index could serve as a hedging instrument for medium- and long-term equity investors. Moreover Naeem et al. (2021) explained that green bonds could serve as a diversifier during extreme events. A significant explanatory power on the yield difference by the market volatility, would further support these statements. Tang and Zhang (2020) found a significant impact of the markets volatility on the yield difference when looking at the yield difference in the primary market.

The variable we included to capture the market volatility, is the close VIX index price (in logarithm). We downloaded the daily series from March 2016 until January 2021 from the Cboe Exchange (2021). The VIX Index is used by investors to measure the level of risk, fear, or stress in the market when making investment decisions (Kuepper, 2021). The equation for our regression is given by:

$$\Delta\widetilde{y}_{i,t} = p_i + \beta\Delta BA_{i,t} + \gamma Log(VIX) + \epsilon_{i,t} \tag{10}$$

6 Results

This section presents results from the fixed-effects estimation, using specification (6) to isolate the green premium. We also examine the subsamples to see where the greenium is most prominent and if it varies across bonds with different characteristics. We present results from our attempt to uncover the determinants of the greenium, using OLS regression defined by specifications (7), (8), and (9). Lastly, this section presents the results on the green premium dynamics before and after the COVID-19 pandemic, started in March 2020, to assess if the investors' preferences may have changed during or after this period.

6.1 The Green Premium

The evidence from the fixed-effects estimation is presented in Table 11. The liquidity control variable, $\Delta BA_{i,t}$, is revealed to be significant in the first model. The coefficient indicates that a one basis point increase in the bid-ask spread between the green bond and the synthetic bond will result in a decrease of 0.0561 basis points in the greenium. However, robust estimation shows that $\Delta BA_{i,t}$ is no longer significant when controlling for disturbances in the model, indicating that it does not have any statistically significant causal effect on the green premium. In addition the model has a low R^2 of 1,2 percent. This is an indication that the liquidity control variable explains very little of the variations in the green premium, a fact that is also supported by a relatively low residual-liquidity differential coefficient. This result is different from what Zerbib (2019) observed in his research, in which he found that a 1 bps increase in the bid-ask spread differential would result a 9.88 bps decrease in the green premium, with significant explanatory power. In contrast, Bour (2019) found that liquidity does not affect the green premium, thus in line with results in this study. Furthermore, he explained this finding by emphasizing that the matching procedure in itself controls for the difference in liquidity.

The different values of the 78 fixed-effects p_i, which represent the greenium for each of the green bonds, is what is most interesting for this thesis. Table 12 shows a distribution in the green premium, which ranges from a minimum of -44.16 bps to a maximum of 46.44 bps, with mean and median values of -1.11 bps and -0.02 bps, respectively. Across all the 78 bonds, 39 were found to have a negative premium and 39 were found to have a positive premium. This shows us that the distribution between positive and negative premiums is relatively even. Figure 6 presents the distribution of the green premium over the full sample.

Table 11: Results from within fixed-effects regression

	Within regression	**w/Robust std.errors**
$\Delta BA_{i,t}$	-0.0561^{***}	-0.0561
t-value	-3.78	-0.25
$P > \|t\|$	0.00	0.805
Constant	-0.0136^{***}	-0.0136^{***}
t-value	-13.38	-7.88
$P > \|t\|$	0.00	0.00
Observations	36.110	36.110
R^2	0.012	0.012
F-statistic	14.82	
$(df = 1 : 36031), p = 0.000$		
Number of groups	78	78

This table presents the results from the within-regression, also with Robust std.errors. using specification (6).
Note: $^{*}p < 0.1;^{**} p < 0.05;^{***} p < 0.01$.

Table 12: The estimated green bond premium

Min	1st Quartile	Median	Mean	3rd Quartile	Max	Std.dev
-0.4416	-0.0753	-0.0002	-0.0111	0.3893	0.4644	0.1489

This table shows the estimated green bond premium, and the distribution, from the fixed-effects regression.

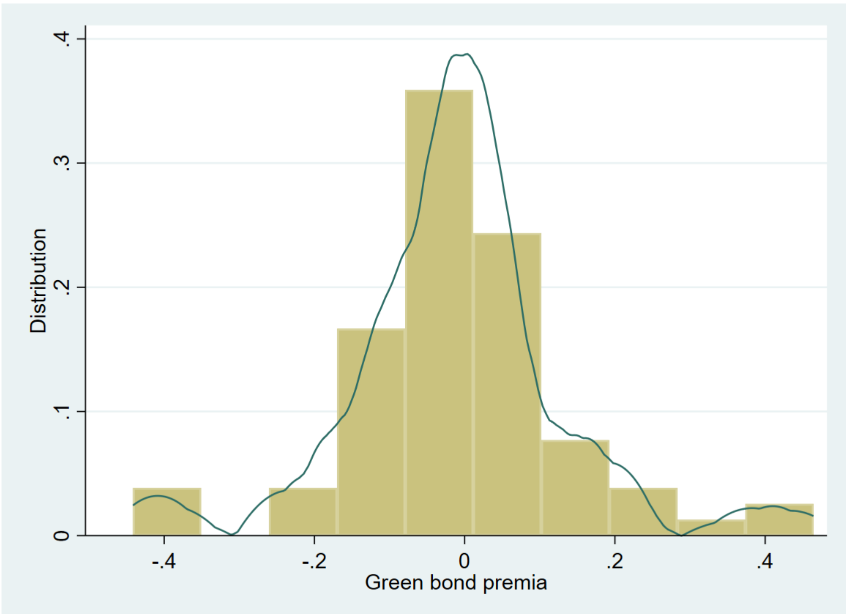


Figure 6: Distribution of the green bond premium

This figure shows the distribution of the green bond premium across all the 78 bonds

The results indicate that investors may be willing to accept a lower yield of -1.11 bps for green bonds compared to conventional bonds. It can be argued that the estimated greenium is irrelevant since the difference is so small compared to the average ask yield of the bond. The relatively normal distribution of the greenium substantiates this, as the amplitudes are relatively even in the upside and the downside. The greenium across the 78 bonds, in other words, fluctuates around zero.

To check the significance of the greenium we applied a Wilcoxon signed-rank test, with a null-hypothesis that $p_i = 0$. This test estimates whether the greenium is statistically different from zero. The p-value is equal to 0.393, so we cannot reject the null hypothesis, even at the 30% level. Accordingly, we cannot say that the mean greenium of -1.11 bps is statistically different from zero. Our results, therefore, indicates that there is no existence of a green premium in the green bond market on the basis of our dataset, uniformly across bonds in different sectors, different ratings, different countries and different currencies.

To see if there could be any difference across samples, we divided the sample into several subsamples that represent the different characteristics of each bond, namely its sector, rating, and currency. The fixed-effects average and median greenium were then estimated for the different subsamples. Then, again, we applied the Wilcoxon signed-rank test for subsamples with seven or more bonds. This constraint is to ensure a sufficient number of observations in each specific subsample. Zerbib (2019) used a constraint of at least 10 bonds, but to be able to include the technology sector, we loosened this constraint to at least seven bonds.

Table 13 shows the average and mean greenium per subsample, with their corresponding p-values. The estimated greenium for the total sample, -1.11 bps, was not statistically significant from zero, as mentioned in the previous paragraph. This appears to be the case for the different subsamples as well. We observe a negative premium in eight of the subsamples, a positive premium in nine of the subsamples, and one subsample with a yield difference equal to zero. However, the only subsample with a significant premium is A1-A3 rated bonds, which indicate a negative yield difference of -5.3 bps, which is statistically significant at the 10% level. Thus, our results indicate that investors are willing to give up 5.3 bps to invest in green-labeled bonds rated between A1-A3.

Table 13: The estimated green bond premium in several subsamples

		Mean	Median	Prob>|z|	GB
Total		−0.011	0.000	0.393	78
Sector	Financials	−0.013	0.003	0.582	41
	Energy	−0.003	−0.005	0.735	13
	Real Estate	−0.002	−0.023	0.735	13
	Technology	0.011	0.007	0.688	7
	Other	−0.107	0.026		3
Rating	Aaa-Aa1	−0.059	−0.008		3
	Aa2-Aa3	0.002	0.016	0.285	10
	A1-A3	−0.053	−0.026	0.064*	19
	Baa1-Ba2	0.000	0.002	0.966	34
	NR	0.024	0.012	1.000	12
Currency	AUD	0.024	0.030		3
	CNY	−0.059	−0.059		1
	EUR	−0.010	−0.003	0.648	40
	INR	0.174	0.174		1
	JPY	−0.032	−0.032		1
	NOK	0.012	0.012		1
	SEK	0.036	0.012		3
	TWD	0.026	0.026		1
	THB	0.032	0.032		1
	USD	−0.033	−0.053	0.183	25

This table shows the mean and median of the green bond premium on the different subsamples.
Note: $^{*}p < 0.1;^{**}p < 0.05;^{***}p < 0.01$.

Our results are consistent with Zerbib (2019), who found a small negative yield difference of -1.8 bps, with a mixed variation of positive and negative green bond premium between different subsamples. He also found that a negative premium is more prominent for low-rated bonds, which is also partially consistent with the findings in this thesis, given the significancy of A1-A3 rated bonds. Despite this, due the insignificance of the green premium presented in this thesis, our results provide evidence that investors in the secondary market are unwilling to pay a premium to invest in green bonds, with A1-A3 rated bonds as the only exception.

6.2 Determinants of the Green Bond Premium

To explore potential determinants for the green premium, we performed a linear regression, as explained in Section 5.2. The estimated greeniums from Section 6.1 are used as the dependent variable, and characteristics of the bonds are used as explanatory variables to possibly explain variations in the green premium. Table 14 shows the three regression specifications: (a) represents the most general specifications, including all subgroups with at least three observations; (b) excludes the variables maturity and log(issued amount); and (c) further excludes the currency dummies, but adds back maturity and log(issued amount). All regressions were performed with robust standard errors.

In specification (a), bonds in SEK are significant at the 10% level, indicating that the green bonds in SEK would give a 15.5 bps lower green premium than those in EUR, given all else equal. Furthermore, the log(issued amount) is significant at the 1% level. Statistically, this indicates that a 1% increase in the total issued amount will result in a 9,6 bps decrease in the green bond premium, given all else equal. Specification (b) shows no significant explanatory variables, while specification (c) shows significant effects for both the log(issued amount) and for the maturity, with 5% and 10% significance, respectively. In all, our results show that investors may have a feel for SEK denominated green bonds and bonds with higher issued amount. The latter may suggest that green bonds issued by large well known institutions are more attractive to the investors relative to those issued from smaller corporations with lower issued amounts.

Table 14: Determinants of the green bond premium

Specification	(a)	(b)	(c)
Constant	1.021^{*}	0.041	0.858^{***}
	(0.362)	(0.074)	(0.250)
Energy/Utility	0.032	0.003	0.023
	(0.060)	(0.062)	(0.060)
Housing	0.02	−0.016	−0.01
	(0.068)	(0.072)	(0.065)
Technology	0.061	0.016	0.03
	(0.066)	(0.068)	(0.058)
Other	−0.104	−0.127	−0.092
	(0.091)	(0.115)	(0.097)
Aaa-Aa1	0.073	−0.102	0.033
	(0.085)	(0.087)	(0.073)
Aa2-Aa3	0.076	−0.047	0.041
	(0.085)	(0.091)	(0.066)
A1-A3	0.061	−0.083	0.025
	(0.068)	(0.076)	(0.061)
Baa1-Ba2	0.103	−0.033	0.072
	(0.069)	(0.069)	(0.068)
AUD	−0.041	0.024	
	(0.063)	(0.051)	
SEK	-0.155^{*}	0.043	
	(0.088)	(0.085)	
USD	−0.034	−0.029	
	(0.050)	(0.049)	
log(Issue Amount)	-0.096^{***}		-0.066^{**}
	(0.039)		(0.027)
Maturity	−0.004		-0.004^{*}
	(0.003)		(0.002)
Observations	78	78	78
R^2	0.182	0.069	0.148
$Adjusted R^2$	0.016	−0.086	0.021
Residual Std.Error	$0.022 df(64)$	$0.024 df(66)$	$0.022 df(67)$
F-statistic	$1.43 df(13, 64)$	$0.45 df(11, 66)$	$1.83 df(10, 67)$

This table shows the results from the OLS-regression, using specification (7), (8) and (9). The independent variables are described in table 9. Robust standard errors are presented in the parenthesis. Note: $^{*}p < 0.1$;$^{**}p < 0.05$;$^{***}p < 0.01$.

6.3 Investor Preferences Before and After COVID-19

To see if COVID-19 may have affected the pricing of green bonds, we examined the evolution of the green premium from the beginning of 2019 until January 2021. The results from the total sample are presented in Table 15 and Figure 7. Over the period from Q1 2019 to Q1 2021, the greenium weakly fluctuated around zero, within the range of -1.8 bps to 1.5 bps. When applying a Wilcoxon signed-rank test, the means of the total sample is not significantly different from zero for any of the quarters, which leaves us unable to conclude that there is any significant green premium, in alignment with findings in Section 6.1.

By further examining the sample, we noticed a much larger variation in the green bond premium during the second quarter of 2020. Prior to Q2 2020, the standard deviation ranged between 0.128 and 0.225, but in Q2 2020, it rose to 0.408, indicating an increase in volatility of the pricing between green and conventional bonds during this period. The minimum and maximum values are another indication of this. Furthermore, observations of the greenium for the total sample were skewed right prior to Q2 2020, indicating somewhat greater amplitudes on the upside. Notably, this changed after the second quarter of 2020, in which the amplitudes shifted to be greater on the downside. This could be an indication of the shifting preferences of investors in the green bond market. While earlier there had been an overrepresentation of investors that demanded extra yield to invest in green bonds, we now see that there is an overrepresentation of investors that are willing to forego extra yield to invest in green bonds although the differences are small.

Table 15: Quarterly estimated green bond premium - full sample

Full Sample

	2019-Q1	**2019-Q2**	**2019-Q3**	**2019-Q4**	**2020-Q1**	**2020-Q2**	**2020-Q3**	**2020-Q4**	**2021-Q1**
Mean	−0.018	0.004	−0.001	0	0.002	0.015	0	0.002	0.003
Std.dev	0.225	0.174	0.153	0.139	0.159	0.408	0.217	0.153	0.128
Skewness	0.086	−0.182	−2.233	−2.194	−0.92	−0.339	0.728	0.718	0.782
Kurtosis	5.677	5.99	10.721	11.76	8.243	9.073	8.053	6.296	6.583
Median	−0.042	−0.009	0.01	0.016	0.004	0.056	0.002	0.009	0.027
Min	−0.661	−0.582	−0.685	−0.645	−0.629	−1.515	−0.736	−0.404	−0.255
Max	0.656	0.438	0.262	0.299	0.496	1.409	0.873	0.636	0.555
1st.quart	−0.099	−0.057	−0.021	−0.03	−0.027	−0.063	−0.091	−0.082	−0.062
3rd.quart	0.106	0.054	0.063	0.06	0.055	0.106	0.03	0.067	0.058
N	31	40	44	48	53	57	66	69	75

This table shows the development in the green bond premium and its descriptive statistics from Q1 2019 until Q1 2021.
Note: $^{*}p < 0.1$;$^{**}p < 0.05$;$^{***}p < 0.01$.

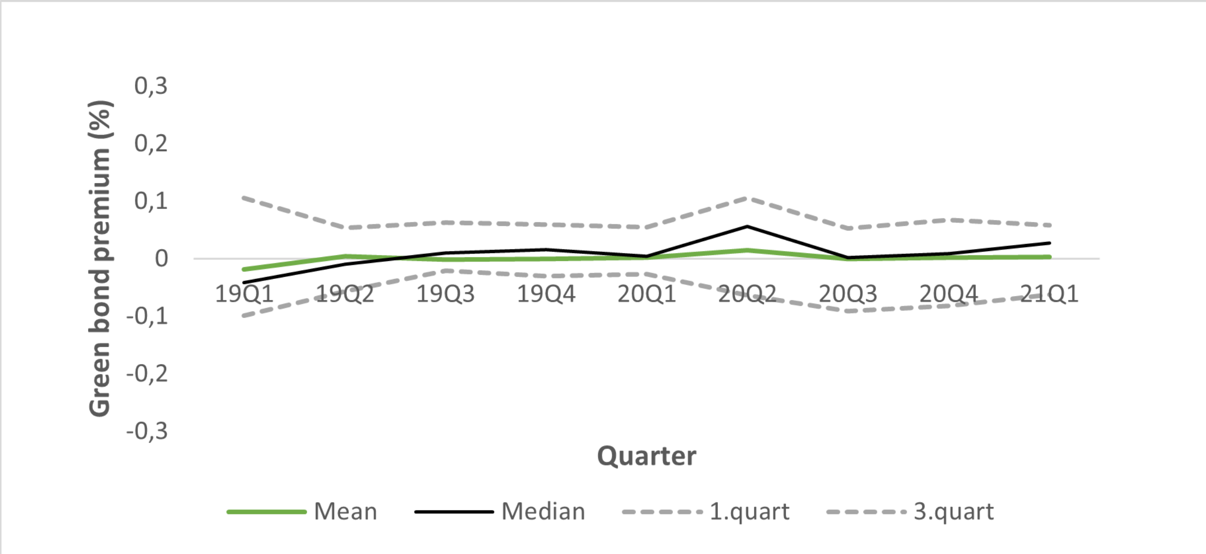


Figure 7: Green bond premium dynamics for the full sample
This figure shows the development in the green bond premium when including 75 out of the 78 bonds in our sample.

In the financial sector, the green premium was mostly negative up until Q3 2020, but then shifted to being positive by the end of 2020 and into 2021. Notably, the standard deviation in Q2 2020 increases a great deal, with large extreme values on the downside. By going from a negative skewness to a positive skewness in Q2 2020, the results suggest that the amplitudes are somewhat greater on the downside during and after COVID-19. This may be a possible indication that more investors' have shifted toward having pro-environmental preferences, giving up yield to invest in green bonds. However, there is a high kurtosis statistic, with a degree of extreme values affecting the sample. Without any significance and the observed positive green bond premium after Q2 2020, we cannot definitively conclude with any change in investors preferences. The statistics for the financial sector can be seen in Table 16.

The energy and utilities sector seems to have a somewhat different trend than the financial sector. It had a positive mean greenium of 7.6 bp in Q1 2019 which then declined steadily over the quarters, until it turned negative in Q3 2020 at -4.7 bp. Examining the other statistics, there is no other notable difference in the dynamics of the green premium during this period, as there are relatively consistent statistics before and after March 2020. Furthermore, none of the quarters show a significant green premium, and the sample contains relatively few observations. The statistics from the energy and utilities sector are presented in Table 17.

Table 16: Quarterly estimated green bond premium - Financial sector

Sector: Financial

	2019-Q1	2019-Q2	2019-Q3	2019-Q4	2020-Q1	2020-Q2	2020-Q3	2020-Q4	2021-Q1
Mean	−0.034	0.007	−0.028	−0.024	−0.006	−0.066	−0.001	0.0236	0.023
Std.dev	0.214	0.189	0.18	0.162	0.196	0.377	0.254	0.18	0.147
Skewness	−1.21	−0.63	−2.082	−2.48	−0.915	2.43	0.462	0.611	0.919
Kurtosis	5.531	5.901	8.5	9.473	6.37	9.254	6.772	5.221	5.757
Median	−0.055	−0.02	0.01	0.012	0.025	0.05	0.01	0.021	0.027
Min	−0.661	−0.582	−0.685	−0.645	−0.629	−1.515	−0.736	−0.404	−0.226
Max	0.256	0.438	0.262	0.144	0.496	0.398	0.873	0.636	0.555
1st.Quart	−0.081	−0.059	−0.042	−0.03	−0.029	−0.133	−0.125	−0.087	−0.033
3rd.Quart	0.078	0.06	0.044	0.067	0.087	0.107	0.0652	0.103	0.089
N	17	23	25	27	29	31	37	39	41

This table shows the development in the green bond premium for the financial sector and its descriptive statistics from Q1 2019 until Q1 2021

Note: $^{*}p < 0.1$;$^{**}p < 0.05$;$^{***}p < 0.01$.

Table 17: Quarterly estimated green bond premium - Energy/Utility sector

Sector: Energy/Utility

	2019-Q1	2019-Q2	2019-Q3	2019-Q4	2020-Q1	2020-Q2	2020-Q3	2020-Q4	2021-Q1
Mean	0.076	0.103	0.073	0.052	0.022	0.054	−0.047	−0.056	−0.04
Std.dev	0.35	0.188	0.095	0.11	0.152	0.159	0.118	0.118	0.11
Skewness	0.405	0.819	0.117	0.427	0.09	−0.53	0.53	−0.597	−0.813
Kurtosis	2.601	2.13	1.372	2.134	2.296	3.101	2.794	1.768	2.268
Median	0.049	−0.008	0.081	0.026	0.01	0.06	−0.087	−0.003	0.014
Min	−0.403	−0.068	−0.027	−0.091	−0.22	−0.263	−0.231	−0.266	−0.255
Max	0.656	0.426	0.196	0.239	0.243	0.293	0.187	0.054	0.068
1st.Quart	−0.081	−0.028	−0.018	−0.046	−0.053	0.001	−0.103	−0.178	−0.081
3rd.Quart	0.187	0.288	0.174	0.151	0.117	0.126	0.014	0.049	0.048
N	6	7	7	7	8	9	10	12	13

This table shows the development in the green bond premium for the Energy/Utility sector and its descriptive statistics from Q1 2019 until Q1 2021.

Note: $^{*}p < 0.1$;$^{**}p < 0.05$;$^{***}p < 0.01$.

The housing sector consists of a relatively small sample of green bonds, so the foundation for this analysis is somewhat weak. However, the results show that the green premium is negative until Q2 2020, ranging between -6.2 bps and -1.4 bps. Then, in this quarter, it jumps to positive 18 bps. The standard deviation indicates that this period was very volatile, with minimum and maximum values of -0.972 and 1.409, respectively. The magnitude of the positive greenium seems to be driven by the large extreme values on the upside because after this quarter, the greenium falls back to previous levels, -3.3 bps and -4.3 bps. The evidence thus indicates no notable differences before and after the second quarter of 2020. The statistics for the housing sector can be seen in Table 18.

Table 18: Quarterly estimated green bond premium - Housing sector

Sector: Housing

	2019-Q1	2019-Q2	2019-Q3	2019-Q4	2020-Q1	2020-Q2	2020-Q3	2020-Q4	2021-Q1
Mean	−0.062	−0.064*	−0.024	−0.014	−0.019	0.18	0.011	−0.033	−0.043
Std.dev	0.138	0.108	0.097	0.047	0.0375	0.724	0.22	0.095	0.094
Skewness	0.072	−0.425	−1.622	−0.71	−0.464	0.481	1.881	0.389	−0.337
Kurtosis	1.576	1.89	4.674	2.341	2.26	2.695	6.343	3.644	1.993
Median	−0.076	−0.015	−0.015	−0.003	−0.015	0.042	−0.021	−0.023	−0.043
Min	−0.24	−0.226	−0.247	−0.1	−0.084	−0.972	−0.251	−0.183	−0.22
Max	0.106	0.074	0.064	0.038	0.028	1.409	0.611	0.181	0.079
1st.Quart	−0.17	−0.185	−0.029	−0.042	−0.042	−0.093	−0.086	−0.081	−0.115
3rd.Quart	0.081	−0.003	0.039	0.021	0.008	0.106	0.018	0.006	0.043
N	6	7	8	8	8	9	11	12	13

This table shows the development in the green bond premium for the Housing sector and its descriptive statistics from Q1 2019 until Q1 2021.
Note: $^{*}p < 0.1$;$^{**}p < 0.05$;$^{***}p < 0.01$.

The Wilcoxon signed-rank test only shows a significant greenium for the housing sector in Q2 2019 at the 10% level. For the rest of the quarters, there is no significant greenium in any of the sectors. As mentioned above, our conclusion is, therefore, that there is no significant difference in the green premium after COVID-19. That is, the preferences of the investors cannot be said to have changed after this period. The developing greenium in the respective sectors is presented in Figure 8.

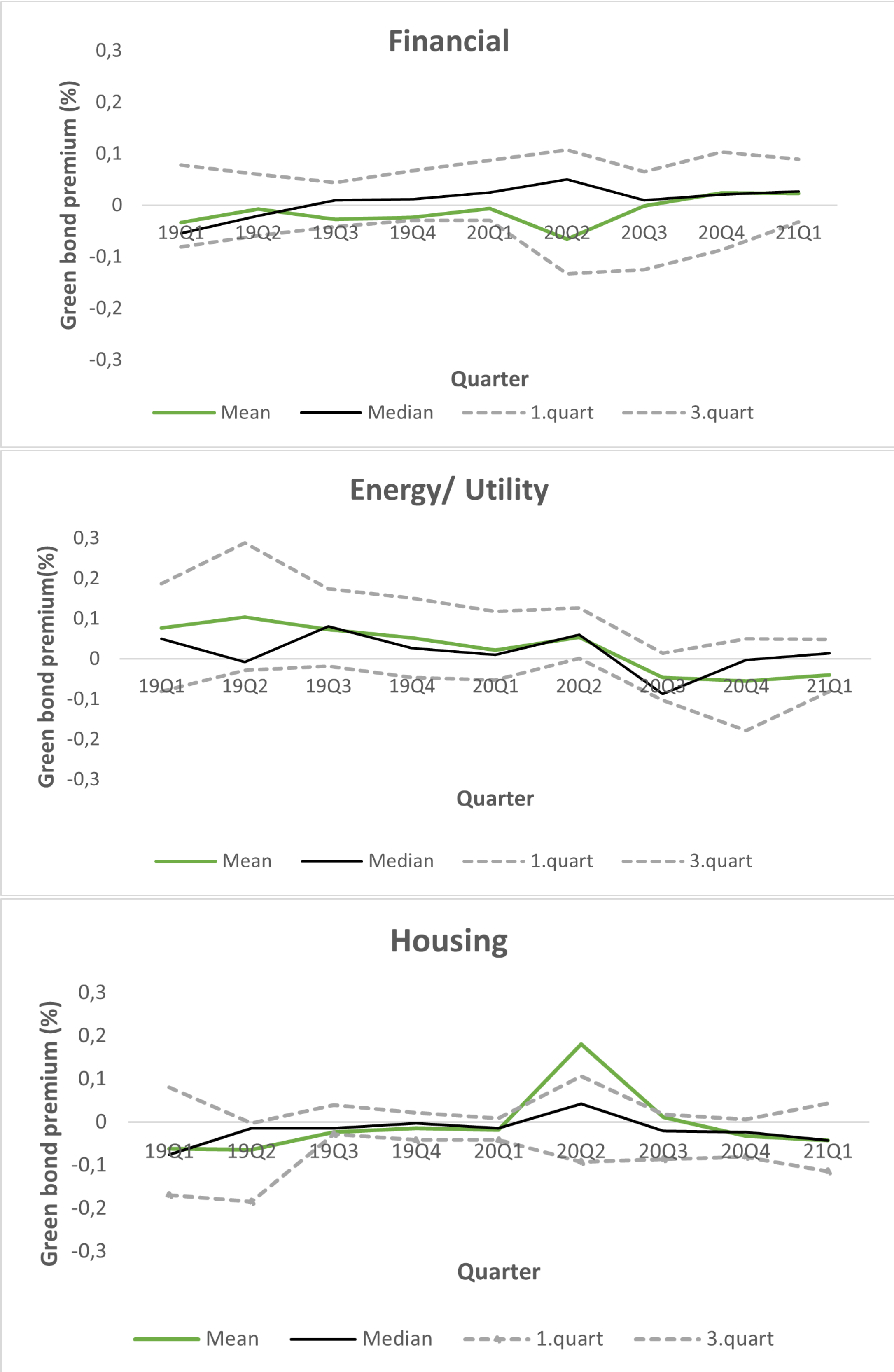


Figure 8: Green bond premium dynamics for the financial, energy and housing sector
This figure shows the development of the green bond premium in the financial-, energy- and housing sector.

6.4 Market Volatility's Impact on the Greenium

Finally, we examined whether the green premium may have been affected by uncertainty in the stock market. We ran the within fixed-effects regression in Eq. (10) to control for the impact of both liquidity and volatility of the greenium. While the impact of liquidity is not significant, the coefficient of the Log(VIX) variable indicates that a one per cent increase in the volatility of the market led to a 4.72 bps decrease in the greenium over the sample period. The estimates are significant at the 1% level for the within regression, and at the 5% level using robust standard errors. Although the inclusion of the VIX-Index as an explanatory variable shows significant effect on the greenium, the explained variation is still low, at 1,07%. This result indicates that investors may want to accept a lower premium on green bonds in times of high uncertainty in financial markets. We re-estimated model specifications (a), (b), (c) to verify if by controlling for market uncertainty, the significance of the determinants in Table 14 may have changed. Results are similar to results in Table 14, as indicated by the estimates in Table A6 of the Appendix.

Table 19: Results from within fixed-effects regression with the VIX Index

	Within regression	**w/Robust std.errors**
$\Delta BA_{i,t}$	-0.0715^{***}	-0.0715
t-value	-4.76	-0.32
$P > \|t\|$	0.000	0.753
Log(VIX Index)	-0.0472^{***}	-0.0472^{**}
t-value	-17.87	-2.19
$P > \|t\|$	0.000	0.031
Constant	0.128^{***}	0.128^{*}
t-value	16.00	1.98
$P > \|t\|$	0.000	0.052
Observations	35,057	35,057
R^2	0.0107	0.0107
F-statistic	167.58	
$(df = 2, 34977)$, $p = 0.000$		
Number of groups	78	78

This table presents the results from the within-regression including the VIX Index as an independent variable .

Note: $^{*}p < 0.1;^{**} p < 0.05;^{***} p < 0.01$.

7 Discussion

7.1 Discussion of Results

As previously mentioned in the literature review, findings on the presence of a significant green bond premium are mixed. Around 70% of the research on green bond pricing finds a significant negative greenium based on data observations prior to 2018. Larcker and Watts (2020) argued that mixed evidence from prior studies is due to biased estimates from misspecifications of methodological design. By tightening the matching methodology, they found that the green premium is essentially zero in the municipal green bond market.

The results from our fixed-effect regression indicate a nonsignificant green premium of -1.11 bps, which is, therefore, in line with the latest studies, including research from Flammer (2021) and Larcker and Watts (2020). Therefore, according to this thesis, investors are still unwilling to forego yield due to their pro-environmental preferences. Larcker and Watts (2020) and Flammer (2021) confirmed this nonexistent preference through interviews with several industry practitioners, where it was almost unanimously stated that they would not invest in green bonds if the returns were not competitive to that of conventional bonds, supporting the findings of this thesis.

However, both Larcker and Watts (2020) and Flammer (2021) used more stringent criteria to collect data. This thesis mostly follows the methodology of Zerbib (2019) but differs by allowing matches based on the same industry, as Bour (2019) did. This may have introduced some additional bias, capturing effects other than solely environmental preferences. In addition, this thesis also narrowed the focus to the corporate green bond market which may be a possible explanation of the differing results. As mentioned in Section 4.5, the sample makes up for 2.6% of the green bond universe. It may therefore be debatable whether we can generalize the findings to the whole corporate green bond universe.

The increasing diversity of bond structures, transparency, and adoption of new initiatives in the recent years may be a possible explanations for increasing pressure on demand from the investors' side as it could attract a broader investor base. However, the amount of issuance has increased rapidly in the last few years; therefore, the supply of green bonds may have accommodated or exceeded demand, causing a mismatch in supply and demand and possibly explaining the nonsignificant pricing difference. A report from S&P Global (2019) has researched why corporate green bonds have been slowly adopted in the US. They suggest that finding a greenium can still be equivalent to finding a unicorn and support this by suggesting a supply and demand mismatch. While green bonds issuance has increased dramatically, global green bond funds have not grown at the same pace, and this could be a possible explanation of the limited price difference between green and conventional bonds.

Earlier research has also pointed to a negative relationship between bond yields and liquidity, and the non-existing green bond premium has been explained with the green bond markets' poor liquidity (Chiang, 2017; Chen et al., 2007; Schwert, 2017). The bid-ask liquidity proxy in this thesis does not have any significant effect on the yield difference and therefore suggests that the liquidity control variable is not necessary. However, concluding that liquidity does not have any effect on bond yields is reductive since this is the opposite of what the literature suggests. A possible explanation of the non-significant liquidity variable is that the green bond market has developed to be as liquid as conventional bond markets, which may explain the non-significant liquidity proxy. This is in line with Larcker and Watts (2020), who found no significant liquidity differential between green and conventional bonds, as we also observed in this study.

Larcker and Watts (2020) proposed the most likely explanation for zero greenium: green projects are profitable enough to generate competitive returns. They further noted that it is likely that asset prices are a function of the impact of ESG and CSR on future profitability and risk, consistent with the literature that shows a positive relationship between ESG and performance and a negative relationship between ESG and risk.

The evidence from our analysis on different subsamples supports that there is no pricing difference between green and conventional bonds across sectors, ratings and currencies. The only subgroup with significant greenium at the 10% level is the A1-A3 rated bonds, which presented a green premium of -5.3 bps. This may be explained by mismatches in supply and demand. According to the European European Commission (2016), issuers of green bonds have struggled to obtain a good rating relative to conventional bonds. Green bonds with lower credit ratings result in a higher cost of capital for the issuer; therefore, the issuance of a lower-rated green bond may be less attractive, which could explain the observed significant greenium. However, when we examined other rating classes, we saw no significance for higher- and lower-rated bonds relative to ratings between A1-A3. This makes us somewhat wary of our findings and it begs the question of whether the significance can be justified on the basis of our small data sample.

There are also indications that the green premium is more prominent in EUR and USD currencies. A reasonable assumption is that green bonds with EUR and USD are more liquid and are therefore "safer" than with other currencies. This could be due to the fact that these currencies attract a broader investor base, leading to a more liquid green bond market of USD and EUR green bonds. Lack of liquidity in the other currencies could, therefore, be a possible explanation for why the analysis indicates a negative premium in USD and EUR currencies and a positive to nonexistent premium in the other currencies. However, without any statistical significance, we cannot support this conclusion.

The CBI's Green Bond Treasury survey (2020b) was designed to highlight the benefits and challenges of issuing green bonds. While their expectation was that cheaper pricing was the principal benefit, their results proved otherwise. Most enterprises are exposed to climate risk and need to transition their business models toward a zero-carbon future. Climate risks can become financial risks, and managers must account for these risks to protect revenues and reputation; green bonds can play a role in this transition process (CBI, 2020b). The respondents from this report believed that the costs associated with implementing these adjustments were justified, as they were able to create a more robust infrastructure and a positive sentiment between companies and stakeholders, which led to transformative effects on their organizations. Furthermore, 98% of the respondents said that their green bonds attracted new investors, and 91% said that green bonds facilitated more engagement with investors, compared to conventional bonds. Green bonds can therefore benefit issuers by broadening the investor base and offering new engagement opportunities. Most of the respondents said that their top motivation for issuing green bonds were due to reputational benefits, as green bond issuers can signal to the world that they are open for green business and encourage better standards that ultimately benefit humanity. Respondents also highlighted that green bond issuance has resulted in positive changes to internal relationships , which, again, can lead to momentum for addressing climate risk (CBI, 2020b).

Lastly, it is worth mentioning that the corporate green bond market is still under development and is still in its relatively early stages; the findings of a non-significant green premium in this study will not necessarily hold true in the future, when more data will be available for empirical analyses. Investors' preferences may change with more investors committing to the United Nations' Principles of Responsible investing (PRI) to work toward sustainable markets (United Nations PRI, 2017). In addition, the possible usage of green bonds in the "building back better agenda" can have its effect on green bond yields.

Most of the possible determinants in both our research and in Zerbib's (2019) were not significant. In contrast to our results, Zerbib (2019) found that rating significantly affects the premium: the lower the rating of a green bond, the lower the green premium. The effect is particularly significant for the AA and A bond. Our results show no significant effects for the rating of the green bond. In contrast to both Zerbib (2019) and Larcker and Watts (2020), our thesis finds a significant relationship between the issued amount on a particular security and the yield difference. This indicates that investors are more willing to forego yield to invest in green bonds, as the issued amount increases. A possible explanation to this could be that investors have more trust in large projects, as their impact on the environment could be more visible to the public.

Of the different currencies studied, we saw that SEK is the only significant variable relative to EUR green bonds. On average, investors would be willing to pay a 15.5 bps premium on SEK green bonds relative to the reference currency EUR, given all else equal. Nordic issuers embraced the green bond market when it was still in its infancy, and banks in the region fund many sustainable assets via loans. Nordic players are also at the forefront of promoting market integrity, demonstrating best practices in external reviews, pushing investor standards, and leading the international dialogue (CBI, 2018b). This could be a factor in its attractiveness to investors. Our research, however, only features four observations of green corporate bonds from the Swedish market.

Pareto Asset Management (2020) wrote a report on the Swedish green bond market during the outbreak of COVID-19, examining how green bonds could potentially act as stabilizers in bond portfolios in times of liquidity crisis. Compared to the European high yield and investment grade indices, the Swedish green bonds have suffered less drawdown during the COVID-19 crisis and have had a much less volatile trajectory during the recovery phase. With this in mind, one might expect investors to be willing to pay a greater premium for green bonds, especially after they have proven their quality in a time of distress as they did in the Swedish market. Our results of a non-significant greenium in the quarters after the pandemic, however, indicate no reason to believe that investors are increasingly willing to pay a larger premium for green bonds. The greenium in the quarters after the pandemic was about the same as in the quarters before the pandemic, yielding no significant greenium. However, there are indications that investors in the energy and utilities sector and the housing sector are increasingly willing to pay a premium, perhaps hoping to see greater benefits after the pandemic. The greenium observed in the latest quarters of our data falls notably, but is not significant, so a conclusion cannot be drawn from these results.

The greenium in the financial sector seems to have moved in the opposite direction from the other two previously mentioned sectors after the pandemic. From being consistently negative, with its most negative greenium in Q2 2020, the greenium in the financial sector became positive in the two last quarters. Even though none of the quarters are significantly positive or negative, this could be an indication that investors are less interested in green bonds issued by banks and financial institutions and more interested in other issuers. CBI (2020c) stated that by the issuers in the private sector, non-financial corporations proved themselves to be less volatile than financial corporations. This may be an explanation of the different trends across sectors.

Lastly, we examined the impact of the markets' volatility on the green bond premium. We found a significant relationship between the Ask Yield Difference and the VIX Index. The results indicate that investors may be drawn to the green bond market during times of high volatility. Naeem et al. (2021) studied the impact of COVID-19 on the pricing of fixed-income securities and found that green bonds can serve as a valuable diversifier during extreme events. Furthermore, Arif et al. (2021) explored the hedging potential of green bonds and revealed that the green bond index could serve as a diversifier for equity, currency and commodity investments. Our findings are in line with these studies, as it indicates lower greenium in times of high uncertainty in financial markets. Still, the degree of explanation on the yield difference is relatively low, as also illustrated by the fact that the greenium does not change significantly during Q2 2020, even though the VIX Index is relatively high in this period.

7.2 Limitations

We used Zerbib's (2019) matching method to isolate the potential green premium by calculating the yield difference between a green bond and a synthetic bond made out of two identical conventional bonds. In practice, finding identical matches is not possible, and some limitations must be addressed. For most bonds we matched, we compromised on certain characteristics, and had to allow for some leeway, as described in Section 4.2. This means that the green bonds and their synthetic conventional counterparts could never be identical, and the unexplained variance may include factors other than the green premium and the liquidity difference. In addition to this, about half of the synthetic bonds are constructed with bonds from different issuers, which further increases the risk of structural differences in the matched sample and may not offer evidence of a greenium.

Another aspect of the matching method that may raise some concerns is the maturity interpolation and extrapolation. The synthetic bond is made out of two conventional bonds with similar characteristics as the green bond, with a maturity as close to the green bond as possible. For the maturity interpolation (extrapolation) to be an adequate method to match the green bonds' maturity, we must truly believe that the maturity and the yield have a linear relationship. The relationship is well established, but the yield curve can also take different shapes (J.P.Morgan, 2016), which could potentially lead to a poorly estimated yield.

Furthermore, a limited amount of matchable green corporate bonds makes it more difficult to obtain significant results, even though there are indications of both negative and positive greenium in the different subgroups and in the different quarters. Especially for the quarterly analysis of the different sectors, further analysis with a richer dataset is required to draw stronger conclusions.

Another limitation for the quarterly analysis is the fact that we compare quarters with different amount of green bonds, which makes it difficult to compare the changes in statistics directly. This was done to have as many observations around the COVID-19 breakout as possible. Another analysis could have looked at the dynamics of the 31 green bonds available from Q1 2019 over the two year period. However, the limited amount of observations would have made the results less representative for the corporate green bond market.

Our study and most studies up to now have ignored the impact of specific evaluations of greenness levels in external reviews (i.e., the shade of green methodology in second party-opinions) on the green bond premium, despite their existence and increasing popularity in recent years (Cicero, 2021). These reviews are still scarce and were not available for all of the green bonds in our sample; therefore, they could not be included in our research.

8 Conclusion

In this thesis, we analyzed the corporate green bond market in an attempt to explore investors pro-environmental preferences, applying Zerbib (2019) methodology. This is of interest because of the exponential growth of green financial instruments and a growing demand for more sustainable investments.

To answer our first research question of whether investors are willing to pay a premium for investing in green labeled corporate bonds, we applied the matching method and fixed-effects regression. We found a nonsignificant greenium of -1.1 bp. Furthermore, only the issued amount and maturity, as well as corporate green bonds in SEK denominations, showed significant effects on the greenium. Thus, we cannot conclude that there is significant greenium in the corporate green bonds market.

Our second research question of whether the demand for corporate green bonds has changed because of the COVID-19 pandemic was investigated by looking at quarterly greenium from Q1 2019 until Q1 2021. Similar to the greenium for the full time period, we found no significant quarterly greenium. However, when dividing the sample into different sectors, we found indications of an increasing greenium for corporate green bonds issued by energy and utilities as well as housing companies after the pandemic. For the financial sector, we observed an opposite trend, with a nonsignificant positive yield difference in the most recent quarters.

Lastly, the VIX Index was showed to have a significant impact on the yield difference between green and conventional bonds in our sample. This could indicate that investors are more willing to pay a premium for green bonds in times of uncertainty. The degree of explanation on the yield difference is, however, small, and the impact must therefore be said to be limited.

Our results of no significant greenium in the corporate green bond market is in line with Flammer's (2021) conclusion that there is no significant difference in yield between green and conventional bonds. Our research adds to this by examining recent years, as well as analyzing the market during the pandemic. Investors do not seem to want to sacrifice yields for pro-environmental causes at the current state of the market. Further research could study the different sectors over a longer period after the pandemic to validate and strengthen indications from our results that investors preferences towards green bonds in different sectors may have changed due to COVID-19.

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Appendices

Table A1: List of all the green bonds

Issuer	ISIN	Sector	Currency	Rating
A2A SpA	XS2026150313	Utility	EUR	Baa2
ABN Amro Bank NV	XS1422841202	Banking	EUR	A1
Alexandria RE Equities Inc	US015271AM12	Real Estate Inv.	USD	Baa1
Apple Inc	US037833BU32	Electronics	USD	Aa1
Avangrid Inc	US05351WAA18	Utility	USD	Baa1
Banco Bilbao Vizcaya Argentaria SA	XS1820037270	Banking	EUR	Baa2
Banco de Sabadell SA	XS2228245838	Banking	EUR	Baa2
Banco Santander SA	XS2063247915	Banking	EUR	A2
Bank of America Corp	US06051GHH56	Banking	USD	A2
Bank of Nova Scotia	US064159QD10	Banking	USD	A2
Bank of the Phillipine Islands	XS2050923825	Banking	USD	Baa2
BNP Paribas SA	XS1527753187	Banking	EUR	Aa3
BTS Group Holdings PCL	TH0221039504	Transportation	THB	NR
Byd Co Ltd	CND10001TT10	Electronics	CNY	NR
Castellum AB	SE0009161615	Home Builders	SEK	NR
CIFI Holdings Co Ltd	XS2205316941	Home Builders	USD	Ba2
Confinimmo SA	BE0002269380	Financial - Other	EUR	NR
Commerzbank AG	DE000CZ40NG4	Banking	EUR	Baa2
Commonwealth Bank of Australia	AU3CB0243657	Banking	AUD	Aa3
Consolidated Edison Company of N.Y	US209111FY40	Utility	USD	Baa1
Covivio SA	FR0013170834	Home Builders	EUR	NR
Credit Agricole SA	XS2067135421	Banking	EUR	Baa1
Daimler AG	DE000A289QR9	Auto. Manufacturer	EUR	A3
Danske Bank A/S	XS1963849440	Banking	EUR	Baa3
DBS Group Holdings Ltd	US24023LAC00	Banking	USD	Aa2
E.ON SE	XS2047500926	Utility	USD	Aa2
EDP Finance BV	XS1893621026	Financial - Other	EUR	Baa3
Electrolux AB	XS1969611943	Electronics	SEK	NR
ENN Energy Holdings Ltd	US26876FAC68	Gas-Utility	USD	NR
Entra ASA	NO0010774797	Service-Other	NOK	NR
Equinix Inc	US29444UBM71	Real Estate Inv.	USD	Baa3
Far Eastern New Century Corp	TW000B501576	Textiles/Apparel/Shoes	TWD	NR
First Abu Dhabi Bank PJSC	XS1587035996	Banking	USD	Aa3
Georgia Power Co	US373334KE00	Utility	USD	Baa1
Gunma Bank Ltd	JP327640AKB0	Banking	JPY	NR
HSBC Holdings PLC	XS1917601582	Banking	EUR	A2
Icade SA	FR0013281755	Home Builders	EUR	NR
Indian Railway Finance Corp Ltd	XS1733877762	Financial - Other	USD	Baa3
Bank of China Asia Ltd	XS1839372601	Banking	USD	A1
ING Groep NV	USN4580HAA51	Banking	USD	Baa1
Interstate Power and Light Co	US461070AP91	Utility	USD	Baa1
Intesa Sanpaolo SpA	XS1636000561	Banking	EUR	Baa1
Iren SpA	XS1704789590	Utility	EUR	Baa2
JPMorgen Chase & Co	US46647PBS48	Banking	USD	A2
KBC Groep NV	BE0002602804	Banking	EUR	Baa1
Mediobanca BdCF SpA	XS2227196404	Banking	EUR	Baa1
Mitsubishi UFJ Financial Group Inc	US606822AH76	Banking	USD	A1
Mizuho Financial Group Inc	XS1691909920	Banking	EUR	A1
Muenchener Hypothekenbank EG	DE000MHB21J0	Banking	EUR	Aaa
National Australia Bank Ltd	AU3CB0226090	Banking	AUD	Aa3
Nordea Bank Abp	XS1640493372	Banking	EUR	Aa3

Continued on the next page

Table A1 – continued from previous page

Issuer	ISIN	Sector	Currency	Rating
Orsted A/S	XS1721760541	Service - Other	EUR	Baa1
Owens Corning	US690742AJ00	Bulding Products	USD	Baa3
PNB Housing Finance Ltd	INE572E07019	Financial - Other	INR	NR
PNC Financial Services Group Inc	US693475AY16	Banking	USD	A3
Royal Bank of Canada	XS1989375412	Banking	EUR	A2
Samhallsbyggnadsbolaget I Norden AB	SE0012256741	Home Builders	SEK	Baa3
Schneider Electric SE	FR0013015559	Electronics	EUR	A3
SK Hynix Inc	USY8085FBD16	Electronics	USD	Baa2
Skandinaviska Enskilda Banken AB	XS1567475303	Banking	EUR	Aa2
Snam SpA	XS1957442541	Gas - Utility	EUR	Baa2
Societe Generale SA	XS1500337644	Banking	EUR	A1
Societe Generale SFH SA	FR0013434321	Financial - Other	EUR	Aaa
Sparebank 1 SMN	XS2051032444	Banking	EUR	A1
SSE PLC	XS1676952481	Utility	EUR	Baa1
Sumitomo Mitsui Financial Group Inc	XS1694219780	Banking	EUR	A1
Svenska Handelsbanken AB	XS1848875172	Banking	EUR	Aa2
Swedbank AB	XS1711933033	Banking	EUR	Aa3
Terna Rete Elettrica Nazionale SpA	XS1858912915	Utility	EUR	Baa2
Unibail-Rodamco-Westfield SE	XS1038708522	Real Estate Inv.	EUR	A3
Union Electric Co	US906548CS94	Utility	USD	A2
UPM-Kymmene Oyj	XS2257961818	Building Products	EUR	Baa1
Verbund AG	XS1140300663	Utility	EUR	A3
Verizon Communications Inc	US92343VES97	Telecommunications	USD	Baa1
Vodafone Group PLC	XS2002017361	Telecommunications	EUR	Baa2
Wallenstam AB	SE0011643329	Home Builders	SEK	NR
Welltower Inc	US95040QAK04	Real Estate Inv.	USD	Baa1
Westpac Banking Corp	AU3CB0237683	Banking	AUD	Aa3

Table A2: Clustered Sector Group

Sector	Bonds(N)	Cluster group
Banking	36	Financial
Financial - Other	5	Financial
Utility	11	Energy/Utility
Gas - Utility	2	Energy/Utility
Service-Other(Orsted A/S)	1	Energy/Utility
Electronics	5	Technology
Telecommunications	2	Technology
Real Estate Inv.	4	Housing
Home builders	6	Housing
Building products	2	Housing
Service-Other(Entra ASA)	1	Housing
Transportation	1	Other
Automotive Manufacturer	1	Other
Textirel/Apparel/Shoes	1	Other

This table describes the clustering process by using the Sector classes from Thomson Reuters Eikon.

Table A3: Clustered Rating Group

Rating	Bonds(N)	Clustered group
Aaa	2	Aaa-Aa1
Aa1	1	Aaa-Aa1
Aa2	3	Aa2-Aa3
Aa3	7	Aa2-Aa3
A1	7	A1-A3
A2	7	A1-A3
A3	5	A1-A3
Baa1	15	Baa1-Ba2
Baa2	12	Baa1-Ba2
Baa3	6	Baa1-Ba2
Ba1	0	Baa1-Ba2
Ba2	1	Baa1-Ba2

This table describes how we have clustered the rating groups into four categories, based on Moody's and Fitch ratings available on Thomson Reuters Eikon

Table A4: Coupon types

Coupon type	Bonds (N)
Plain Vanilla Fixed Coupon	68
Fixed Margin Over Index	5
Fixed then Floating	5

This table describes the different coupon types from our sample of 78 bonds.

Table A5: Seniority types

Seniority	Bonds (N)
Senior Unsecured	58
Senior Preferred	11
Senior Non-preferred	4
Senior Secured	4
Subordinated Unsecured	1

This table describes the different seniority types from our sample of 78 bonds.

Table A6: Re-estimation of determinants

Specification	(a)	(b)	(c)
Constant	0.963***	0.050	0.807***
	(0.363)	(0.073)	(0.250)
Energy/Utility	0.027	0.001	0.018
	(0.061)	(0.062)	(0.060)
Housing	0.178	−0.016	−0.012
	(0.069)	(0.073)	(0.066)
Technology	0.061	0.017	0.030
	(0.066)	(0.067)	(0.057)
Other	−0.104	−0.126	−0.092
	(0.089)	(0.113)	(0.095)
Aaa-Aa1	0.073	−0.101	0.032
	(0.084)	(0.084)	(0.071)
Aa2-Aa3	0.074	−0.050	0.036
	(0.085)	(0.090)	(0.066)
A1-A3	0.064	−0.079	0.027
	(0.069)	(0.075)	(0.061)
Baa1-Ba2	0.106	−0.030	0.074
	(0.070)	(0.068)	(0.068)
AUD	−0.046	0.018	
	(0.064)	(0.052)	
SEK	−0.152*	0.006	
	(0.088)	(0.084)	
USD	−0.036	−0.030	
	(0.050)	(0.049)	
log(Issue Amount)	−0.096**		−0.066**
	(0.039)		(0.027)
Maturity	−0.003		−0.004*
	(0.003)		(0.002)
Observations	78	78	78
R^2	0.176	0.067	0.142
$Adjusted R^2$	0.008	−0.089	0.014
Residual Std.Error	$0.022 df(64)$	$0.024 df(66)$	$0.022 df(67)$
F-statistic	$1.36 df(13, 64)$	$0.84 df(66)$	$1.69 df(10, 67)$

This table shows the results from the OLS-regression using specification (7), (8) and (9). The fixed effects calculated from Eq.(10) are used as dependent variable.
Note: $^{*}p < 0.1;^{**} p < 0.05;^{***} p < 0.01$.

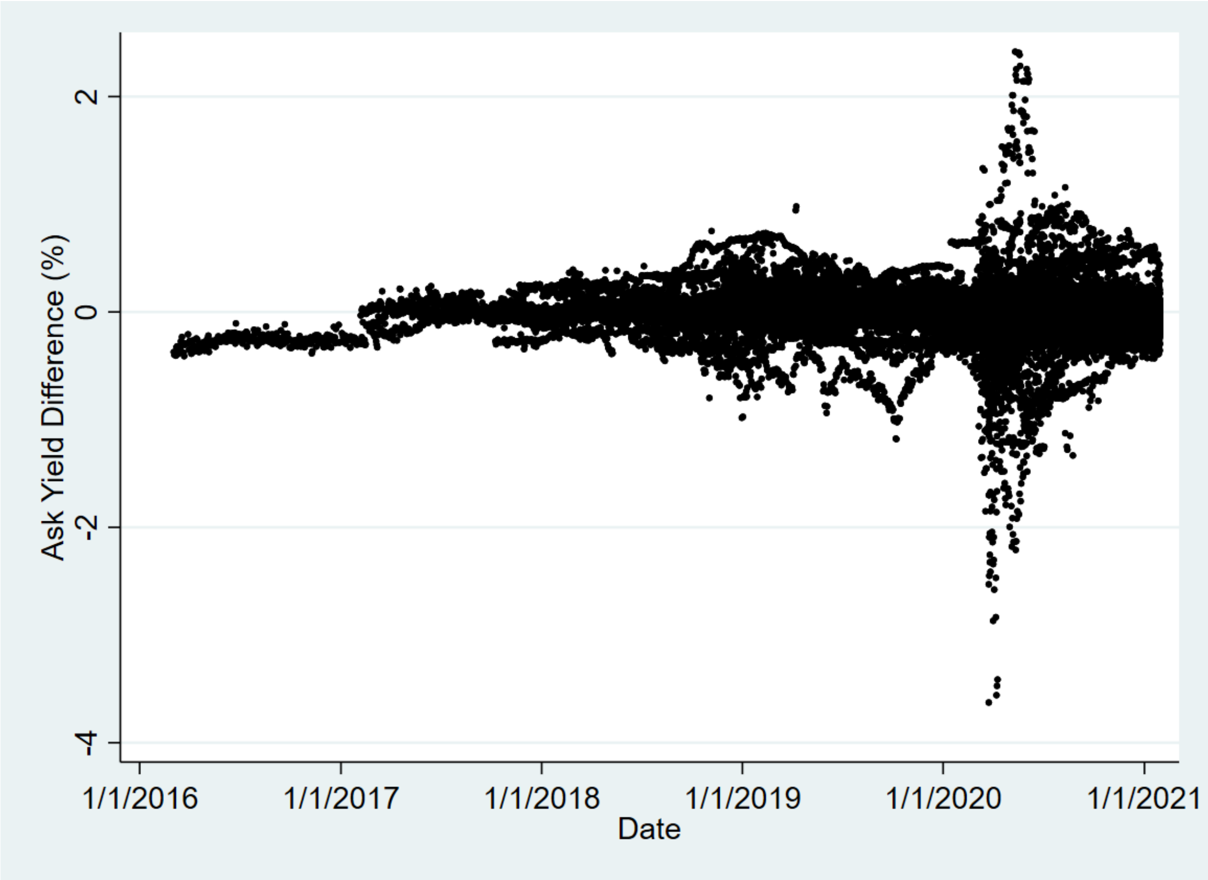

Figure A1: Distribution of the yield differential

This figure shows the distribution of the yield differential between green bonds and conventional bonds.

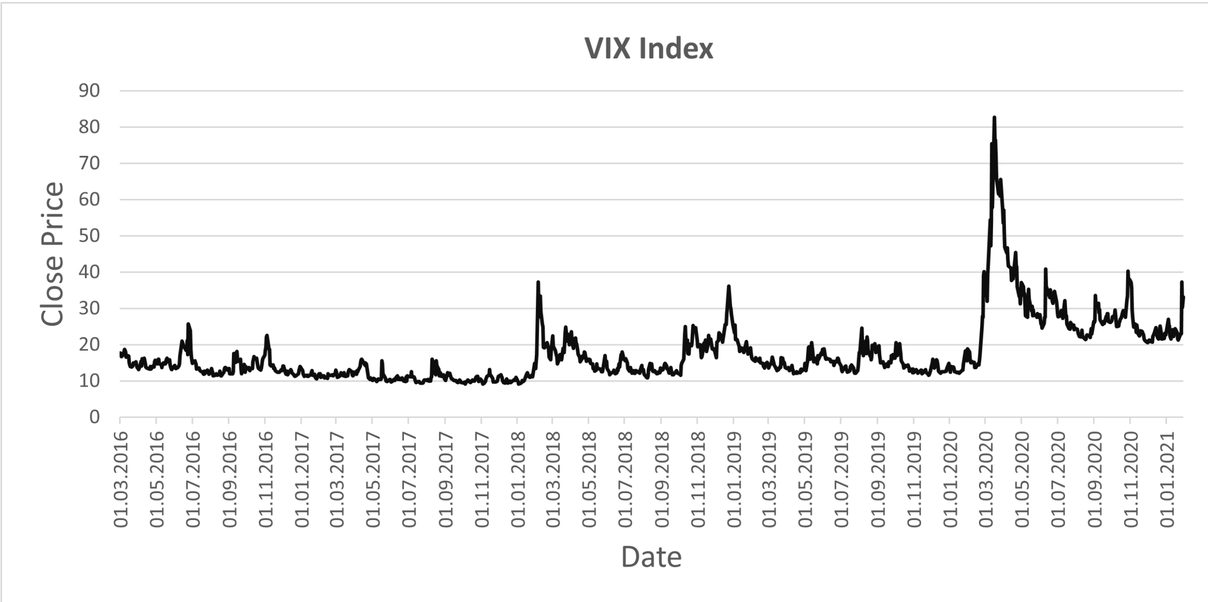

Figure A2: VIX index chart

This figure shows the close price for the VIX index from March 2016 until January 2021. Source: CBOE Exchange, 2021.

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